# 2019

# H2 Physics

| | | |
|---|---|---|
| 1. | Anderson Serangoon Junior College | |
| 2. | Catholic Junior College | |
| 3. | Dunman High School | |
| 4. | Hwa Chong Institution | |
| 5. | Jurong Pioneer Junior College | |
| 6. | Millennia Institute | |
| 7. | Nanyang Junior College | |
| 8. | National Junior College | |
| 9. | Raffles Institution | |
| 10. | River Valley High School | |
| 11. | St. Andrew's Junior College | |
| 12. | Tampines Meridian Junior College | |
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Name: _____ (  )  Class: 19 / _____

# ANDERSON SERANGOON JUNIOR COLLEGE

## 2019 JC2 Preliminary Examination

## PHYSICS Higher 2 9749/01

**Paper 1 Multiple Choice** **Thursday 19 September 2019**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet

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**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.
Write your name and class on the Multiple Choice Answer Sheet.
Shade and write your NRIC/FIN.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet.
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this question paper.
The use of an approved scientific calculator is expected, where appropriate.

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This document consists of 17 printed pages and **3** blank pages.


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**Data**

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

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**Formulae**

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

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**1** A double-slit interference experiment is used to determine the wavelength of light from a monochromatic source.

The following measurements are used.

slit separation $a = 0.50 \pm 0.02$ mm
fringe separation $x = 1.7 \pm 0.1$ mm
distance between slits and screen $D = 2.000 \pm 0.002$ m

What is the percentage uncertainty in the calculated wavelength?

**A** 0.1% **B** 1% **C** 6% **D** 10%

**2** In order that a train can stop safely, it will always pass a signal showing a yellow light before it reaches a signal showing a red light. Drivers apply the brake at the yellow light and this results in a uniform deceleration to stop exactly at the red light.

The distance between the red and yellow lights is $x$.

What must be the minimum distance between the lights if the train speed is increased by 20%, without changing the deceleration of the train?

**A** 1.20$x$ **B** 1.25$x$ **C** 1.44$x$ **D** 1.56$x$

**3** A ball is thrown horizontally in still air from the top of a tall building.

What happens to the horizontal and to the vertical components of the ball's velocity after a long time?

| | horizontal component of velocity | vertical component of velocity |
|---|---|---|
| **A** | decreases to zero | increases at a constant rate |
| **B** | decreases to zero | increases to a constant value |
| **C** | remains constant | increases at a constant rate |
| **D** | remains constant | increases to a constant value |

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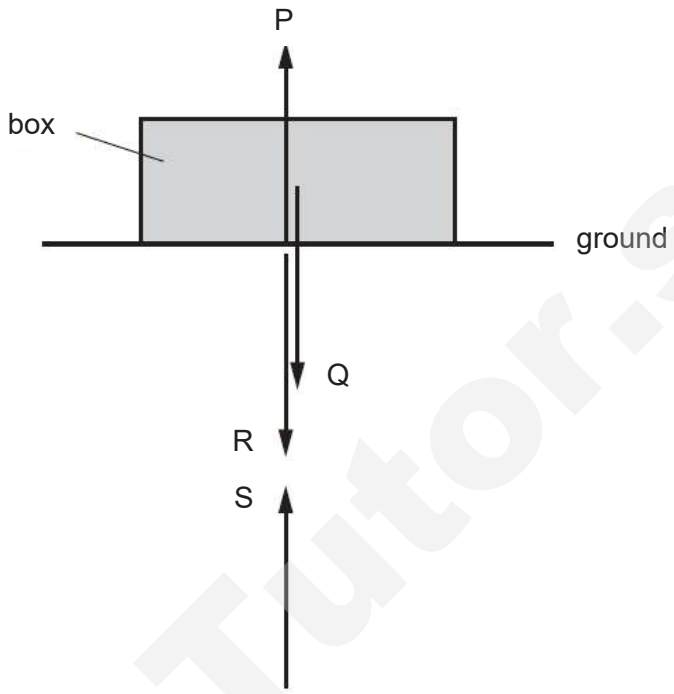
**4** A box is shown resting on the ground. Newton's third law implies that four forces of equal magnitude are involved. These forces are labelled P, Q, R and S.

Forces P and Q act on the box. Forces R and S act on the Earth.

For clarity, the forces are shown slightly separated.




Which statement about the forces is correct?

**A** P is the equal and opposite force to Q and both are forces of contact.

**B** Q is the equal and opposite force to P and both are gravitational forces.

**C** R is the equal and opposite force to S and both are forces of contact.

**D** S is the equal and opposite force to Q and both are gravitational forces.

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**5** A small ball P moves with speed $v$ towards another identical ball Q along a line joining the centres of the two balls. Ball Q is at rest. They collide elastically.




Which one of the following situations is the outcome of the collision between the balls?

**A**



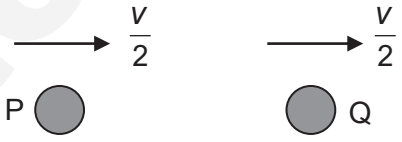

**B**



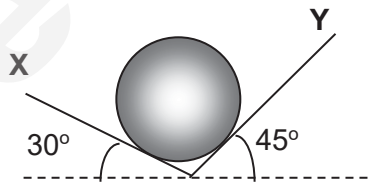

**C**




**D**




**6** A ball rests against two frictionless walls, X and Y, as shown in the figure below.




What is the ratio of reaction forces of wall X to that of wall Y?

**A** 0.71 **B** 0.82 **C** 1.0 **D** 1.4

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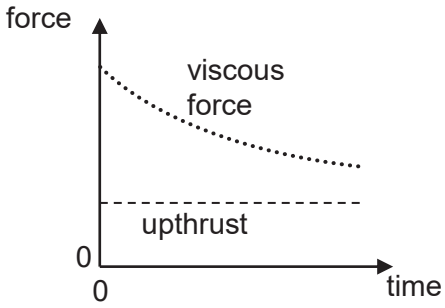
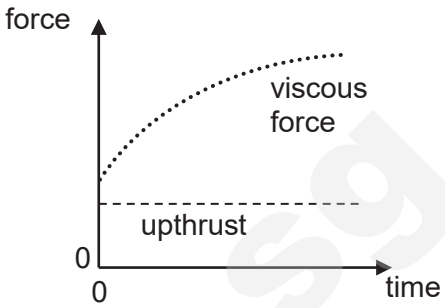
**7** A ball bearing is thrown downwards at high speed in a viscous liquid. Which of the following graphs would represent the variation of the upthrust and viscous force acting on the ball bearing with time?

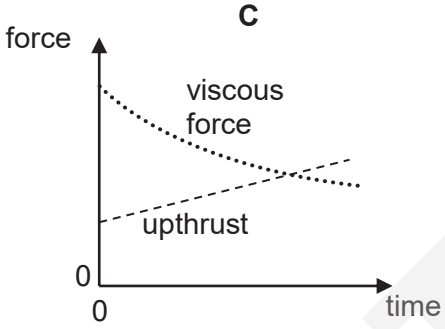
**A**



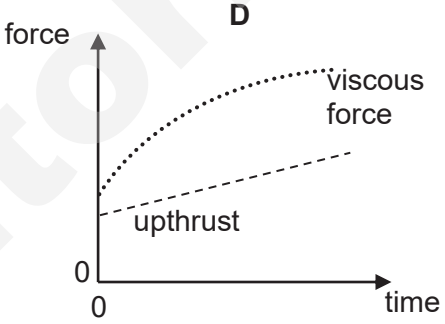

**B**




**C**




**D**




**8** A mass is attached to the end of a spring which obeys Hooke's law.

When a load of 3.0 N is placed on the spring, the spring is extended by 0.030 m.

What additional elastic potential energy will be stored in the spring if it is then extended a further 0.010 m?

**A** 0.0050 J **B** 0.030 J **C** 0.035 J **D** 0.080 J

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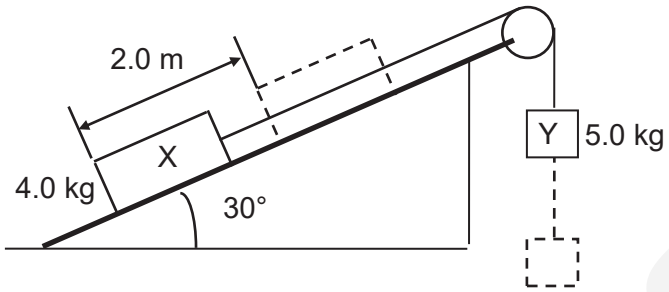
**9** The diagram shows two bodies X and Y connected by a light cord passing over a light, free-running pulley. X starts from rest and moves on a slope inclined at 30° to the horizontal. X has a mass of 4.0 kg, and Y has a mass of 5.0 kg. Friction between X and the slope is 5.0 N.

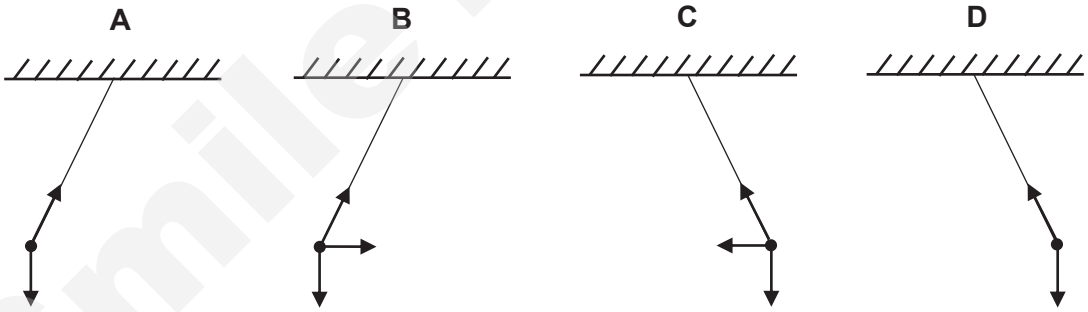



Which of the following is the total kinetic energy of the system when X has travelled 2.0 m along the plane?

**A** 9.6 J **B** 30 J **C** 49 J **D** 69 J

**10** A passenger is sitting in a railway carriage facing in the direction in which the train is travelling. A pendulum hangs down in front of him from the carriage roof. The train travels along a circular arc bending to the right.

Which one of the follow diagrams shows the position of the pendulum as seen by the passenger and the directions of the forces acting on it?




**11** Two satellites, A and B, orbiting around Earth have the same kinetic energy. Satellite A has a larger mass than satellite B. Which of the following statements is correct?

**A** Satellite A has the same total energy as satellite B.

**B** Satellite A has a smaller gravitational potential energy than satellite B.

**C** Satellite A has a larger gravitational potential energy than satellite B.

**D** Satellite A has a larger angular velocity than satellite B.

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**12** An ideal gas is contained in a cylinder with a movable piston. At pressure $p$, volume $V$ and temperature $T$, it has $N_v$ molecules per unit volume. If the pressure of the gas is changed to $0.50p$, and the temperature to $2.0T$, the number of molecules per unit volume becomes

**A** $0.25\ N_v$ **B** $0.50\ N_v$ **C** $1.0\ N_v$ **D** $4.0\ N_v$

**13** Which statement about internal energy is correct?

**A** The internal energy of a system can be increased without transfer of heat.

**B** The internal energy of a system is the sum of the kinetic energies of the molecules.

**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.

**14** An ideal gas has thermodynamic temperature $T$, and its molecules has root-mean-square speed $c_{rms}$. If the gas is heated to temperature $2T$, what is the new root-mean-square speed of the molecules?

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

**15** Diagram 1 shows the variation with displacement $x$ of velocity $v$ of a simple harmonic oscillator. Diagram 2 shows the variation with time $t$ of the velocity $v$ of the oscillator.

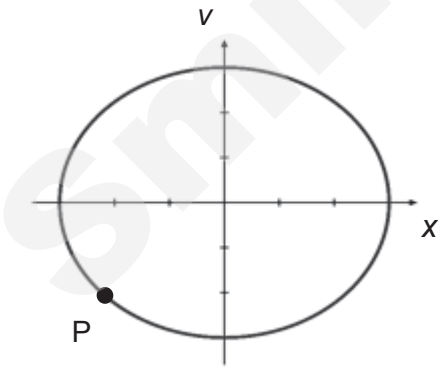


diagram 1

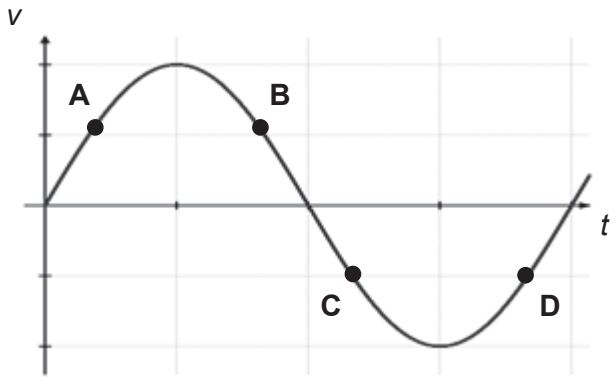


diagram 2

Which of the points on diagram 2 corresponds to the state of motion represented by point P on diagram 1?


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**16** Which statement about a light wave and a sound wave is correct?

**A** Both can be polarised.

**B** Both can travel through free space.

**C** Both have a frequency inversely proportional to their wavelength.

**D** Both have an intensity proportional to their amplitude.

**17** A light wave of amplitude $A$ is incident normally on a surface of area $S$. The power per unit area reaching the surface is $P$.

The amplitude of the light wave is increased to $2A$. The light is then focused on to a smaller area $\frac{1}{3}S$.

What is the power per unit area on this smaller area?

**A** $6P$

**B** $12P$

**C** $18P$

**D** $36P$

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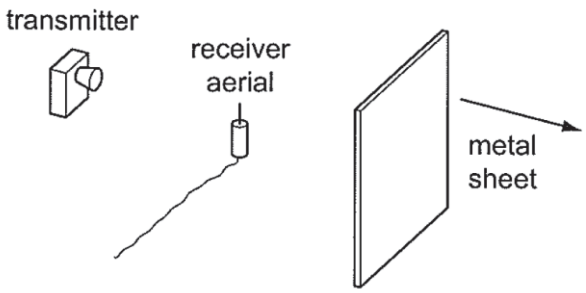
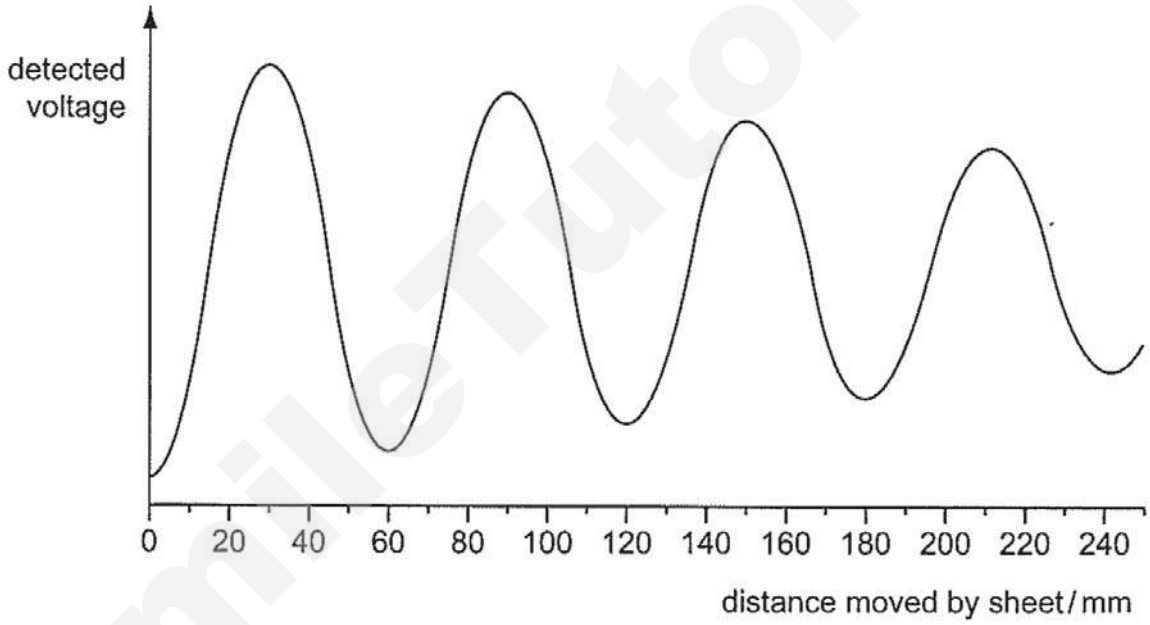
**18** A receiver aerial is placed on a laboratory bench between a transmitter emitting microwaves at a single fixed frequency and a metal sheet.




The metal sheet is moved away from the aerial. The detected voltage at the receiver aerial varies with the distance moved by the sheet as shown.




What is the wavelength of the microwaves?

**A** 180 mm **B** 120 mm **C** 60 mm **D** 30 mm

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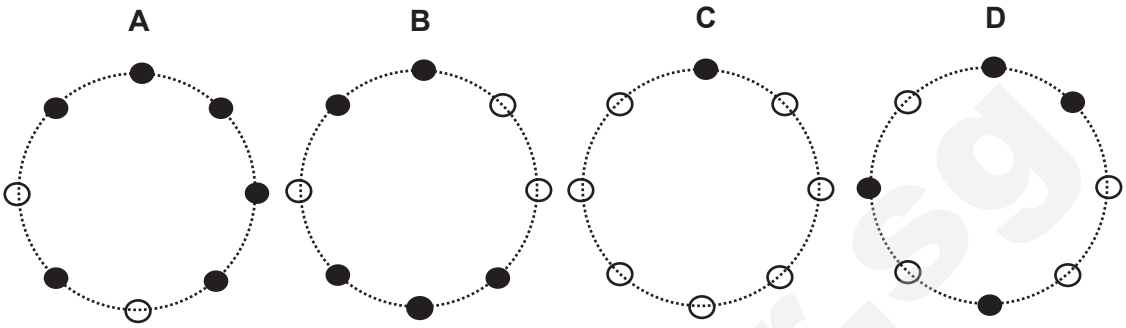
**19** A combination of eight electrons (denoted by O ) and protons (denoted by ● ) are fixed in place and evenly spread along the circumference of circle as shown.

Which of the combinations has the smallest magnitude of resultant electric field strength at the centre of the circle?




**20** An electron is projected horizontally with a speed of $3.1 \times 10^7$ m s$^{-1}$. It passes in between the two charged horizontal plates. The uniform electric field between the plates is 20000 N C$^{-1}$. As the electron passes through the plates, it is deflected. The time taken for the electron to travel the length of the plate is $4.0 \times 10^{-9}$ s.




What is the vertical distance travelled by the electron after it has travelled the length of the plate?

**A** $1.76 \times 10^{-17}$ m **B** $7.85 \times 10^{-17}$ m **C** 0.0281 m **D** 0.152 m

**21** The potential difference between point X and point Y in an electric circuit is 18 V. The current passing through is 1.5 A and the time taken for charge carriers to move from X to Y is 0.2 s.

What is the change in the energy of the charge carriers as they pass between X and Y?

**A** 0.017 J **B** 5.4 J **C** 60 J **D** 135 J

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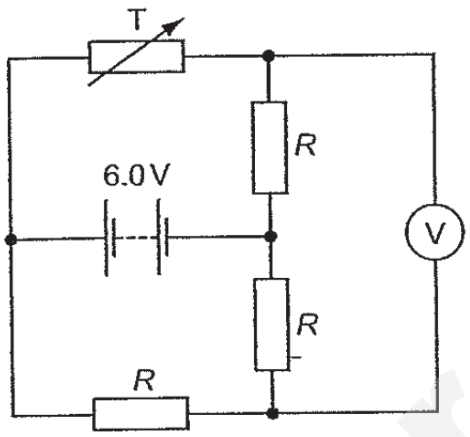
**22** A battery of e.m.f. 6.0 V and negligible internal resistance is connected to three resistors, each of resistance *R*, and a variable resistor T, as shown.




The resistance of T changes from *R* to 2*R*.

What is the change in the reading of the high resistance voltmeter?

**A** zero **B** 1V **C** 2V **D** 3V

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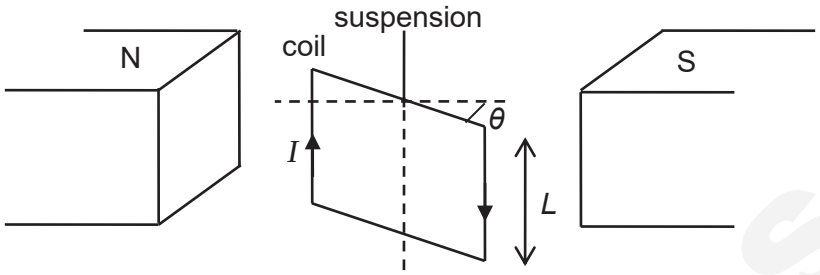
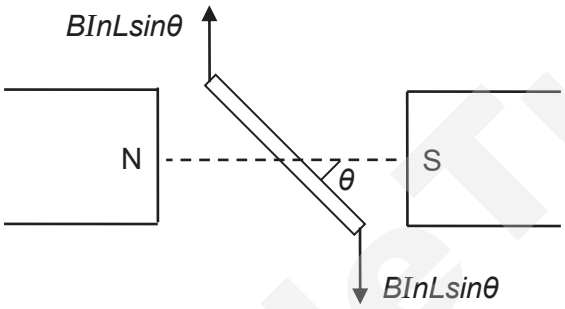
**23** A current $I$ is carried by a rectangular coil of *n* turns and side *L* suspended vertically as shown in a uniform horizontal magnetic field of flux density *B*.

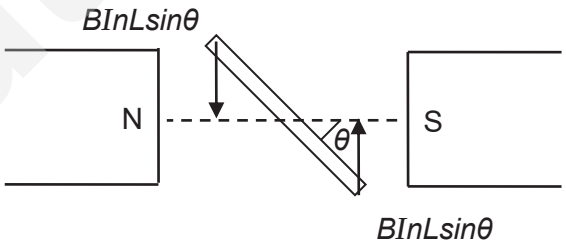



Which of the following diagrams, viewed from the top, correctly shows the magnitude and direction of the forces acting on the vertical sides of the coil?

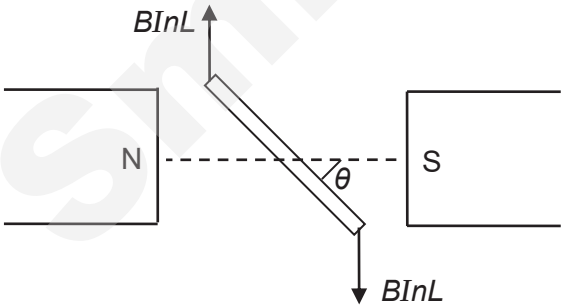
**A**



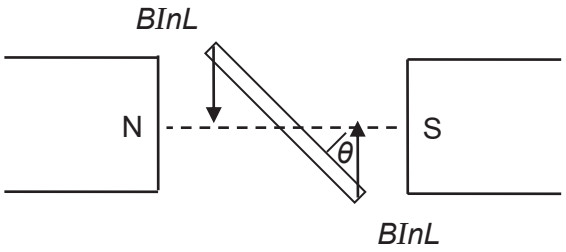

**B**




**C**




**D**

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**24** 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.

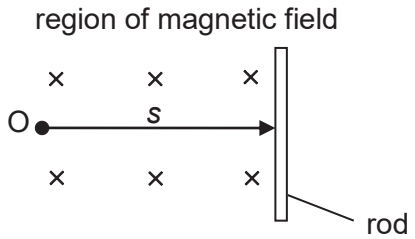



diagram 1

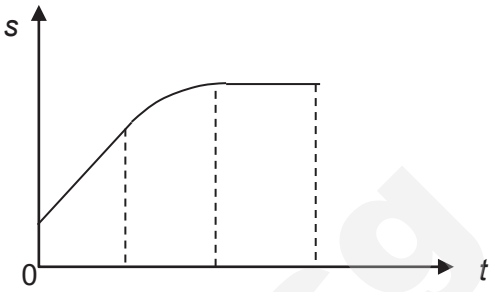
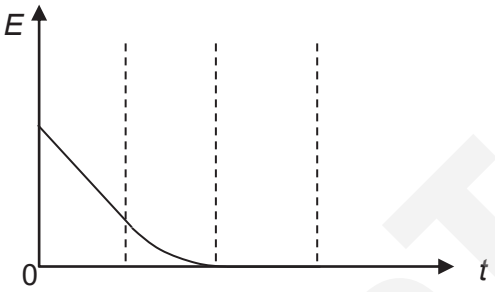


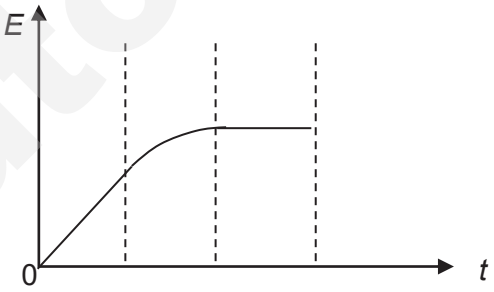

diagram 2

Which graph best shows the variation of *t* of the e.m.f. *E* induced in the rod?

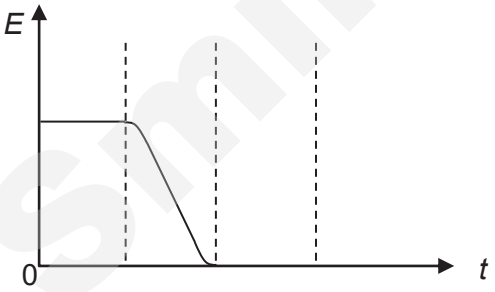
**A**



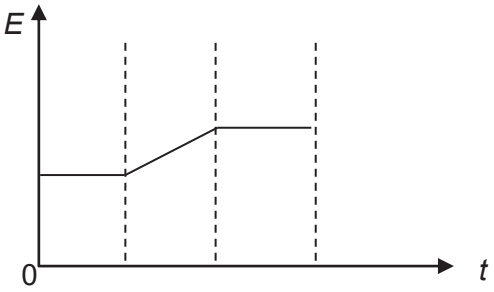

**B**




**C**




**D**




**25** An alternating current of peak value 2 A and a steady direct current $I$ flowing through identical resistors dissipate heat at equal rates.

What is the value of current $I$ ?

**A** $\frac{1}{2\sqrt{2}}$ A **B** $\sqrt{2}$ A **C** 2 A **D** $2\sqrt{2}$ A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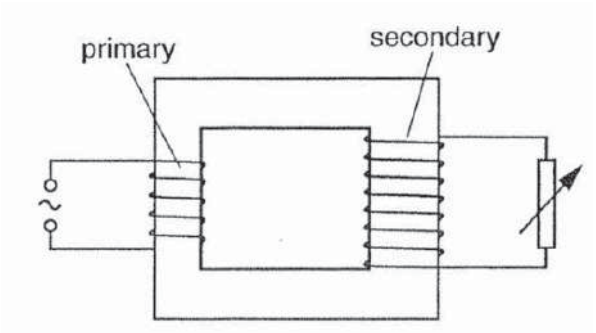
**26** The primary coil of a transformer is connected to an alternating voltage supply. The secondary coil is connected across a variable resistor.




Which change will cause a decrease in the p.d. across the secondary coil?

**A** Increasing the number of turns of the primary coil

**B** Increasing the cross-sectional area of the secondary coil

**C** Increasing the resistance of the variable resistor

**D** Decreasing the resistance of the variable resistor

**27** In an X-ray tube, electrons, each with a charge $q$, are accelerated through a potential difference $V$ and are then made to strike a metal target. If $h$ is the Planck constant and $c$ is the speed of light, what is the expression for the minimum wavelength of the emitted radiation?

**A** $\frac{hq}{cV}$ **B** $\frac{qV}{hc}$ **C** $\frac{qV}{h}$ **D** $\frac{hc}{qV}$

**28** An electron is measured to have a speed of $2.05 \times 10^6$ m $s^{-1}$ in the x-direction. The precision in measuring its speed is 0.50%.

What is the minimum uncertainty of its position of the electron along the x-direction?

**A** 0 **B** $3.37 \times 10^{-20}$ m **C** $1.97 \times 10^{-14}$ m **D** $7.10 \times 10^{-8}$ m

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**29** Which of the following statements concerning nuclear properties is true?

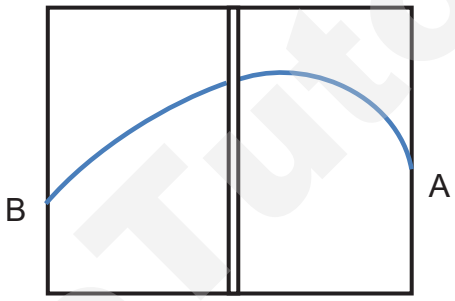
**A** The greater the binding energy of a nucleus, the more stable it is.

**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** When a stationary nucleus decays by emitting a $\gamma$-photon, the nucleus will move off in an opposite direction to the photon.

**D** The half-life of a radioactive substance can be changed by allowing the substance to react chemically to produce a new radioactive compound.

**30** Radiation from a radioactive source enters an evacuated region in which there is a uniform magnetic field perpendicular to the plane of the diagram. This region is divided into two by a sheet of aluminum about 1 mm thick. The curved, horizontal path followed by the radiation is shown in the diagram below.




Which of the following correctly describes the type of radiation and its point of entry?

| | type of radiation | point of entry |
|---|---|---|
| **A** | alpha | A |
| **B** | alpha | B |
| **C** | beta | A |
| **D** | beta | B |

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Name: _____ (  )  Class: 19 / _____

# ANDERSON SERANGOON JUNIOR COLLEGE

## 2019 JC2 Preliminary Examination

## PHYSICS Higher 2 9749/02

**Paper 2 Structured Questions** **Tuesday 17 September 2019**

**2 hours**

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

---

**READ THESE INSTRUCTIONS FIRST**

Write your name, class index number and class in the spaces provided above.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.

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 | |
|---|---|
| **Paper 2 (80 marks)** | |
| **1** | |
| **2** | |
| **3** | |
| **4** | |
| **5** | |
| **6** | |
| **7** | |
| **Significant Figure** | |
| **Total** | |

---

This document consists of **23** printed pages and **1** blank page.


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**Data**

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

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**Formulae**

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

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

**1** A hollow tube contains some sand. When placed in a liquid, the tube floats upright as shown in Fig. 1.1.

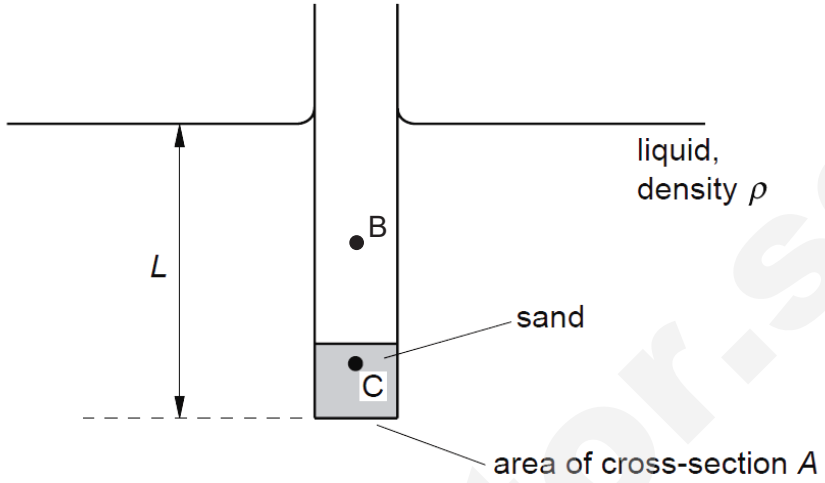


**Fig. 1.1**

The centre of mass of the tube and the sand is at C.

The centre of buoyancy of the tube, which is the point at which upthrust on the tube may be considered to act, is at B.

**(a)** On Fig. 1.1, draw labelled arrows to represent the forces acting on the system of the tube and the sand. [1]

**(b)** When placed in water of density 0.99 g $cm^{-3}$, the length $L$ is 12.1 cm. The tube is then transferred to a liquid of density 1.11 g $cm^{-3}$. Calculate the change in the submerged length.

change in length = ……cm [3]

**(c)** **(i)** Explain why, when the tube is tilted at a small angle, it returns to the upright position.

……

…… [1]

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**(ii)** The tube is now displaced vertically and then released. It undergoes vertical oscillations.

Describe the restoring force that gives rise to the oscillations.

……

……

……

…… [2]

[Total: 7]

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**2** A rocket is launched from the surface of a planet and moves along a radial path, as shown in Fig. 2.1.

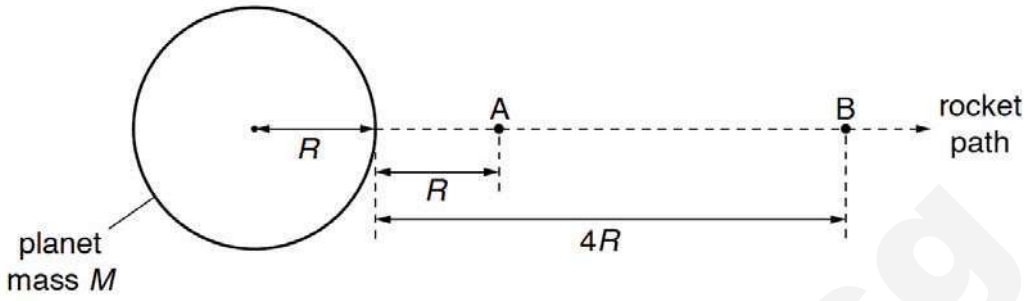


**Fig. 2.1**

The planet may be considered to be an isolated sphere of radius $R$ with all of its mass $M$ concentrated at its centre. Point A is a distance $R$ from the surface of the planet. Point B is a distance $4R$ from the surface.

**(a)** Show, for moving a short distance $h$ near the surface of the planet, that the change in gravitational potential energy $\Delta E_P$ of the rocket is given by the expression

$$\Delta E_P = mgh$$

where $g$ is the acceleration of free fall.

……

……

……

……

……

……[3]

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**(b)** The rocket motor is switched off at point A. During the journey from A to B, the rocket has a constant mass of $4.7 \times 10^4$ kg and its kinetic energy changes from 1.17 TJ to 0.35 TJ.

For the planet, the product $GM$ is $4.0 \times 10^{14}$ $Nm^2 kg^{-1}$. It may be assumed that resistive forces to the motion of the rocket are negligible.

Determine the distance from A to B.

distance = ……m [4]

**(c)** The rocket eventually reaches a distance far away from the planet.

Suggest one similarity and one difference between the gravitational fields at the surface of the planet and at the surface of the rocket.

similarity: ..……..

……..

difference: ……..

…….....[2]

[Total: 9]

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**3** A ball is held between two fixed points A and B by means of two stretched springs, as shown in Fig. 3.1.

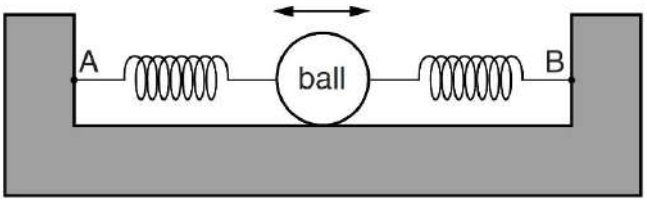


**Fig 3.1**

The ball is free to oscillate along the straight line AB. The springs remain stretched and the motion of the ball is simple harmonic.

The variation with time $t$ of the displacement $x$ of the ball from its equilibrium position is shown in Fig. 3.2.

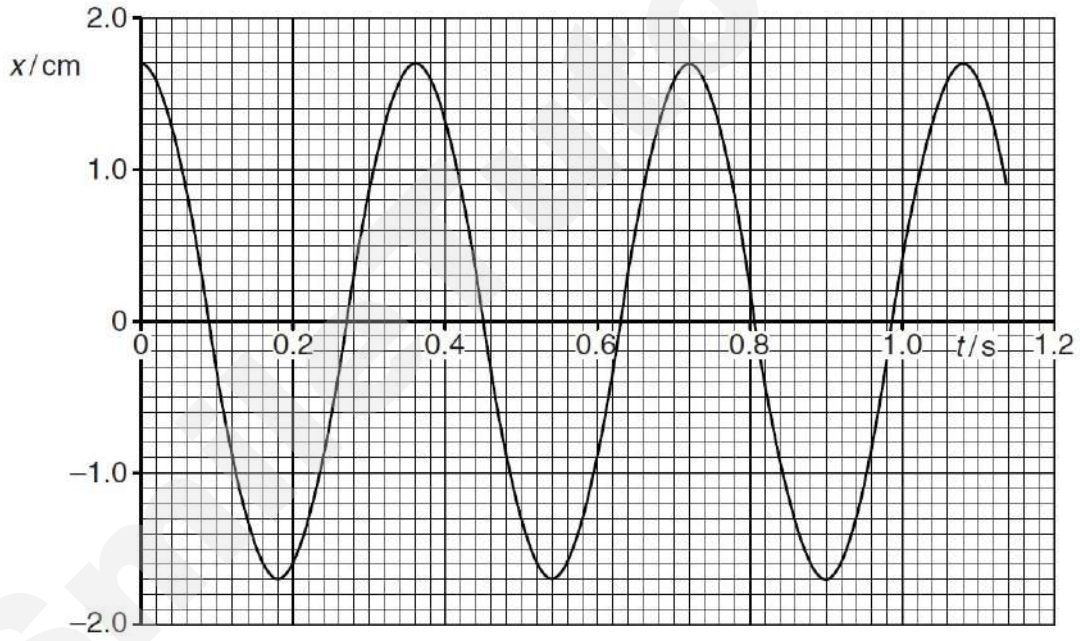


**Fig 3.2**

**(a)** Calculate the maximum acceleration of the ball.

maximum acceleration = ..... m $s^{-2}$ [3]

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**(b)** Calculate the displacement of the ball at which its kinetic energy is equal to half of the total energy of oscillation.

displacement = …….cm [3]

**(c)** The spring-mass system in Fig 3.1 is placed on a rough vibrating surface.
Fig. 3.3 shows how the amplitude of the ball varies with the frequency of the vibrating surface.

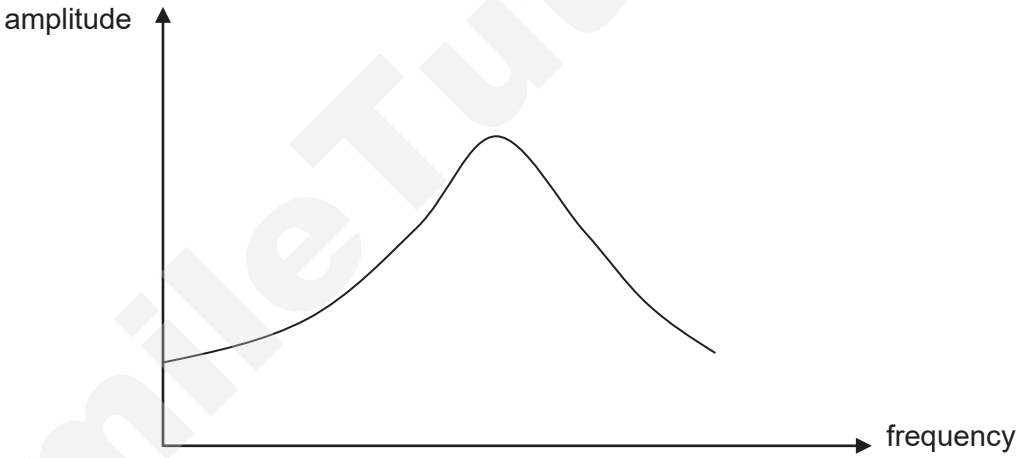


**Fig. 3.3**

The spring-mass system is then placed on a smoother vibrating surface.

On Fig. 3.3, sketch to show how the amplitude of the ball varies with the frequency of the vibrating surface.

[2]

[Total: 8]

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**4** **(a)** A ripple tank is used to show the diffraction and interference of waves.
On Fig. 4.1, plane wavefronts are shown approaching an object.

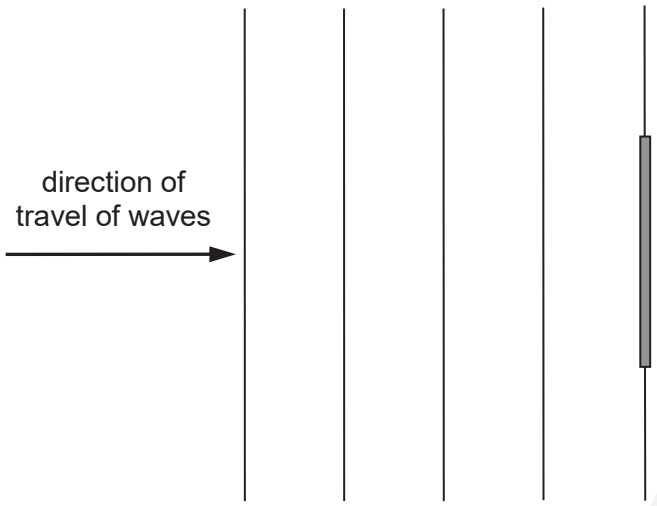


**Fig. 4.1**

**(i)** On Fig. 4.1, draw four wavefronts to show the waves after they have passed through the object. [2]

**(ii)** The object is now made shorter.

Describe the change in appearance of the diffracted wavefronts.

……

…… [1]

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**(b)** A laser is placed in front of a slit as shown in Fig. 4.2.

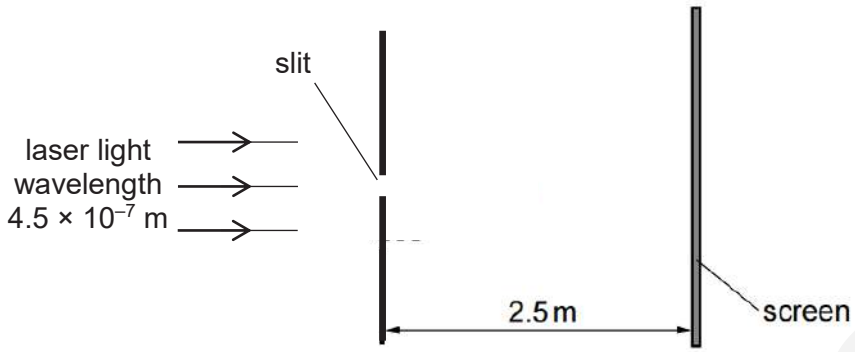


**Fig. 4.2** (not drawn to scale)

The laser emits light of wavelength $4.5 \times 10^{-7}$ m. The distance from the slit to the screen is 2.5 m. The width of the slit is 0.50 mm.

An interference pattern is observed on the screen.

The width of the central fringe as observed on the screen is *y*.

**(i)** Show that *y* is 4.5 mm.

[2]

**(ii)** The single slit is replaced with a double slit as shown in Fig. 4.3.

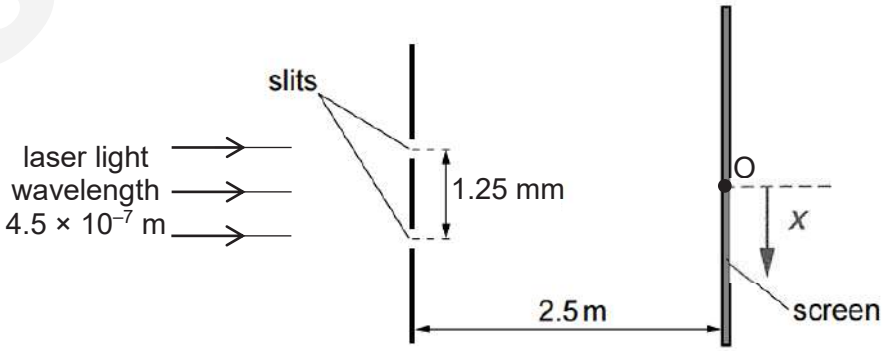


**Fig. 4.3** (not drawn to scale)

The separation of the slits is 1.25 mm. The width of each slit is 0.50 mm.

The centre of the interference pattern formed on the screen is at O.


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**1.** Explain why an interference pattern is formed on the screen.

……

……

……

……

……

…… [3]

**2.** Show that there are five bright fringes in the region $-\frac{y}{2} \leq x \leq \frac{y}{2}$, where $x$ is the distance measured downwards along the screen from point O.

[2]

**3.** On Fig. 4.4, sketch the variation with distance $x$ from point O of the intensity $I$ for the image observed on the screen.

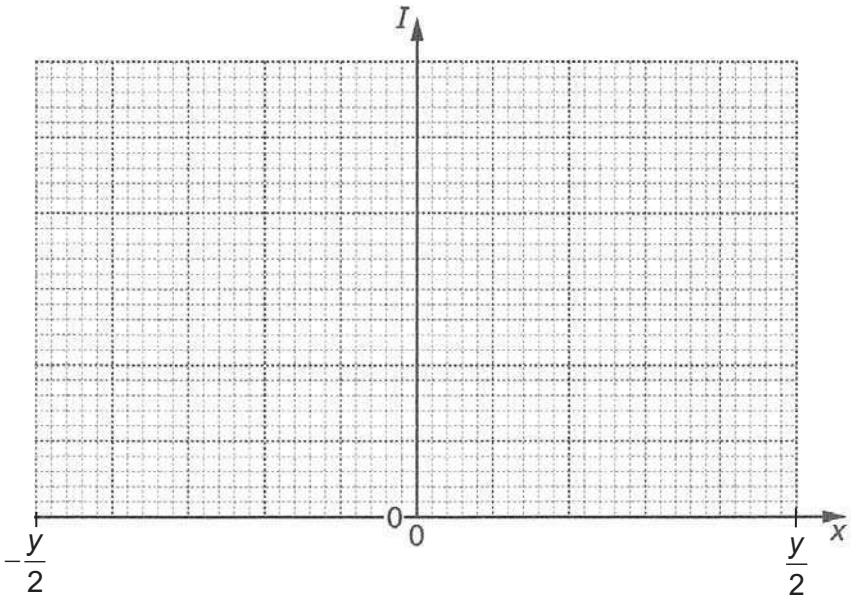


**Fig. 4.4**

[3]

[Total: 13]

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**5** **(a)** A solenoid is connected to a d.c. supply as shown in Fig. 5.1.

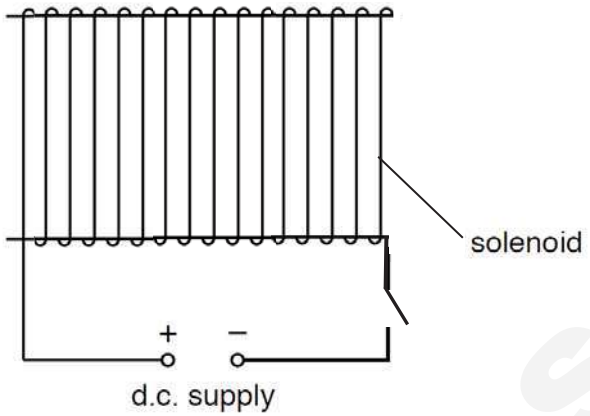


**Fig. 5.1** (not drawn to scale)

Use laws of electromagnetic induction to explain why, when the switch is closed, the current increases **gradually** to its maximum value.

……..

……..

……..

……..

…….....[3]

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**(b)** The solenoid from part **(a)** has a coil C of wire wound tightly about its centre, as shown in Fig. 5.2.

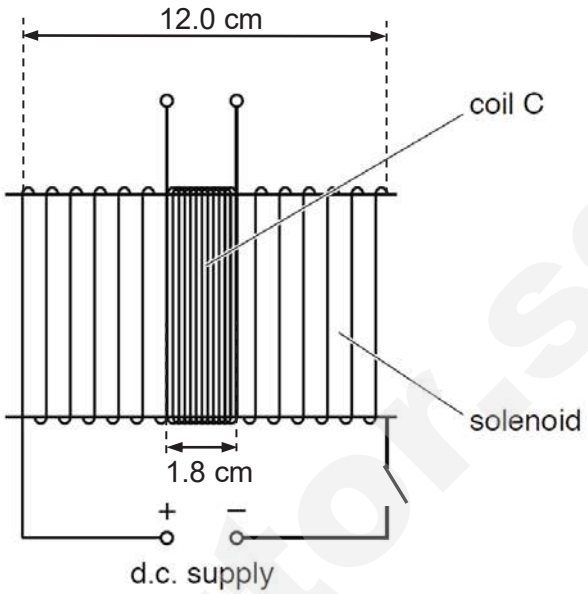


**Fig. 5.2** (not drawn to scale)

The solenoid has length 12.0 cm and circumference 8.8 cm, and consists of 360 turns. The coil C has length 1.8 cm and consists of 96 turns.

**(i)** Define *magnetic flux*.

……

……

…… [1]

**(ii)** When the switch is closed, the current in the solenoid is 2.5 A.

Show that the magnetic flux in coil C is $5.8 \times 10^{-6}$ Wb.

[3]

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**(iii)** Calculate the average electromotive force (e.m.f.) induced in coil C when the current in **(b)(ii)** is reversed in the solenoid in a time of 2.4 ms.

e.m.f = …….V [2]

**(iv)** The d.c. supply in Fig. 5.1 is now replaced with a sinusoidal alternating supply.

Describe qualitatively the e.m.f. that is now induced in coil C.

…….....

…….....

……..... [2]

[Total: 11]

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**6** Experiments are conducted to investigate the photoelectric effect.

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

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

……

……

……

……

……[2]

**(b)** Data for the wavelength $\lambda$ of the radiation incident on the metal surface and the maximum kinetic energy $E_K$ of the emitted electrons are shown in Fig. 6.1.

| $\lambda$/ nm | $E_K$/ $10^{-19}$J |
|---|---|
| 650 | – |
| 240 | 4.44 |

**Fig. 6.1**

**(i)** Without any calculation, suggest why no value is given for $E_K$ for radiation of wavelength 650 nm.

……

……[1]

**(ii)** Use data from Fig. 6.1 to determine the work function energy of the metal.

work function energy = ……J [2]

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

State and explain the effect of this change on

**(i)** the maximum kinetic energy of the photoelectrons,

……

……

…… [1]

**(ii)** the maximum photoelectric current $I$.

……

……

…… [1]

**(d)** Light in a beam has a continuous spectrum that lies within the visible region. The photons of the light beam have energies ranging from 1.60 eV to 2.60 eV.

The beam passes through some hydrogen gas. It then passes through a diffraction grating and an absorption spectrum is observed.

**(i)** All of the light absorbed by the hydrogen is re-emitted. Explain why dark lines are still observed in the absorption spectrum.

……

…… [1]

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**(ii)** Some of the energy levels of an electron in a hydrogen atom are illustrated in Fig. 6.2.

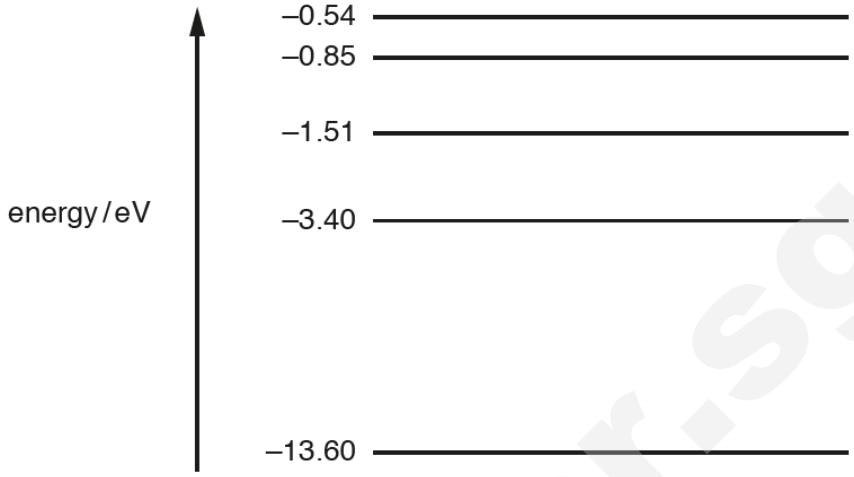


**Fig. 6.2** (not to scale)

The dark lines in the absorption spectrum are the result of electron transitions between energy levels.

On Fig. 6.2, draw arrows to show the initial electron transitions between energy levels that could give rise to dark lines in the absorption spectrum. [2]

**(iii)** Calculate the shortest wavelength of the light in the beam.

wavelength = ……m [2]

[Total: 12]

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**7** When some substances are in the solid state, they exist as positively-charged and negatively-charged ions arranged in a cubic lattice, as illustrated in Fig. 7.1.

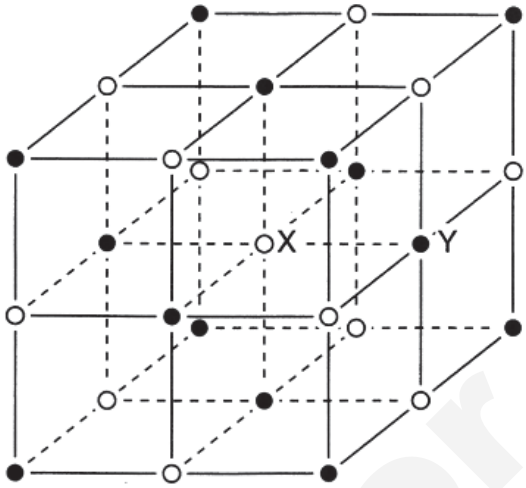


**Fig. 7.1**

A starting point for the understanding of lattice energies is to consider the potential energy $E_p$ between two ions X and Y.

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Fig. 7.2 shows the variation with the distance $r$ between X and Y of $E_p$.

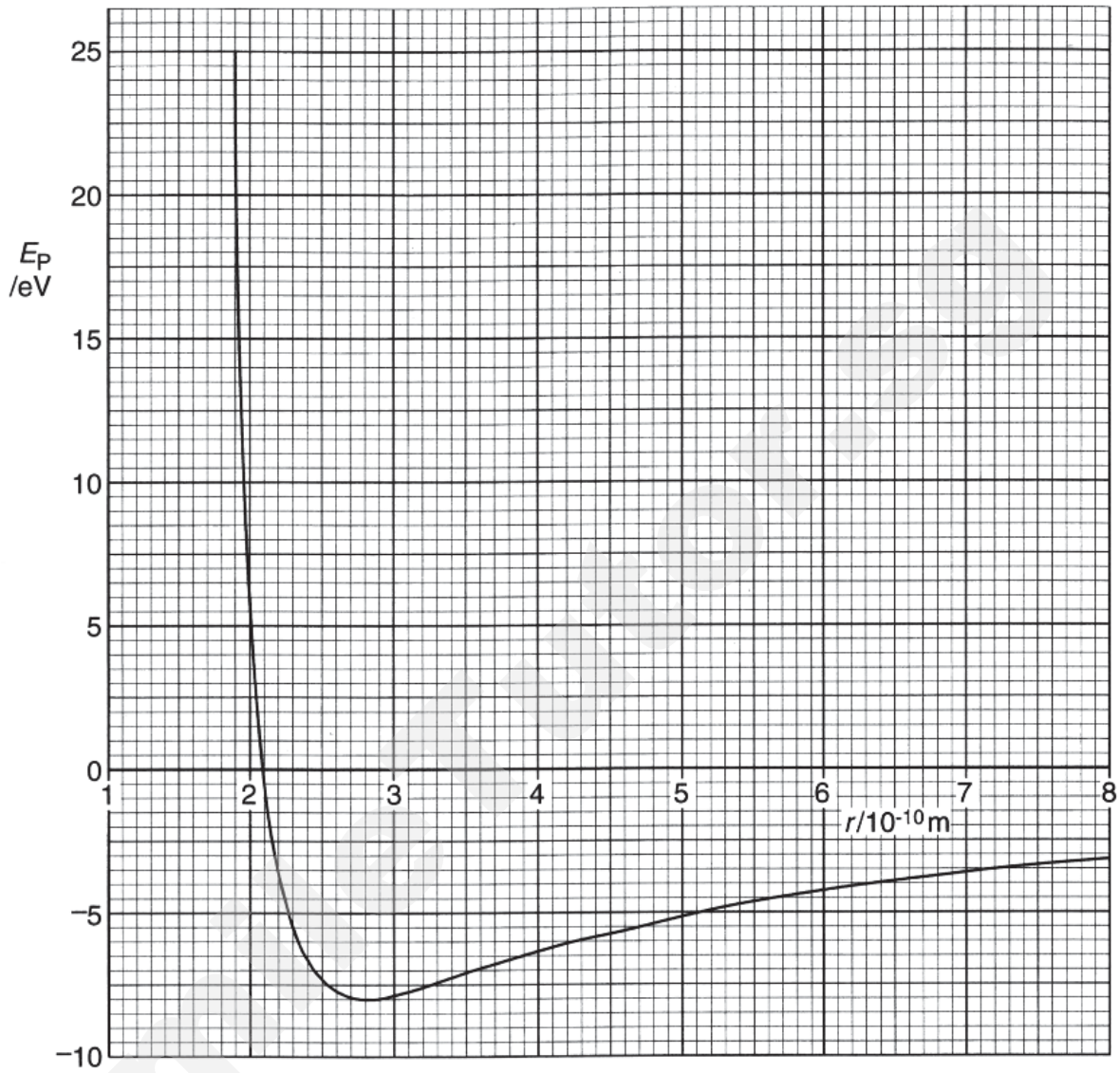


**Fig. 7.2**

**(a)** **(i)** The gradient $G$ of the graph varies with the distance $r$. Show that, starting from the definition of *work done*, for any value of $r$ the magnitude of the force $F$ between X and Y is given by the expression

$$F = G.$$

……

……

……

…… [2]

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**(ii)** Suggest how Fig. 7.2 indicates that, for some values of *r*, the force between X and Y is attractive and, for other distances, the force is repulsive.

……

……

…… [2]

**(iii)** Use Fig. 7.2 and the expression in **(i)** to determine the magnitude of the force, in newton, for values of the distance *r* equal to

**1.** $2.8 \times 10^{-10}$ m,

force = ……N [1]

**2.** $5.0 \times 10^{-10}$ m.

force = ……N [3]

**(b)** The variation with distance *r* of the potential energy $E_p$ may be represented by the expression

$$E_P = -\frac{A}{r} + \frac{B}{r^8}$$

where *A* and *B* are constants.

By reference to Fig. 7.2, state two features of the force represented by the term $\frac{B}{r^8}$ in this expression.

**1.** ……

……

**2**. ……

…… [2]


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**(c)** Fig. 7.3 shows part of Fig. 7.2, drawn on a larger scale.

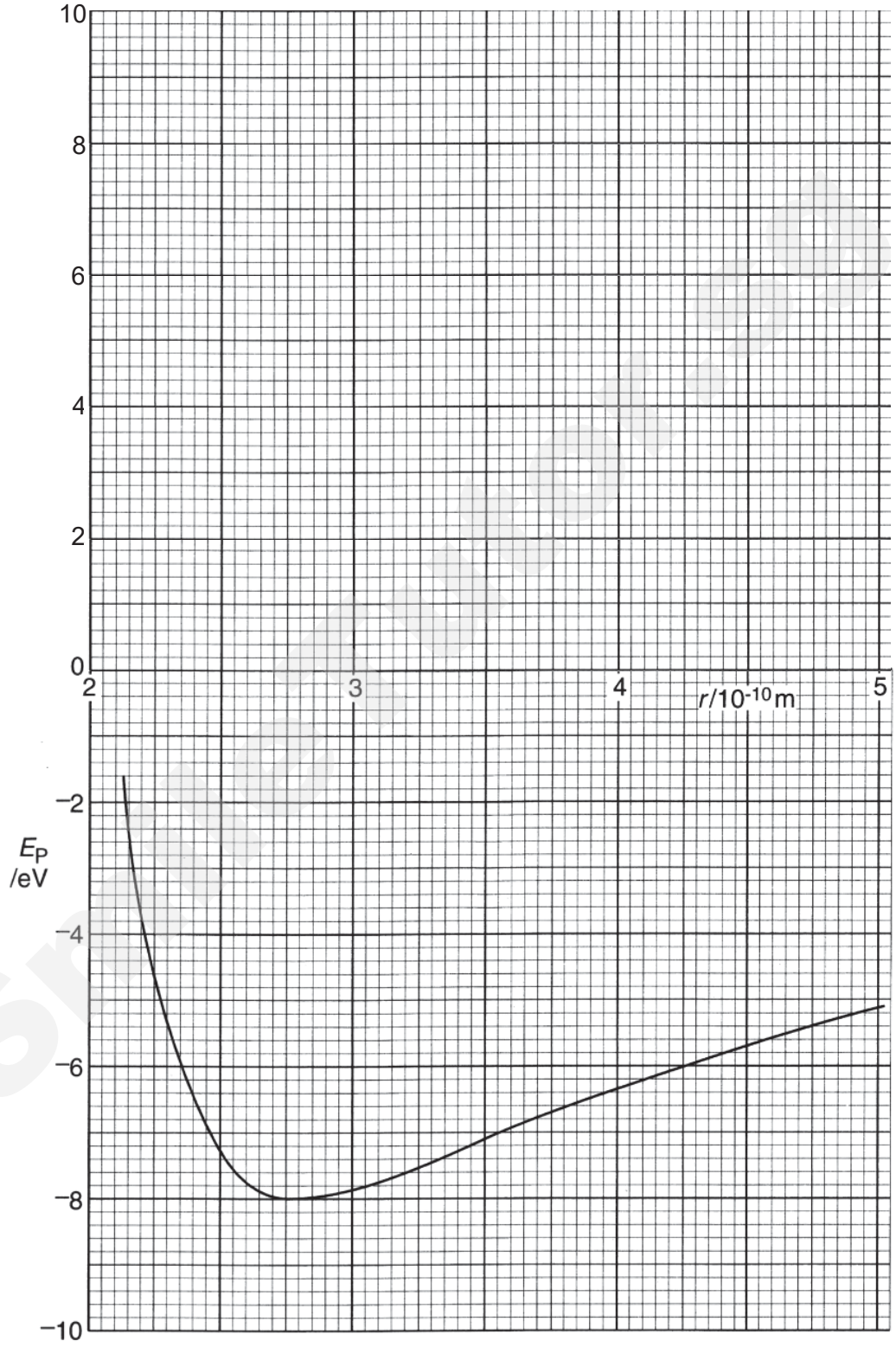


**Fig. 7.3**

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Thermal energy of the ions causes them to vibrate.
The ions have a total energy of ─ 6.0 eV.

**(i)** On Fig. 7.3,

**1.** draw the variation with the distance *r* of the total energy of the ions. Label the line T. [1]

**2.** draw the variation with the distance *r* of the kinetic energy of the ions. Label the line K. [2]

**(ii)** Use Fig. 7.3 to determine, for these ions, the values of *r* between which they vibrate.

minimum value of *r* = ……m

maximum value of *r* = ……m [2]

**(iii)** State and explain whether the oscillations of the ions are simple harmonic.

……

……

…… [2]

**(d)** By reference to Fig. 7.3, suggest why the dimensions of the whole lattice increase as it is heated.

……

……

……

……[3]

[Total: 20]

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Name: _____ (  )  Class: 19 / _____

# ANDERSON SERANGOON JUNIOR COLLEGE

## 2019 JC2 Preliminary Examination

## PHYSICS Higher 2 9749/03

**Paper 3 Longer Structured Questions** **Thursday 29 August 2019**

**2 hours**

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

---

**READ THESE INSTRUCTIONS FIRST**

Write your name, class index number and class in the spaces provided above.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.

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

**Section A**
Answer **all** questions.

**Section B**
Answer **one** question only.

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

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

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

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**Data**

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

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**Formulae**

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

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## Section A

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

**1** **(a)** An object travelling in a circle of radius $r$ at constant speed $v$ is accelerating. By drawing a vector diagram to show the combination of vectors, explain how this is possible.

……

……

……[2]

**(b)** A rider of mass 60 kg was confined in a Rotor, an amusement park ride. The Rotor is a large vertical barrel, rotated about a vertical axis through its centre. The radius of the barrel is 2.5 m. When the barrel is rotated sufficiently fast, the floor is dropped and the rider is stuck to the wall of the barrel.

**(i)** Fig. 1.1 shows a side-view of the position of a rider when the floor was dropped. Draw arrows to show the forces acting on the rider and label the forces clearly.

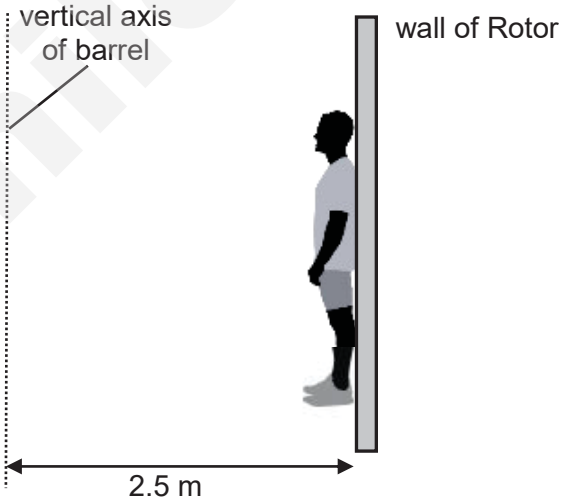


**Fig. 1.1** (not drawn to scale) [2]

**(ii)** Explain why the rider is able to go around in a circle without falling off.

……

……

……

……[2]


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**(iii)** The barrel in part **(i)** is rotating at 33 revolutions per minute.

Calculate the acceleration of the rider.

acceleration = ……m $s^{-2}$ [2]

**(iv)** State and explain the amount of work done on the rider throughout the acceleration in part **(iii)**.

……

……

……

……[2]

[Total 10]

**2** **(a)** State the first law of thermodynamics.

……

……[1]

**(b)** An ideal gas is placed in an insulated cylinder as shown in Fig. 2.1.

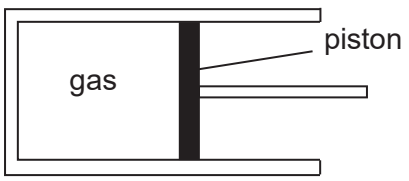


**Fig 2.1**

Initially, its pressure is $1.04 \times 10^5$ Pa and its temperature is 314 K. 28.5 J of heat is then supplied to the gas, causing its volume to increase from $2.90 \times 10^{-4}$ $m^3$ to $4.00 \times 10^{-4}$ $m^3$ while keeping its pressure constant.

**(i)** Calculate the work done on the gas.

work done on gas = …… J [2]


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**(ii)** Show that the change in internal energy of the gas is 17.1 J.

[1]

**(iii)** Calculate the new temperature of the gas.

new temperature = …….. K [2]

**(iv)** Calculate the ratio of the final root-mean-square (r.m.s.) speed to the original r.m.s. speed of the molecules.

ratio = …….. [2]

[Total 8]

**3** **(a)** Distinguish between transverse and longitudinal waves.

……..

……..

…….....[2]


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**(b)** Particle A and particle B oscillate on the same wave.

Fig 3.1 shows the variation with time of the displacement for particle A and particle B.

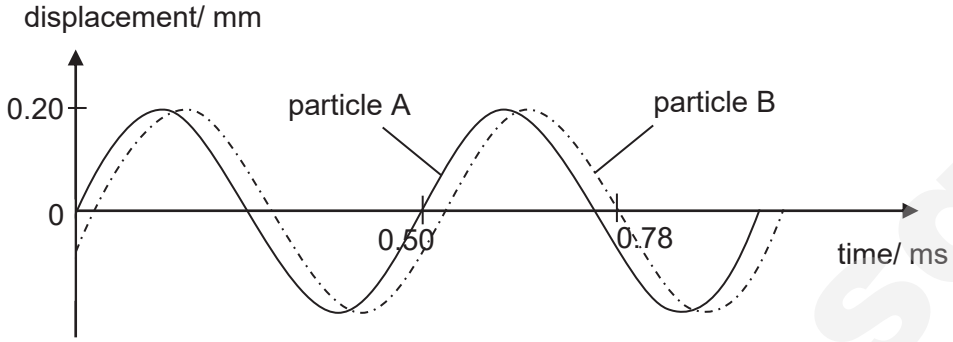


**Fig. 3.1** (not drawn to scale)

**(i)** Calculate the phase angle between the two particles A and B.

phase angle = ……° [2]

**(ii)** The wave on which the particles oscillate travels to the right.

Sketch on the axes of Fig. 3.2 the variation with distance of displacement for the wave at time $t = 0$. The position of particle A is shown on the axes.

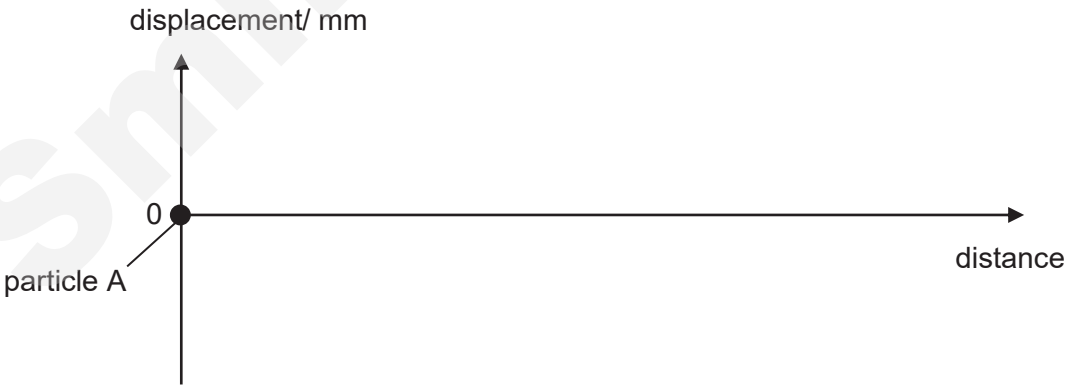


**Fig. 3.2**

[2]

[Total 6]


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**4** **(a)** An electric lamp has a resistance of 960 Ω. The filament of the lamp is made from tungsten that has a resistivity of $7.9 \times 10^{-7}$ Ω m. The diameter of the filament is $12.0 \times 10^{-6}$ m.

Calculate the length of the filament.

length = ..... m [2]

**(b)** Fig. 4.1 shows the variation with voltage $V$ of the current $I$ across a thermistor.

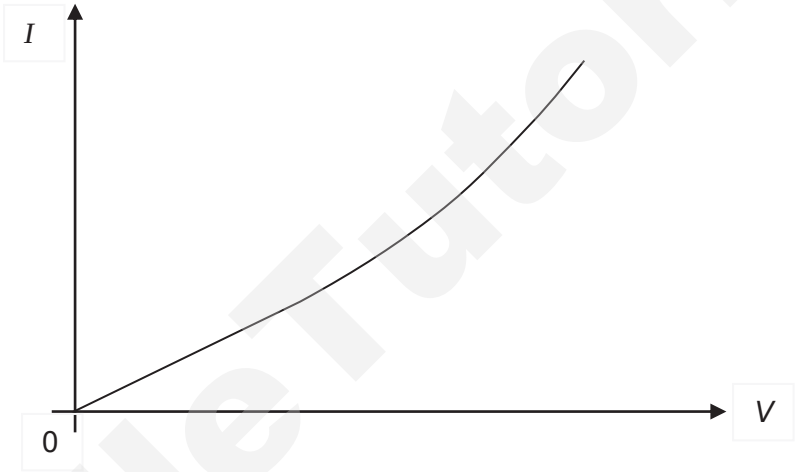


**Fig. 4.1**

**(i)** State how the resistance of the thermistor can be determined from Fig 4.1.

.....

.....[1]

**(ii)** In microscopic terms, explain why the resistance of the thermistor decreases as $V$ increases.

.....

.....

.....

.....

.....

.....

.....[3]


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**(iii)** The thermistor is connected to the lamp in **(a)** into the circuit in Fig 4.2. The resistance of the thermistor is 3900 Ω at 0°C and 1250 Ω at 30°C. The battery of electromotive force (e.m.f) 1.50 V has negligible internal resistance.

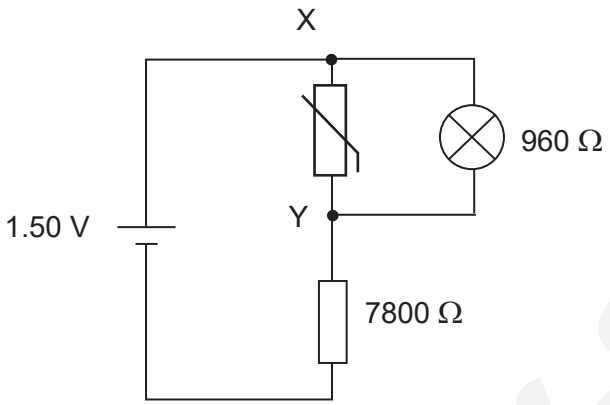


**Fig. 4.2**

**1.** Determine the effective resistance across XY when the temperature is 30°C.

effective resistance = ……Ω [1]

**2.** Determine the potential difference across XY when the temperature is 30°C.

potential difference = ……V [2]

**3.** Explain why the filament lamp becomes brighter when the temperature drops from 30°C to 0°C.

……

……

……

……

……

.....[3]

[Total 12]


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**5** 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. 5.1.

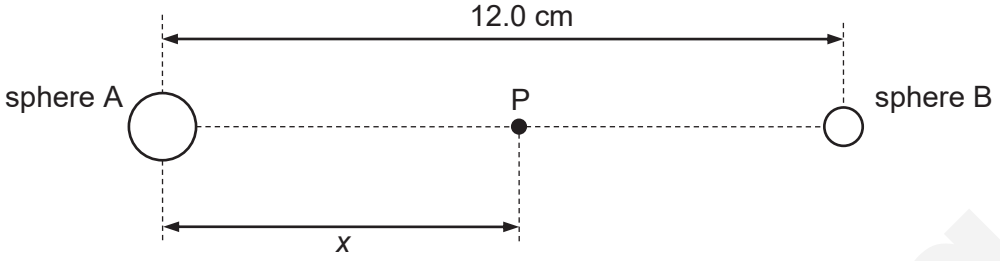


**Fig. 5.1**

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. 5.2.

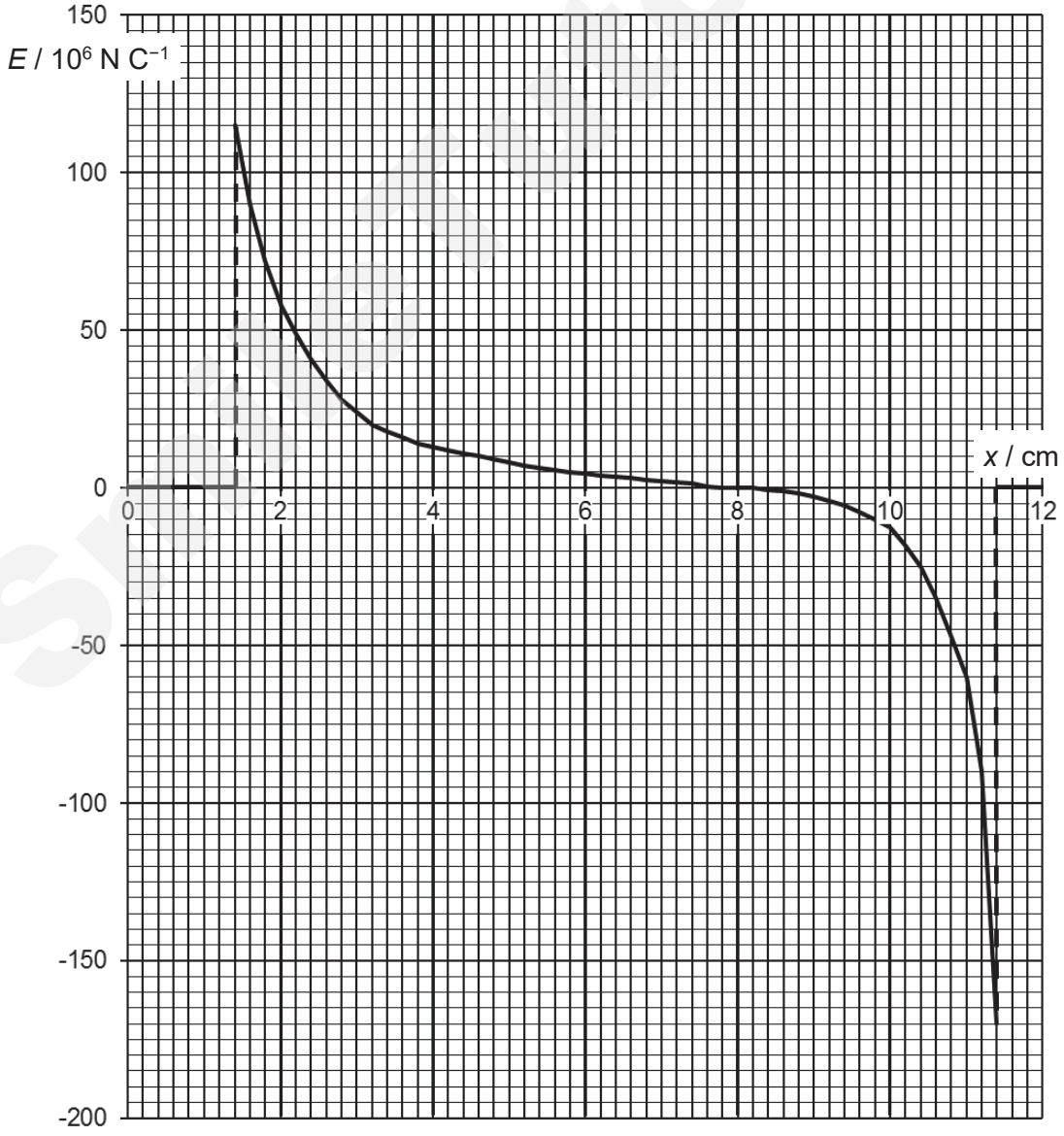


**Fig. 5.2**


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**(a)** State the evidence provided by Fig. 5.2 that the spheres are conductors.

……

……[1]

**(b)** **(i)** State and explain, whether the polarity of the charges on the spheres are of the same sign.

……

……

……

……[2]

**(ii)** Use Fig. 5.2 to determine the ratio $\frac{\text{charge on sphere A}}{\text{charge on sphere B}}$.

ratio = ……[3]

**(iii)** Hence, on Fig. 5.3, sketch the electric field lines due to these two charges.




**Fig. 5.3**

[2]

[Total 8]


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**6** **(a)** A uniform magnetic field has constant flux density *B*. A straight wire of fixed length carries a current $I$ at an angle $\theta$ to the magnetic field, as shown in Fig. 6.1.

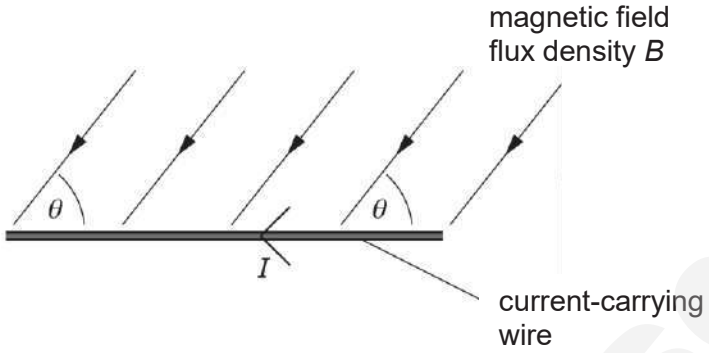


**Fig. 6.1**

**(i)** The current $I$ in the wire is changed, keeping the angle $\theta$ constant.
On Fig. 6.2, sketch a graph to show the variation with current $I$ of the force *F* on the wire.

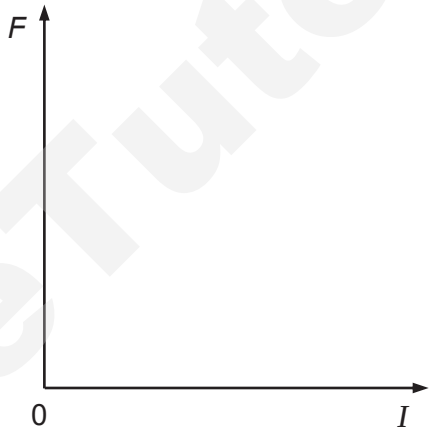


**Fig. 6.2**

[2]

**(ii)** The angle $\theta$ between the wire and the magnetic field is now varied. The current $I$ is kept constant.
On Fig. 6.3, sketch a graph to show the variation with angle $\theta$ of the force *F* on the wire. $F_{max}$ is the maximum force acting on the wire.

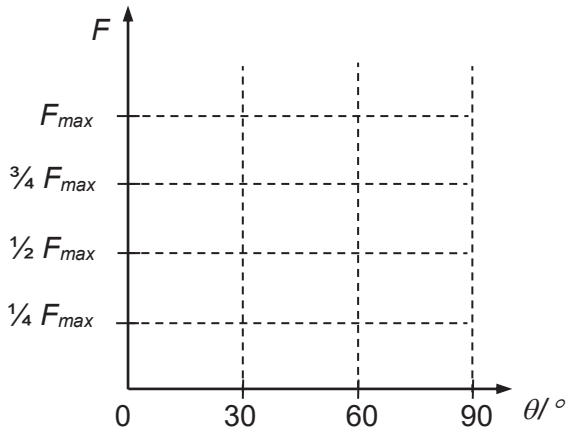


**Fig. 6.3**

[3]


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**(b)** A uniform magnetic field is directed at right-angles to the rectangular surface PQRS of a slice of a conducting material, as shown in Fig. 6.4.

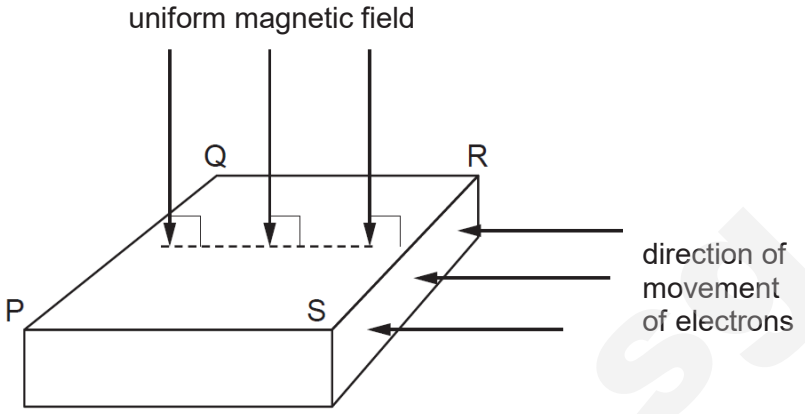


**Fig. 6.4**

Electrons, moving towards the side SR, enter the slice of conducting material. The electrons enter the slice at right-angles to side SR.

**(i)** The electrons initially do not travel in straight lines across the slice from side SR to side PQ.

State and explain to which side, PS or QR, the electrons tend to move.

……

……

…… [2]

**(ii)** Subsequent electrons travel undeflected in straight lines across the slice from side SR to side PQ.

Explain why this happens.

……

……

…… [2]

[Total 9]


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**7** The variation with time $t$ of the current $I$ in a resistor is shown in Fig. 7.1.

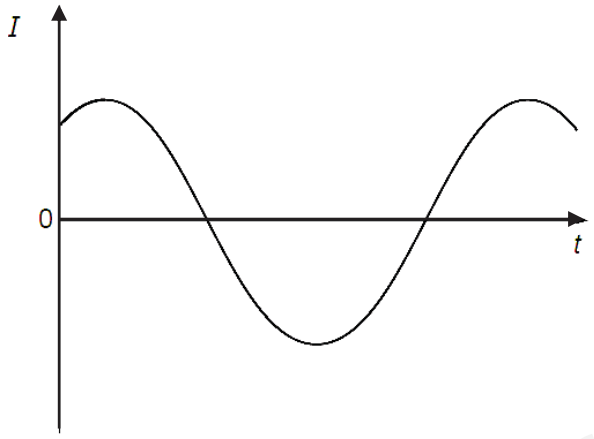


**Fig. 7.1**

The variation of the current with time is sinusoidal.

**(a) (i)** Explain why, although the mean current is zero, power is dissipated in the resistor.

……

…… [1]

**(ii)** Using the relation between root-mean-square (r.m.s.) current and peak current, deduce the value of the ratio

$$\frac{\text{average power disspated in the resistor}}{\text{maximum power disspated in the resistor}}$$

ratio = …… [2]

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**(b)** A simple iron-cored transformer is illustrated in Fig. 7.2.

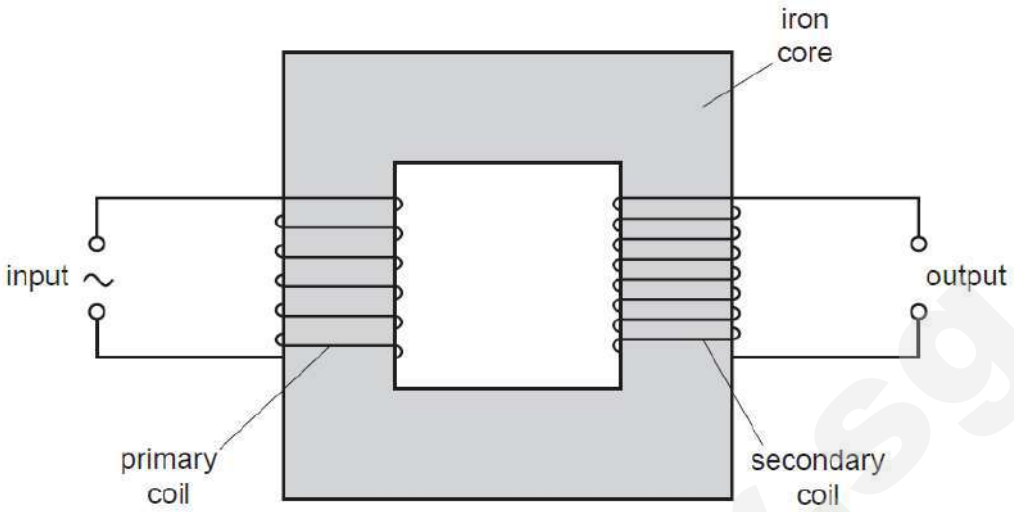


**Fig. 7.2**

**(i)** State why the primary and secondary coils are wound on a core made of soft iron.

……

…… [1]

**(ii)** Explain why thermal energy is generated in the core when the transformer is in use.

……

……

……

…… [2]

**(iii)** State a typical feature in the design of the iron core to reduce power loss.

…… [1]

[Total 7]

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## Section B

Answer **one** question from this Section in the spaces provided.

**8** **(a)** **(i)** The distance *s* moved by an object in time *t* may be given by the expression

$$s = \frac{1}{2}at^2$$

where *a* is the acceleration of the object.

State two conditions for this expression to apply to the motion of the object.

1. .....

.....

2. .....

..... [2]

**(ii)** A student takes a photograph of a steel ball of radius 5.0 cm as it falls from rest. The image of the ball is blurred, as illustrated in Fig. 8.1.
The image is blurred because the ball is moving while the photograph is being taken.

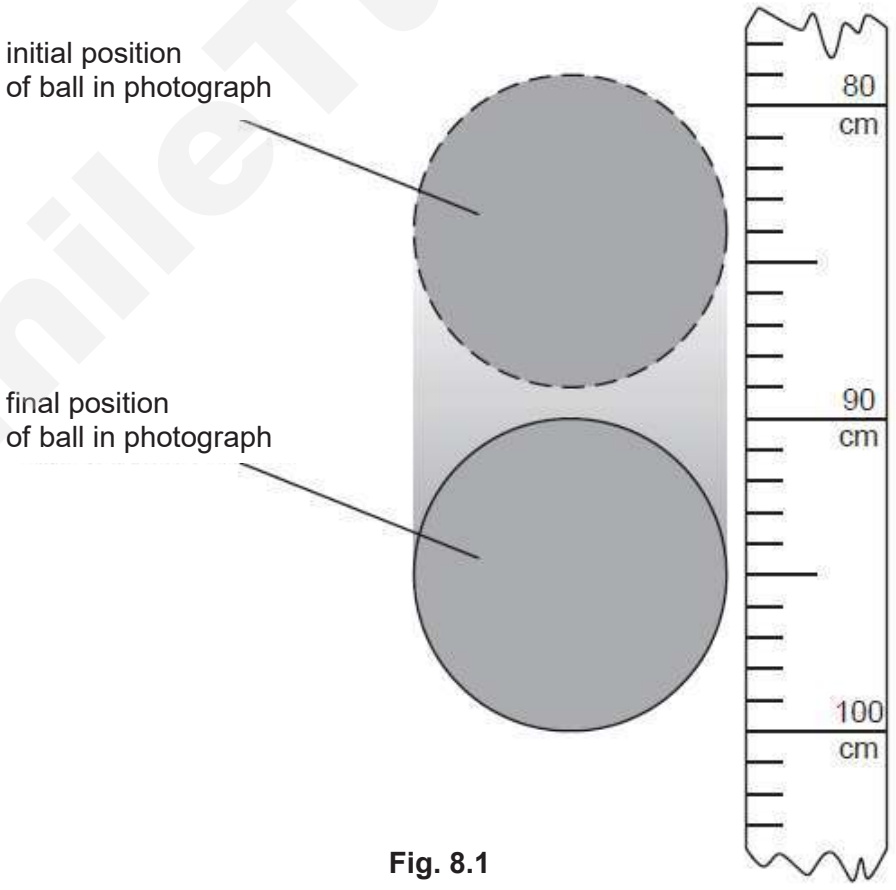


**Fig. 8.1**

The scale shows the distance fallen from rest by the ball. At time $t = 0$, the top of the ball is level with the zero mark on the scale. Air resistance is negligible.


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**1.** Calculate the time the ball falls before the photograph is taken,

time = …….s [2]

**2.** Calculate the time interval $T$ during which the photograph is taken.

$T$ = …….s [2]

**3.** The time for which the shutter stays open is marked as $\frac{1}{30}$ s.
Comment on whether your answer in **(ii)2.** confirms this time.

…….....

…….[2]

**(iii)** The student in **(ii)** takes a second photograph starting at the same position on the scale. The ball has the same radius but is less dense, so that air resistance is not negligible.

State and explain the changes that will occur in the photograph.

…….....

…….....

…….....

……... [2]


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**(b) (i)** State the relation between force and momentum.

……..... [1]

**(ii)** A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 8.2.

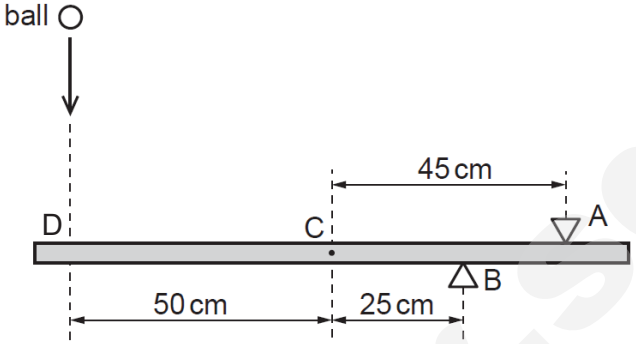


**Fig. 8.2**

The support A is 45 cm from the centre of gravity C of the bar and support B is 25 cm from C.

A ball of mass 140 g falls vertically onto the bar such that it hits the bar at point D, a distance of 50 cm from C, as shown in Fig. 8.2.

The variation with time *t* of the velocity *v* of the ball before, during and after hitting the bar is shown in Fig. 8.3.

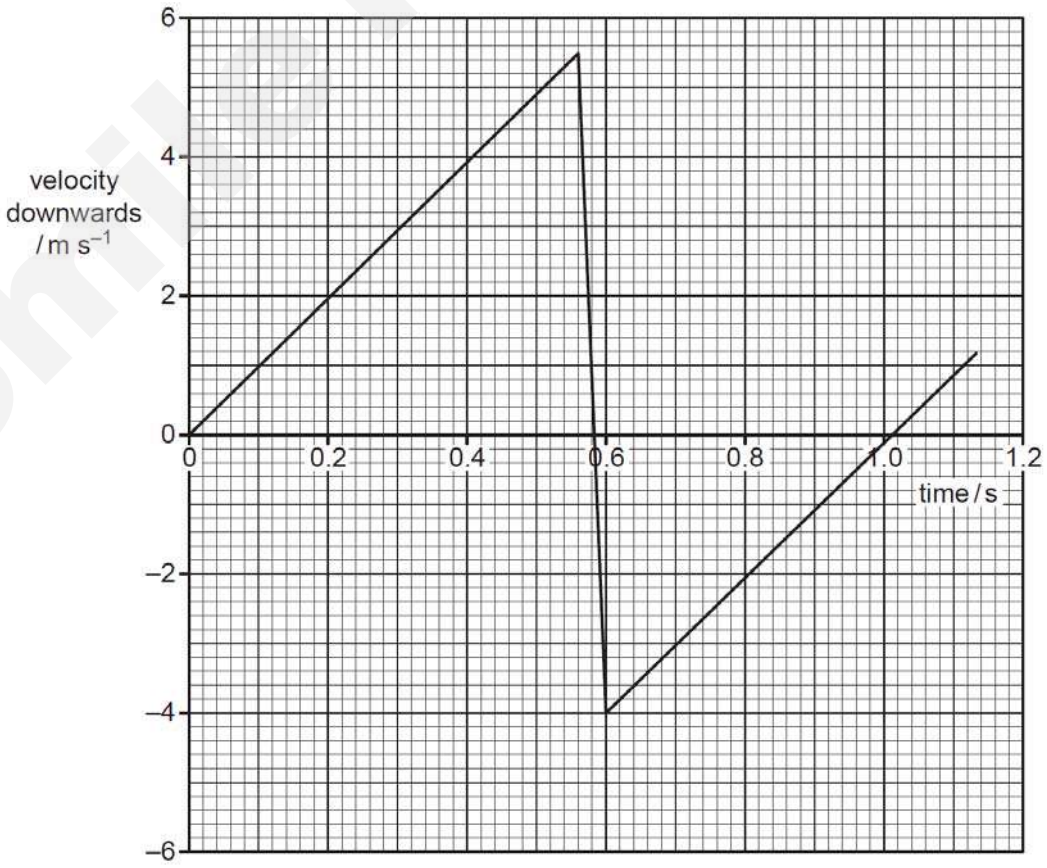


**Fig. 8.3**


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For the time that the ball is in contact with the bar, use Fig. 8.2 and 8.3

**1.** to determine the change in momentum of the ball,

change in momentum = ……kg m $s^{-1}$ [2]

**2.** to show that the magnitude of the average force exerted by the ball on the bar is 35 N,

[2]

**3.** to calculate the average force exerted on the bar by the support A.

force = ……N [3]

**(iii)** The bar is now cushioned with a light sponge at point D.

State and explain the effect on your answer to **(b)(ii)3** when the ball makes contact with the bar.

……

……

……

…… [2]

[Total 20]


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**9** **(a)** State what is meant by *half-life*.

……

……

……[2]

**(b)** A stationary radioactive isotope P decays by emitting a $\beta$-particle and $\gamma$-radiation. The daughter nucleus produced during this decay is Q. An incomplete equation to represent this decay is

$$P \rightarrow \quad Q + \beta + \gamma$$

The variation with time *t* of the number *N* of undecayed nuclei of radioactive sample of isotope P is shown in Fig. 9.1.

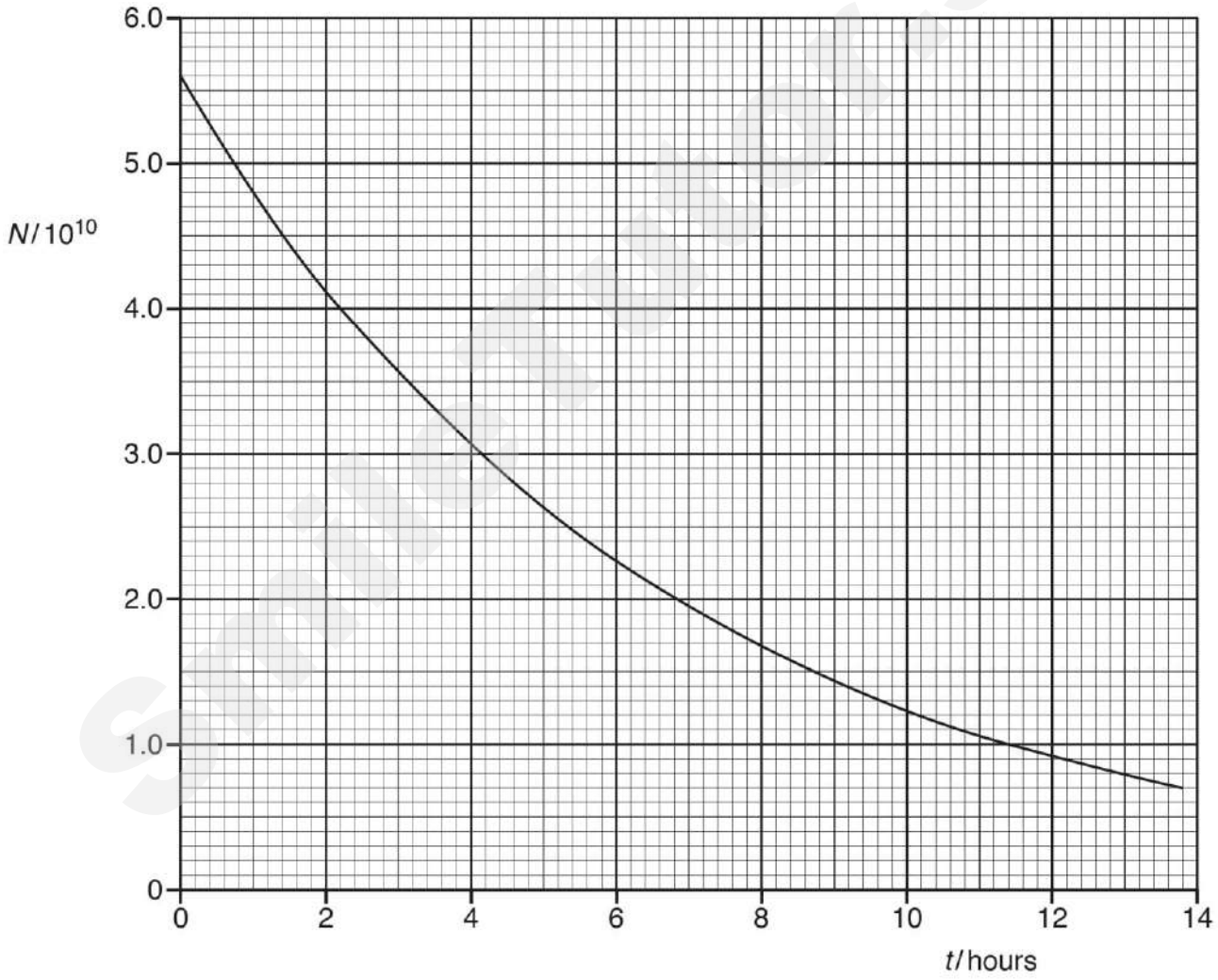


**Fig. 9.1**

**(i)** Use Fig. 9.1 to estimate the half-life of isotope P.

half-life = ……hours [2]


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**(ii)** Initially, there are no Q nucleus in the sample.

After a period of time $t$, the ratio $\frac{\text{number of Q nuclei}}{\text{number of P nuclei}}$ equals 6.

Calculate $t$.

$t$ = ……hours [2]

**(iii)** State the significance of the gradient of the graph.

……

……... [1]

**(iv)** Determine the activity of isotope P at $t$ = 4.0 hours.

activity = ……Bq [3]

**(v)** The daughter nucleus Q is stable. On Fig. 9.1, sketch a graph to show the variation with time $t$ of the number of daughter nuclei Q in the sample. [2]

**(vi)** State and explain why the sum of the kinetic energy of the $\beta$-particle and the energy of the $\gamma$-radiation is less than the total energy released during the decay of isotope P.

……

……

……

……

……... [3]


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**(c)** Isotope P is produced in a laboratory by bombarding a stationary nucleus S with an $\alpha$-particle. It results in the following nuclear reaction.

$$S + \alpha \rightarrow P + {}^{1}_{0}n$$

Fig. 9.2 shows the position of isotope P on a diagram in which nucleon number is plotted against proton number. Each small square represents a unit increase in the nucleon number and proton number in the direction of the axes.

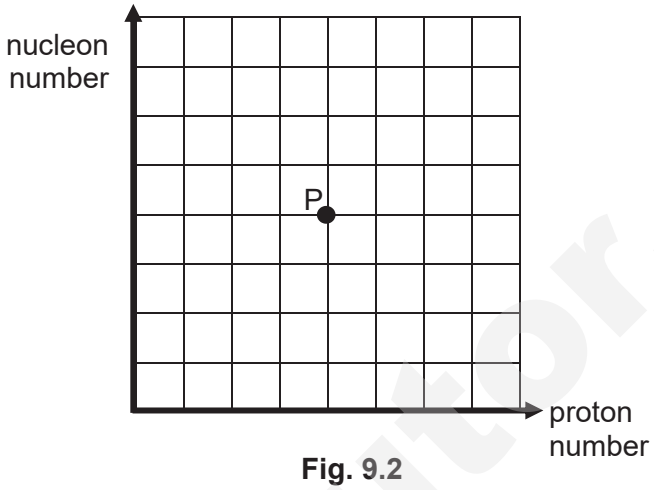


**Fig. 9.2**

**(i)** On Fig. 9.2, mark with the symbol S the position of the nuclide S. [1]

**(ii)** With reference to **(b)**, mark on Fig. 9.2 with the symbol Q the position of the daughter nuclide Q due to the decay of isotope P. [1]

**(d)** Fig. 9.3 shows an $\alpha$-particle approaching a stationary gold nucleus head-on. The distance of closest approach of the $\alpha$-particle to the nucleus S is *d*.

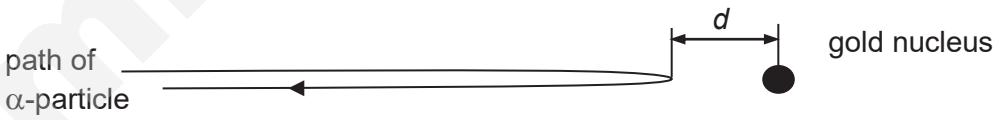


**Fig. 9.3**

At its distance of closest approach *d*, explain whether it is possible for the gold nucleus and the $\alpha$-particle to be at rest simultaneously.

……..

……..

……..

…….....[3]

[Total 20]


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Name: _____ (  )  Class: 19 /_____

# ANDERSON SERANGOON JUNIOR COLLEGE

## 2019 JC2 Preliminary Examination

## PHYSICS Higher 2 9749/04

**Paper 4 Practical** **Monday 2 September 2019**

**2 hours 30 minutes**

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

---

**READ THESE INSTRUCTIONS FIRST**

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

Answer **all** questions.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| **Paper 4 (55 marks)** | |
| **1** | |
| **2** | |
| **3** | |
| **4** | |
| **Total (55 marks)** | |

---

This document consists of **15** printed pages and **5** blank pages.


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For Examiner's Use

**1** In this experiment, you will investigate the motion of a sphere launched from a ramp.

**(a)** Set up the apparatus as shown in Fig. 1.1. Adjust the height of the clamp so that the launch angle $\phi$ is approximately 15°. **Do not bend the ramp throughout the experiment**.

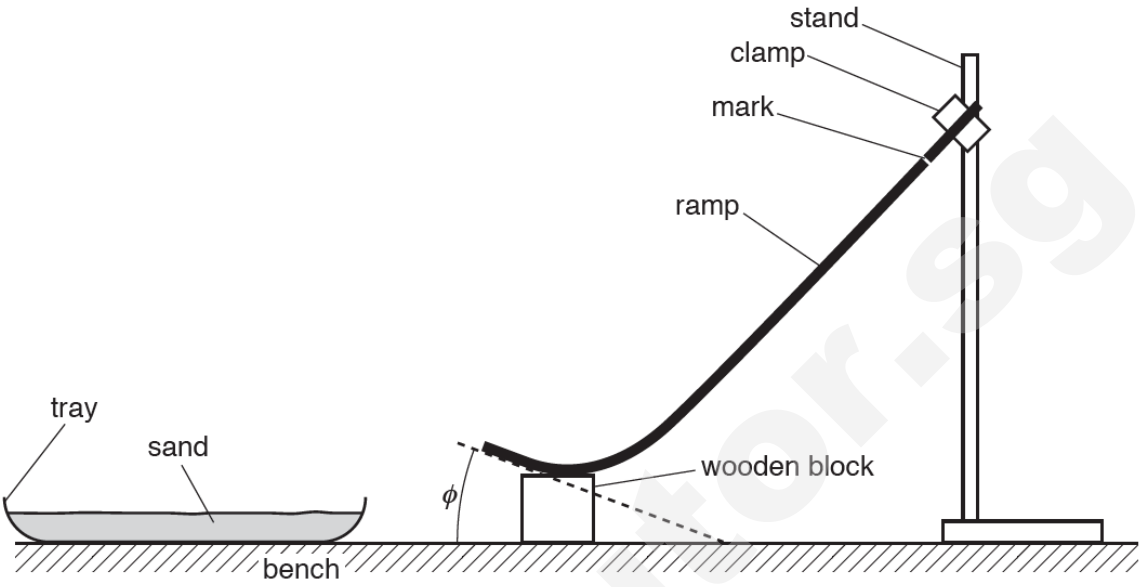


**Fig. 1.1** (not to scale)

**(b)** **(i)** Measure and record $\phi$, as shown in Fig. 1.1.

$\phi$ = ..... [1]

M1

**(ii)** Measure and record the height $h_1$ of the mark above the bench, as shown in Fig. 1.2.

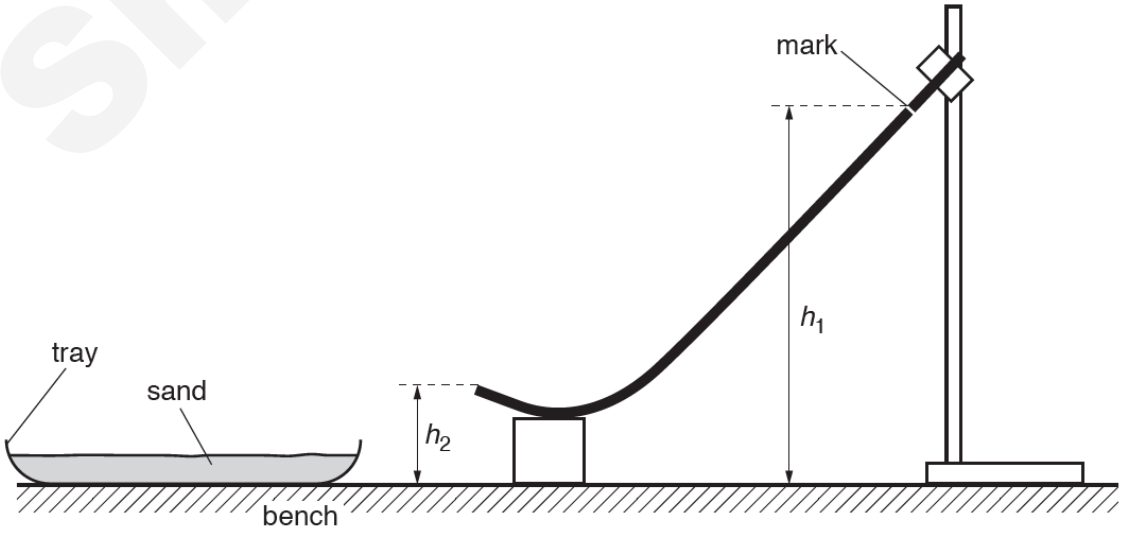


**Fig. 1.2** (not to scale)

$h_1$ = .....



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**(iii)** Measure and record the height $h_2$ of the end of the ramp, as shown in Fig. 1.2.

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M2

$h_2$ = ..... [1]

**(iv)** Calculate the speed $v$ of the sphere when it leaves the ramp using the expression

$$v = \sqrt{2g(h_1 - h_2)}$$

where $g$ = 9.81 m s$^{-2}$.

$v$ = ..... [1]

A1

**(c)** Justify the number of significant figures you have given for your value of $v$.

.....

..... [1]

P1

**(d)** **(i)** Place the sphere on the ramp at the mark. Release the sphere.

**(ii)** Measure and record the horizontal distance $R$ from the end of the ramp to the landing position of the sphere, as shown in Fig. 1.3.

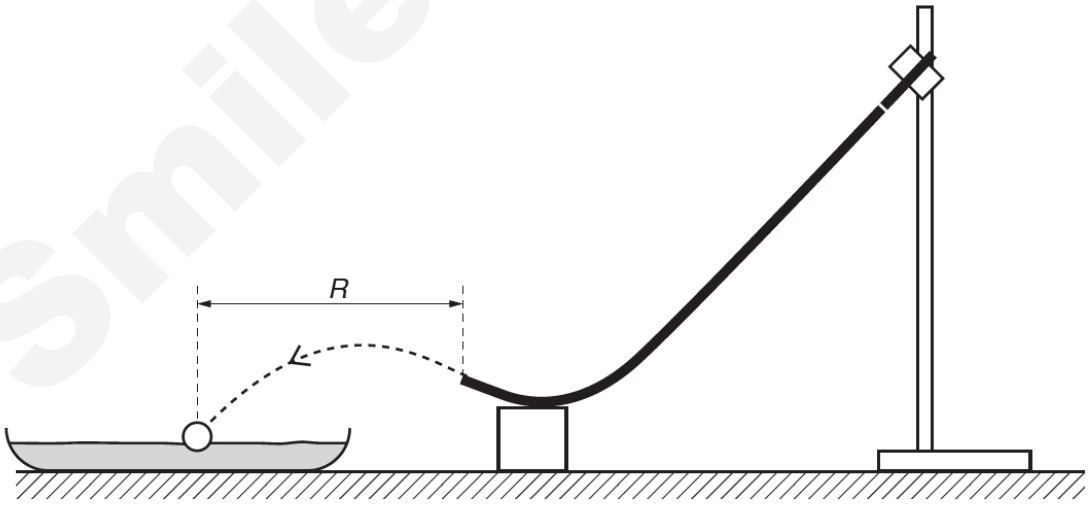


**Fig. 1.3** (not to scale)

M3

M4

$R$ = ..... [2]



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**(e)** Estimate the percentage uncertainty in your value of $R$.

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percentage uncertainty = ..... [1]

A2

**(f)** By lowering the clamp, increase the launch angle $\phi$ to approximately 25°. Repeat **(b)** and **(d)** using the sphere.

$\phi$ = .....

$h_1$ = .....

$h_2$ = .....

$v$ = .....

M5

M6

$R$ = .....[2]

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**(g)** It is suggested that the relationship between $R$, $v$ and $\phi$ is

$$R = k\, v \cos \phi$$

where $k$ is a constant.

**(i)** Using your data, calculate two values of $k$.

first value of $k$ = .....

second value of $k$ = ..... [1]

A3

**(ii)** Explain whether your results support the suggested relationship.

.....

.....

.....[1]

A4

**(iii)** It is not accurate to draw a conclusion based on only two readings as in **g(ii)**. Suggest a way the method can be changed.

.....

.....

.....[1]

A5

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

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.....

.....

.....[1] A6

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

.....

.....

.....[1] A7

**(i)** A student is investigating the motion of a sphere launched horizontally from the ramp with a range of different speeds $v$.

It is suggested that the square of the horizontal distance $R$ from the end of the ramp to the landing position of the sphere is proportional to $v$.

Explain how you would investigate this relationship using the **same apparatus**.

Your account should include:
- your experimental procedure
- control of variables
- how you would use your results to test the relationship.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....[4] PL1 PL2 PL3 PL4

[Total: 18]



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**Question 2 begins on the next page.**

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**2** In this experiment, you will investigate the oscillatory motion of a loaded metre rule supported at one end by a spring.

**(a)** Secure the cork in the clamp so that the pin is mounted horizontally. Suspend one end of the rule from the pin by passing the pin through the hole in the rule. The rule should be able to pivot around the pin.

Hook one end of the spring to the rod of another clamp. Suspend the other end of the rule through the small loop of string. The string should be at the 0.5 cm marking of the rule as shown in Fig. 2.1.

The clamps should be adjusted so that the rule is approximately horizontal.

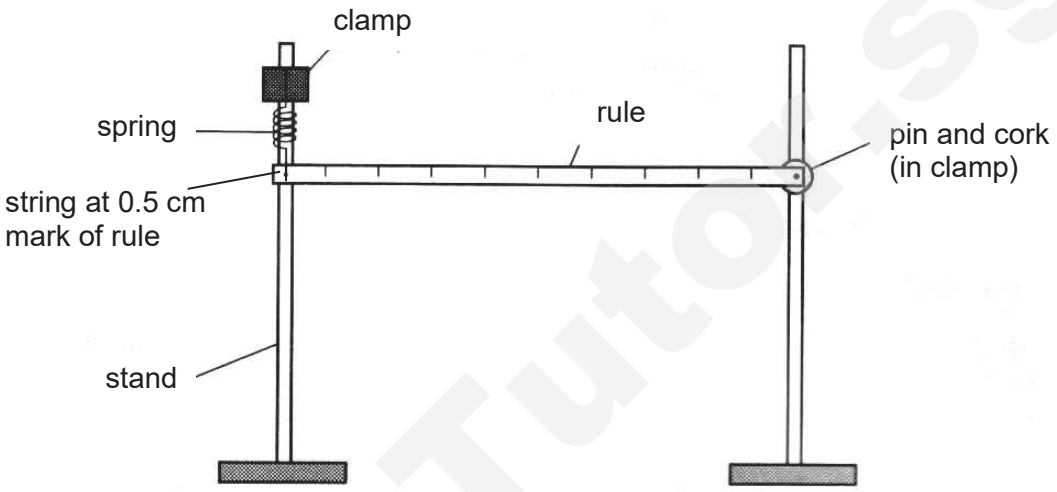


**Fig. 2.1**

**(b)** Tie a loop of string on the rule to suspend a mass of 350 g a distance *d* from the pin as shown in Fig 2.2. The mass should be about halfway along the rule. Adjust the position of the clamps to make the rule approximately horizontal again.

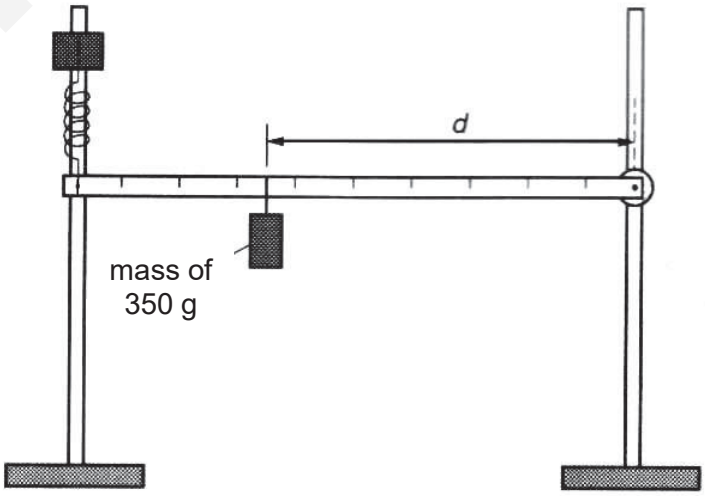


**Fig. 2.2**


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**(c)** Measure and record the value of $d$.

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$d$ = …….....

**(d)** Gently displace the end of the rule so that it performs small oscillations in a vertical plane.

Determine the period $T$ of the oscillations.

| | |
|---|---|
| M1 | |
| A1 | |

$T$ = …….[2]

**(e)** The equation that relates $T$ and $d$ for this oscillator is

$$T^2 = \frac{4\pi^2}{kL^2}(Md^2 + C)$$

where $k$ is 28.0 N m$^{-1}$, $M$ is the mass of the load, $L$ is the length of the rule and $C$ is a constant.

Calculate $C$.

| | |
|---|---|
| A2 | |
| A3 | |
| A4 | |

$C$ = …….[3]

[Total: 5]



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**Question 3 begins on the next page.**

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**3** In this experiment, you will investigate how the current through a milliammeter varies as the resistance of a resistor is changed.

**(a)** Set up the circuit as shown in Fig. 3.1.

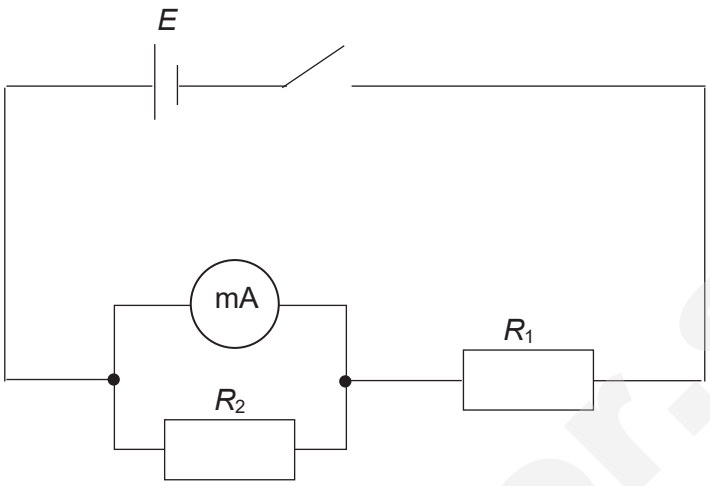


**Fig. 3.1**

**(b)** The resistor of resistance $R_2$ can be made using any combination of the resistors provided. The resistance of each resistor is 100 Ω.

**(c)** Set the value of $R_2$ to 100 Ω and close the switch. Record the current $I$ through the digital milliammeter.

$I$ = .....A [1]

M1

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**(d)** Change the value of $R_2$ and repeat step **(c)** to obtain further sets of values for $R_2$, and the corresponding values of $I$.

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| M2 | |
|---|---|
| M3 | |
| P1 | |
| P2 | |
| P3 | |
| A1 | |

[7]

**(e)** It is suggested that $I$ and $R_2$ are related by the equation,

$$\frac{1}{I} = \frac{k}{R_2} + C$$

where $k$ and $C$ are constants.

Plot a suitable graph to determine values of $k$ and $C$.

| A2 | |
|---|---|
| A3 | |
| A4 | |
| A5 | |

$k$ = .....

$C$ = .....

[7]



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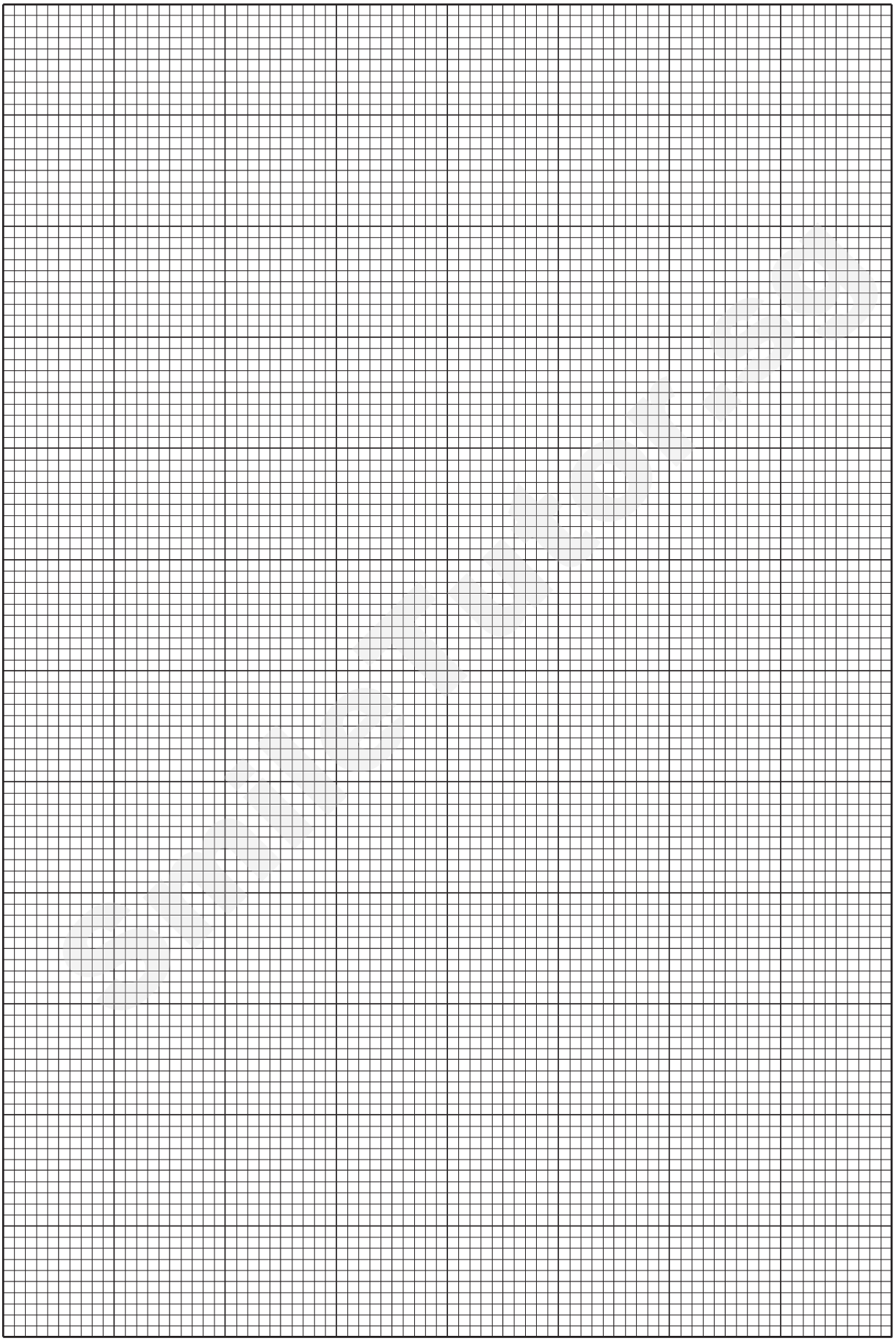

| | |
|---|---|
| P4 | |
| P5 | |
| P6 | |



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

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……

……[1] M4

**(ii)** Measure and record a value of the e.m.f. $E$ of the power supply using the analogue voltmeter.

$E$ = ……[1] M5

**(g)** Theory suggests that $k = \frac{R_1 S}{E}$

where $S$ is the resistance of the digital milliammeter.

Given that $R_1$ = 470 Ω, together with your answers to **(e)** and **(f)(ii)**, determine a value for $S$.

A6

$S$ = ……[1]

**(h)** $C$ is inversely proportional to $E$.

On the graph grid on page 13, sketch a second graph to represent the results if $E$ is increased. Label this graph Z.

A7

A8

[2]

[Total: 20]



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**Question 4 begins on the next page.**

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**4** Two identical light sources are viewed from a distance, as shown in Fig 4.1. When the angle $\theta$ between the light sources is large, they are seen as separate.

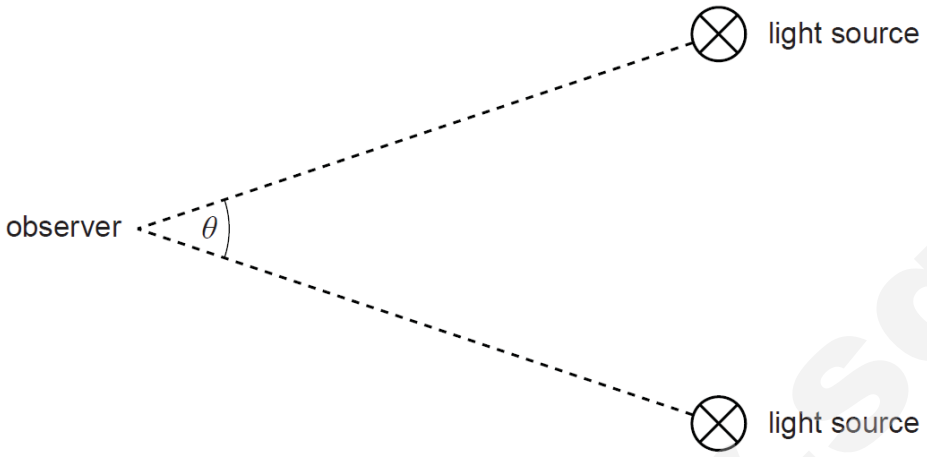


**Fig. 4.1** (not to scale)

The sources are moved closer together. At a particular angle $\theta_1$ the two sources appear as a single source.

The relation between $\theta_1$ and the wavelength $\lambda$ of the light from the sources may be written in the form of

$$\theta_1 = \frac{\lambda}{b}$$

where *b* is a constant.

It is inappropriate to measure $\theta_1$ using a protractor as it is a small angle.

Design a laboratory experiment using two light sources to determine the value of *b*.

You should draw a diagram to show the arrangement of your apparatus and you should pay particular attention to

**(a)** the equipment you would use
**(b)** the procedure to be followed
**(c)** how the wavelength $\lambda$ and angle $\theta_1$ would be determined
**(d)** the control of variables
**(e)** any precautions that should be taken to improve the accuracy and safety of the experiment.


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**Diagram**

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[12]

[Total: 12]


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**Anderson Serangoon Junior College 2019 H2 Physics Prelim Mark Scheme**

**Paper 1 (30 marks)**

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

**1** **D**

$$x = \frac{\lambda D}{a}$$

$$\lambda = \frac{ax}{D}$$

$$\frac{\Delta\lambda}{\lambda} = \left(\frac{\Delta a}{a} + \frac{\Delta x}{x} + \frac{\Delta D}{D}\right)\text{x}100\%$$

$$= \left(\frac{0.02}{0.50} + \frac{0.1}{1.7} + \frac{0.002}{2.000}\right)\text{x}100\%$$

$$= 10\ \%$$

**2** **C**

Use $v^2 = u^2 + 2as$

$0 = u^2 + 2ax \Rightarrow u^2 = -2ax$

$0 = (1.20u)^2 + 2ax'$

$1.44(-2ax)^2 = -2ax'$

$x' = 1.44x$

**3** **B**

Ultimately, the vertical component of the ball will achieve terminal velocity when the force due to air resistance cancels out the weight of the ball.

**4** **D**

P – contact force on box due to ground
Q – gravitational force on box due to Earth
R – contact force on ground due to box
S – gravitational force on Earth due to box

**5** **B**

Conservation of linear momentum : Total initial momentum = *mv*

Total final momentum of Option A
= *mv* – *mv* = 0
By velocity of approach and separation, KE not conserved for option A

Total final momentum of Option B



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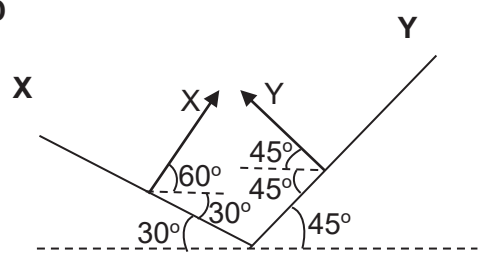
| | |
|---|---|
| | $= m(v + 0) = mv$<br>KE is conserved for option B.<br><br>Total final momentum of Option C<br>$= m(\frac{3v}{4} - \frac{v}{4}) = \frac{1}{2}mv$<br>By velocity of approach and separation, KE is conserved for option C<br><br>Total final momentum of Option D<br>$= m(\frac{v}{2} + \frac{v}{2}) = mv$<br>By velocity of approach and separation, KE not conserved for option D |
| **6** | **D**<br>  <br><br>consider horizontal equilibrium,<br>$X_x = Y_x$<br>$X\cos 60^o = Y\cos 45^o$<br>$\frac{X}{Y} = 1.41$ |
| **7** | **A**<br>Since object is thrown at high speed, it experiences large upward viscous force, so resultant force upwards. This decelerates the ball, decreasing its speed and viscous force.<br>Upthrust is dependent on the pressure difference acting on the object. As pressure difference remain the same as object falls, upthrust will remain unchanged. |
| **8** | **C**<br>When 3.0 N load is placed, F = kx, 3.0 = k(0.030), so k = 100 $Nm^{-1}$<br>Using EPE = ½ $kx^2$<br>Additional EPE = ½ k($x_{final}^2 - x_{initial}^2$) = ½ (100)($0.040^2 - 0.030^2$) = 0.035 J |
| **9** | **C**<br><br>Total gain in KE = loss in GPE of Y – loss of GPE of X – work done by friction<br>= (5.0)(9.81)(2.0) - (4.0)(9.81)(2.0 sin 30) – 5(2)<br>= 48.86 ≈ 49 J |
| **10** | **A**<br>Two forces, tension and weight, act on the pendulum. The resultant force should not be drawn. Hence, Options B and C are wrong.<br><br>Pendulum moves along with the train in the circular arc, bending to the right. It must have a centripetal force (net force) directed to the right, towards the centre of the circular arc. Option A fulfils this requirement, the net force is directed to the right. |

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| | |
|---|---|
| **11** | **A**<br>Using TE = $-\frac{GMm}{2r}$, KE = $\frac{GMm}{2r}$, we see that KE = –TE. Satellites with same KE has the same TE. Option A is correct.<br>Using KE = $\frac{GMm}{2r}$, GPE = $-\frac{GMm}{r}$, we see that KE = –½ GPE. Satellites with the same KE has the same GPE. Options B and C are wrong.<br><br>Using KE = $\frac{GMm}{2r}$, we see that satellite A with larger mass must have a larger orbital radius than satellite B. Using $T^2$ proportional to $r^3$ and $\omega = 2\pi/T$, satellite A with larger r will have larger T, hence smaller ω. Option D is wrong. |
| **12** | **A**<br><br>pV = NkT<br>p = (N/V)kT<br>$p = N_v kT$ --(1)<br><br>0.50p = N'k(2.0T) --(2)<br><br>(2)/(1): N' = 0.25 $N_v$ |
| **13** | **A**<br><br>According to 1st law of thermodynamics, the internal energy of a system depends on the heat absorbed and the work done on the system. Thus, the internal energy of the system can also be changed without heating the system.<br><br>For option B and C, it is only true if the system is an ideal gas.<br><br>For option D, internal energy also depends on mass of the system. Two systems with same temperature but different masses will have different internal energies. |
| **14** | **A**<br>$\frac{1}{2}mc_{rms}^{\ 2} = \frac{3}{2}kT$<br>$\Rightarrow c_{rms}^{\ 2} \ \alpha \ T$<br>$\frac{T}{2T} = \frac{c_{rms}^{\ 2}}{c_{new\ rms}^{\ 2}}$<br>$c_{new\ rms} = \sqrt{2}c_{rms}$ |
| **15** | **D**<br><br>From *v*-*x* graph, *v* is negative => option C or D.<br>The gradient of the v-t graph corresponds to the acceleration.<br>Since $a = -\omega^2 x$, *a* and *x* are in opposite directions hence when *x* is negative, *a* is positive. Thus, the gradient of the v-t graph must be positive => options A or D. |



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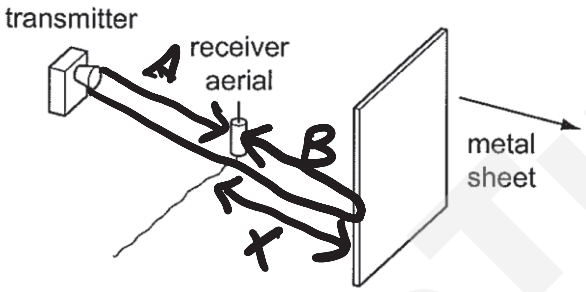
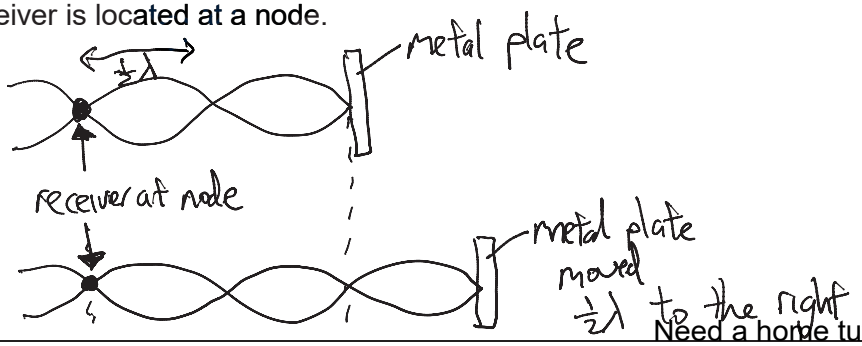
| | |
|---|---|
| | Thus D meets both criteria. |
| **16** | **C**<br><br>For a given velocity, by considering $v = f\lambda$, f is inversely proportional to $\lambda$. |
| **17** | **B**<br><br>Since $I \propto x_o^2$ and $I$ = Power of source/(Area of focus)<br><br>$I \propto x_o^2$ / Area<br><br>Since amplitude is doubled and area of focus is 1/3 of original, the intensity (power per unit area) is 12 times of its original value. |
| **18** | **B**<br><br><u>Method 1:</u><br><br>  <br><br><br>At the receiver, the incoming wave (path A) meet the reflected wave (path B). The resultant displacement is the vector sum of individual displacement of the two waves.<br><br>When path difference $l_B - l_A = 2x = (n+½)\lambda$, the waves arrive in phase, leading to constructive inference, so detected voltage is maximum. This happens at distance moved = 30 mm, from graph provided.<br><br>When metal sheet has moved another 60 mm (at distance moved = 90 mm), the voltage detected is maximum again, so it is another constructive interference, with path $l_B - l_A = 2\,(x + 60) = 2x + 120 = (n+1+½)\lambda$.<br><br>Hence, $\lambda$ = 120 mm<br><br>Method 2:<br><br>The incoming wave from transmitter will undergo phase change of $\pi$ rad upon reflection at the metal plate. The incoming and reflected waves will form a stationary wave, with a node at the metal plate.<br><br>When distance moved = 0, a minimum voltage was detected, showing that the receiver is located at a node.<br><br>  <br> |

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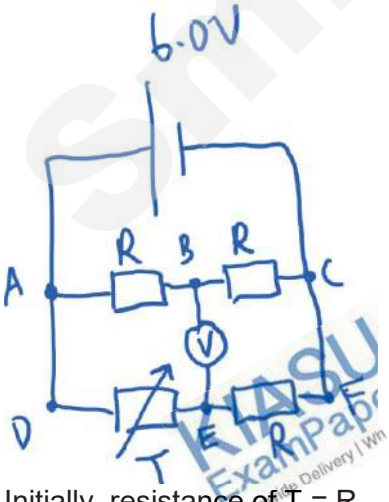
| | |
|---|---|
| | When metal plate moved by ½λ to the right, the stationary receiver will be at a node again, detecting a minimum voltage. This happens when distance moved = 60 mm.<br><br>Hence, ½ λ = 60 mm, so λ = 120 mm |
| **19** | **D**<br><br>Contribution of E-field at the centre by a pair of **like** charges opposite each other will cancel out but by a pair of **unlike** charges, it will result in an E-field strength of 2 units pointing towards the electron.<br>Hence, the net E-field for<br>**A** is 2√2 units, 225° (3rd quadrant);<br>**B** is 2 units, 45° (1st quadrant);<br>**C** is 2 units, 270;<br>**D** is less than 2 units, 112.5° (2nd quadrant). |
| **20** | **C**<br><br>$F_E = ma$<br>$a = \frac{F_E}{m} = \frac{qE}{m} = \frac{1.6\times10^{-19}\times20000}{9.11\times10^{-31}} = 3.51\times10^{15}\ \text{m s}^{-2}$<br><br>$s = ut + 0.5at^2$<br>$s = 0.5(3.51\times10^{15})(4.0\times10^{-9})^2 = 0.0281\ \text{m}$ |
| **21** | **B**<br><br>$W = VQ = VIt = 18\times1.5\times0.2 = 5.4\ \text{J}$ |
| **22** | **B**<br><br>Redraw the circuit diagram.<br>  <br><br>Initially, resistance of T = R.<br>Pd across each resistor = pd across T = 3V.<br>Potential at B = Potential at E = 3V, so pd across BE = 0, so voltmeter reading = 0.<br><br>When resistance of T = 2R, |



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| | |
|---|---|
| | Potential at B is still 3V.<br>Potential at E = $6 \times \frac{R}{2R + R} = 2$ V.<br>Potential across BE = 3 – 2 = 1 V, so voltmeter reading = 1V.<br>Change in voltmeter reading = 1 – 0 = 1V |
| **23** | **C**<br><br>The magnetic force acting on one vertical side = *BInL* since the angle between *B* and *I* is 90°. The direction is obtained using FLHR. |
| **24** | **C**<br><br>For straight conductor cutting magnetic flux, the induced emf *E* = *BLv*. Since the magnetic field and length of rod cutting the flux are both constant, *E* is proportional to the speed of the rod, which is the gradient of *s-t* graph.<br>1st segment: constant gradient of *s-t* graph => const *E*<br>2nd segment: decreasing gradient of *s-t* graph=> decreasing *E*<br>3rd segment: zero gradient of *s-t* graph => zero *E* |
| **25** | **B**<br><br>$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{2}{\sqrt{2}} = \sqrt{2}$ A<br>$I_{dc} = \sqrt{2}$ A |
| **26** | **A**<br><br>A: By using the relationship above, when the number of turns in the primary coil $N_p$ is increased, the p.d. across the secondary coil $V_s$ will decrease.<br>$V_s/V_p = N_s/N_p$<br><br>B: Increasing the cross sectional area does not affect the p.d. across the secondary coil.<br><br>C: Increasing the resistance across the variable resistor only reduces the current in secondary coil (not the p.d. across it).<br><br>D: Decreasing the resistance across variable resistor only increases the current in secondary coil (not the p.d. across it).<br>$V_s/V_p = I_P/I_S$ |
| **27** | **D**<br><br>$KE_{electron} = E_{most\ energetic\ photon} = \frac{hc}{\lambda_{min}}$<br>so, $\lambda_{min} = \frac{hc}{KE_{electron}} = \frac{hc}{qV}$ |
| **28** | **D**<br><br>$p = p_x = m\ v_x = 9.11 \times 10^{-31} \times 2.05 \times 10^6 = 1.868 \times 10^{-24}$ kg m s$^{-1}$ |

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| | |
|---|---|
| | $\Delta p / p = 0.5 / 100 \Rightarrow \Delta p = 9.34 \times 10^{-27}$ kg m s$^{-1}$<br><br>$\Delta x \geq \frac{h}{\Delta p} = \frac{6.63 \times 10^{-34}}{9.34 \times 10^{-27}} = 7.10 \times 10^{-8}$ m |
| **29** | **C**<br>Statement C is the result of conservation of linear momentum. The following statements are incorrect:<br>Statement A – The stability of the nucleus depends on the binding energy per nucleon, not the binding energy.<br>Statement B – The reaction can still occur provided energy is given to the reactants.<br>Statement D – The half-life of a radioactive substance is a constant for a given radioactive substance. |
| **30** | **D**<br><br>It is beta as the particles are able to penetrate through the thin film of aluminum where alpha particles will be stopped by the aluminum film.<br><br>Entry is at B because the beta particles lose energy after passing through the aluminum. Hence, they have a lower speed and hence, a smaller radius, greater curvature of path under the influence of magnetic field. ($Bqv = \frac{mv^2}{r}$ => r = mv / Bq) |

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**Anderson Serangoon Junior College 2019 H2 Physics Prelim Mark Scheme**

**Paper 2 (80 marks)**

| | |
|---|---|
| **1a** | Vertically upward arrow from point B representing upthrust, and vertically downward arrow from point C representing weight of tube and sand. Both arrows are equal in length, representing equal magnitude. |
| **1b** | Upthrust for both cases are the same, equal to weight of tube and sand.<br>Upthrust = weight of fluid displaced<br>$\rho_w A L_w g = \rho_l A L_l g$ = weight of tube and sand<br>$L_l = \rho_w L_w / \rho_l$<br>= 0.99 × 12.1 / 1.11<br>= 10.792 cm<br>Change in L = 10.792 – 12.1<br>= – 1.3 cm |
| **1ci** | Its weight and upthrust provide couple / restoring torque to keep tube upright. |
| **1cii** | When the tube is displaced downward, the upthrust is greater than the tube's weight. Hence, the net force on the block is upward, opposite to the displacement.<br><br>When the block is displaced upward, the block's weight is greater than the upthrust. Hence, the net force on the block is downward, opposite to the displacement. |
| **2a** | $g = GM/R^2$ , so if distances near surface of planet is much smaller than R, $g$ is a constant.<br>force on rocket = $mg$, where $m$ is mass of rocket, ($g$ is the acceleration of free fall / gravitational field strength)<br>$\Delta E_P$ = force × distance moved (or work done)<br>= $mgh$<br><br>OR<br><br>$\Delta E_P = m\Delta\Phi$ where $m$ is mass of rocket<br>$= GMm(1/R - 1/(R+h))$<br>$= GMmh/(R(R+h))$<br>distances $h$ near surface of planet is much smaller than $R$, hence $(R+h) \approx R$ and $g = GM/R^2$<br>$\Delta E_P = mgh$ |
| **2b** | Increase in GPE = Decrease in KE<br>Increase in GPE = $GMm\left(\frac{1}{2R} - \frac{1}{5R}\right) = 4.0 \times 10^{14} \times 4.7 \times 10^4 \times \left(\frac{1}{2R} - \frac{1}{5R}\right)$<br>Decrease in KE = $(1.17 - 0.35) \times 10^{12}$ J<br><br>3R = $2.0634 \times 10^7 = 2.1 \times 10^7$ m |
| **2c** | Similarity: Gravitational fields are directed towards the planet and the rocket.<br><br>Difference (any one):<br>- Gravitational field at surface of planet is at orders of magnitude greater than that at the surface of the rocket.<br>- Gravitational field at surface of planet has radial symmetry or is directed radially, but that at the surface of the rocket is not. |

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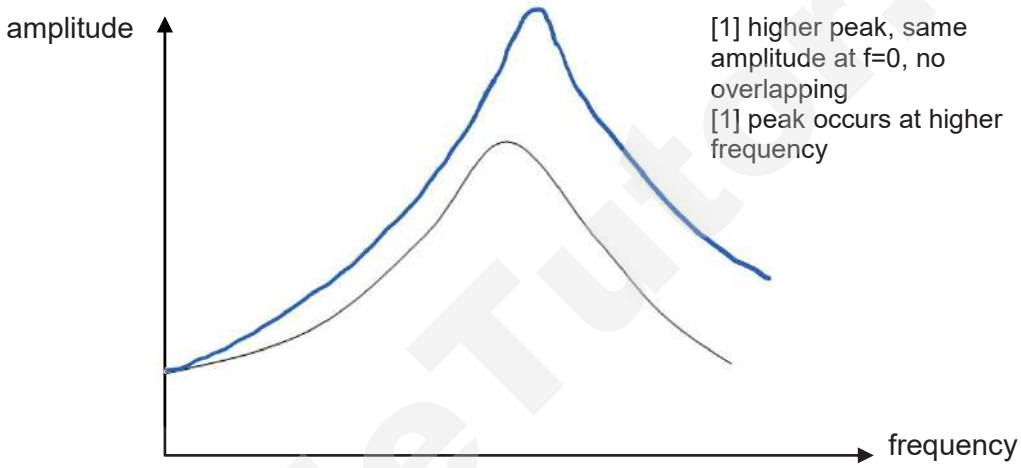
|---|---|
| | - Magnitude of gravitational field at surface of planet is uniform, but that at the surface of the rocket varies. |
| **3a** | period = 0.36 s<br>acceleration = $\omega^2 x_0$<br>= $(2\pi/0.36)^2 \times 1.7 \times 10^{-2}$<br>= 5.2 m $s^{-2}$ |
| **3b** | either kinetic energy = ½ $m\omega^2(x_0^2 - x^2)$<br>or potential energy = ½$m\omega^2x^2$ and potential energy = kinetic energy<br>½$m\omega^2(x_0^2 - x^2)$ = ½ × ½ $m\omega^2x_0^2$ or ½$m\omega^2x^2$ = ½ × ½$m\omega^2$ $x_0^2$<br>$x_0^2 = 2x^2$<br>$x = x_0 / \sqrt{2} = 1.7 / \sqrt{2}$<br>= 1.2 cm |
| **3c** |  <br>[1] higher peak, same amplitude at f=0, no overlapping<br>[1] peak occurs at higher frequency |

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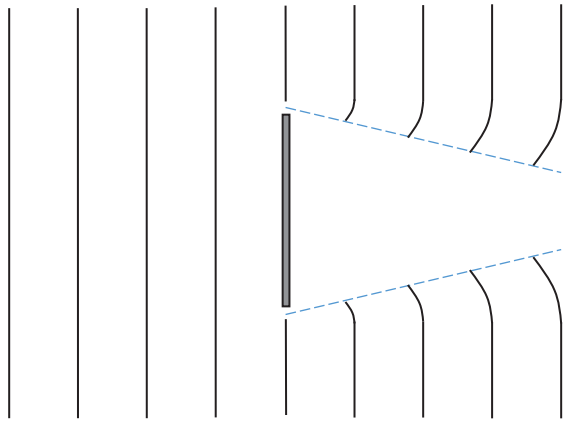
| | |
|---|---|
| **4ai** |  <br>Diagram must show:<br>(1) Wavefront curving into geometric shadow with some spreading<br>(2) Wavelength unchanged<br>(minus 1 mark if less than 4 wavelengths) |
| **4aii** | Angle of diffraction increases or<br>More spreading of the wave. |
| **4bi** | $\sin\theta = \frac{\lambda}{b}$<br>sin $\theta$ = (4.5 × $10^{-7}$)/(0.50 × $10^{-3}$)<br>Let width be c.<br>tan $\theta$ = 0.5 $c$ /2.5<br>$c$ = 4.500 mm = 4.5 mm<br><br>Accept small angle approximations. |
| **4ii1** | Coherent waves (from laser) diffracted from the slits will overlap and interfere.<br><br>When waves meet (in phase) with phase difference of 2nπ rad OR with path difference of nλ, where n = 0, ±1, ±2, …,<br>constructive interference occurs and (maximum intensity is observed).<br><br>And at the points where the waves (meet anti-phase) with phase difference of (2n – 1)π rad OR with path difference of (n+½) λ, destructive interference occurs and (minimum intensity) is observed. |
| **4ii2** | fringe separation, $x = \lambda D/a$<br>= (4.5 × $10^{-7}$ × 2.5) / 1.25 × $10^{-3}$<br>= 9.00 × $10^{-4}$ = 0.90 mm<br><br>Number of bright fringes = 4.5 / 0.90<br>= 5 |

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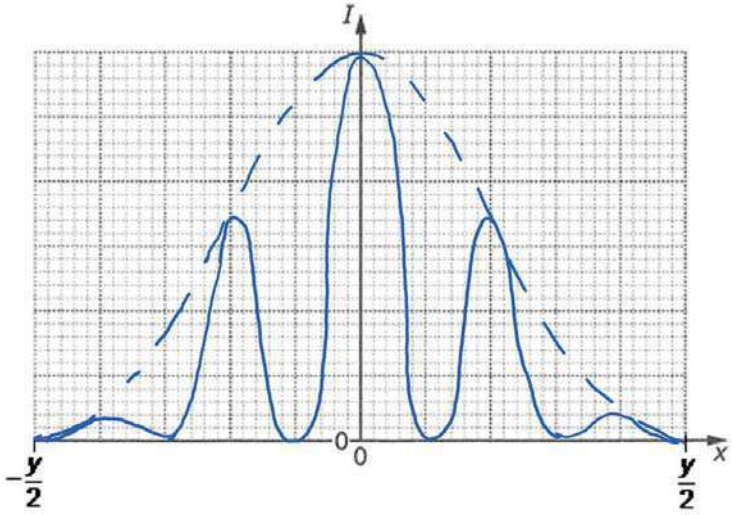
| **4bii3** |  <br>Intensity of maxima varies according to single diffraction envelope.<br>Correct number of fringes<br>Reasonable smooth curve with equal fringe separation |
| **5a** | Increasing current causes increasing mangetic flux (linkage) through the coil.<br>(By Faraday's Law), increasing magnetic flux (linkage) induces e.m.f. in the coil.<br>(By Lenz's Law), induced e.m.f. opposes the growth of current.<br><br>Note: the induced e.m.f. will be opposite to the e.m.f. of the d.c. source. As a result, current increases at a slower rate. |
| **5bi** | It is the product of the magnetic flux density and the area normal to the field through which the field is passing. |
| **5bii** | Magnetic flux density by solenoid B = $\mu_o nI = 4\pi \times 10^{-7} \times (360 / 0.120) \times 2.5$ A<br>flux $\phi$ = BA = B ($\pi D^2/4$) = B [$\pi(0.088/\pi)^2/4$]<br>= $5.808 \times 10^{-6}$ Wb<br>= $5.8 \times 10^{-6}$ Wb |
| **5biii** | In the time given, $\Delta\phi = 2 \times 5.8 \times 10^{-6}$ Wb<br>Average e.m.f. = $N\Delta\phi/t = 96 \times 2 \times 5.8 \times 10^{-6} / 2.4 \times 10^{-3}$<br>= 0.464 V = 0.46 V |
| **5biv** | Alternating / sinusoidal e.m.f.<br>With same frequency as supply |
| **6a** | for a wave, electron can 'collect' energy continuously<br>hence, electron will always be emitted / electron will be emitted at all frequencies after a sufficiently long delay |
| **6bi** | either wavelength is longer than threshold wavelength<br>or frequency is below the threshold frequency<br>or photon energy is less than work function |
| **6bii** | $hc / \lambda = \phi + E_{MAX}$<br>$(6.63 \times 10^{-34} \times 3.00 \times 10^8) / (240 \times 10^{-9}) = \phi + 4.44 \times 10^{-19}$<br>$\phi = 3.8 \times 10^{-19}$ J (allow $3.85 \times 10^{-19}$J) |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| **6ci** | photon energy larger<br>so (maximum) kinetic energy is larger |
| **6cii** | fewer photons (per unit time)<br>so (maximum) current is smaller |
| **6di** | light is re-emitted in all directions / only part of the re-emitted light is in the direction of the beam |
| **6dii** | an arrow between –3.40 eV and –1.51 eV and an arrow between –3.40 eV and –0.85 eV<br>all arrows shown point 'upwards' |
| **6diii** | $E = hc/\lambda$ *or* $E = hf$ and $c = f\lambda$<br>$2.60 \times 1.60 \times 10^{-19} = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / \lambda$<br>$\lambda = 4.8 \times 10^{-7}$ m |

| | |
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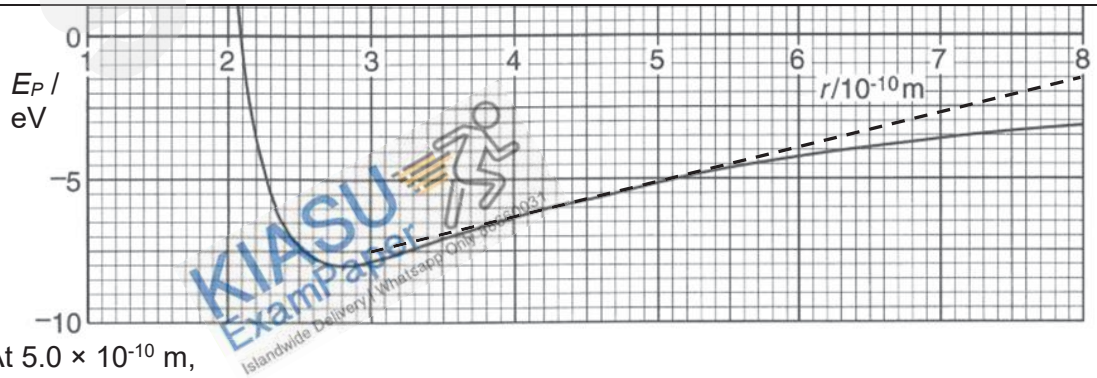
| **7ai** | Work is the product of a force and the distance moved in the direction of the force.<br>$W = F \times \Delta r$<br><br>Potential energy $E_P$ is the work done<br>(by external force in moving a point charge from infinity to the point.)<br>*($E_P = -F \times \Delta r$)*<br>Gradient of the graph G $= \frac{\Delta E_P}{\Delta r} = -F$<br>(accept if no negative sign)<br>Hence the magnitude of $F = G$ |
| **7aii** | For $r < 2.8 \times 10^{-10}$ m, the gradient is negative, hence the force is positive and thus repulsive force.<br><br>For $r > 2.8 \times 10^{-10}$ m, the gradient is positive, hence the force is negative and thus attractive force. |
| **7aiii1** | At $2.8 \times 10^{-10}$ m, gradient is zero.<br>$F = 0$ N |
| **7aiii2** |  <br>At $5.0 \times 10^{-10}$ m,<br>Gradient = $\frac{[-1.5-(-7.5)] \times 1.60 \times 10^{-19}}{(8-3) \times 10^{-10}}$<br>$= 1.9 \times 10^{-9}$<br>$F = 1.9 \times 10^{-9}$ N |

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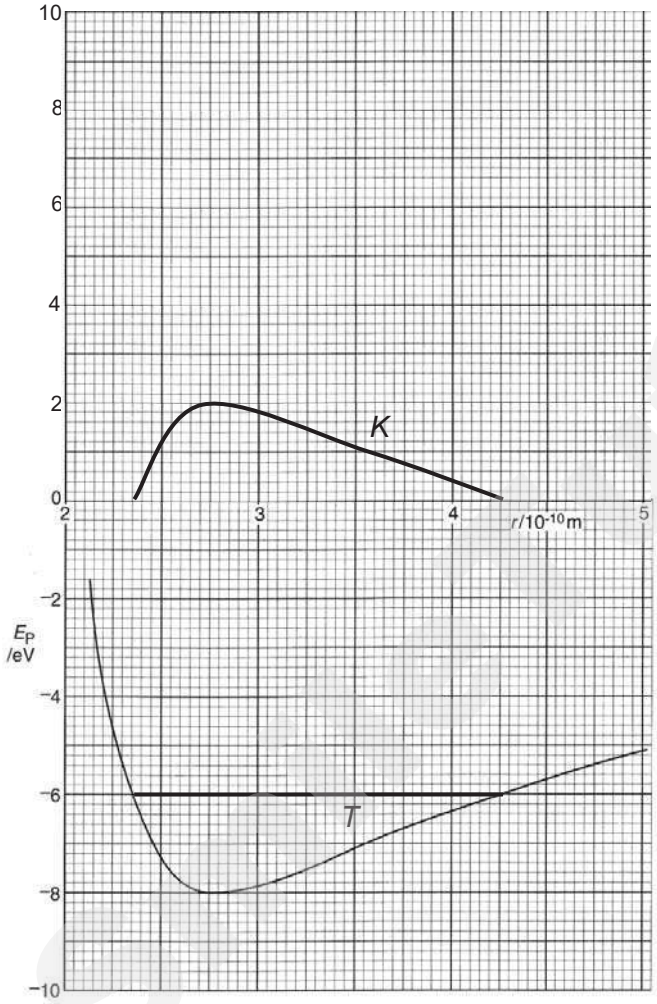
| **7b** | 1. The force causes repulsion between the ions. (This is because the gradient of the graph of the equation $E = \frac{B}{r^8}$ is negative, hence, the force $F = -\frac{dE_P}{dr}$ is positive)<br><br>2. The force is significant when the ions are very close to each other, and decreases rapidly as the distance increases. (As seen from the very steep gradient when the ions are close to each other). |
| **7ci** |  <br>1. Horizontal line at –6 eV for total energy, labelled *T*.<br>2. Reasonable curve starting and ending at zero, with a maximum point<br>Curve's maximum point is at (2.75, 2.0), since potential energy is minimum at that point.<br>By right, K line should be drawn such that at every point, KE + PE = 6eV. |
| **7cii** | Minimum value of $2.35\times10^{-10}$ m.<br>Maximum value of $4.25\times10^{-10}$ m |
| **7ciii** | *F* is not directly proportional to displacement *r*.<br>OR the graph is not symmetrical<br><br>Hence, not simple harmonic. |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| **7d** | As the lattice is heated, its total energy increases.<br><br>The total energy of the ions intersects the graph Fig. 7.3 at higher levels, giving rise to larger changes in potential energy during the oscillations.<br>The ions will vibrate between greater values of separation *r*. |

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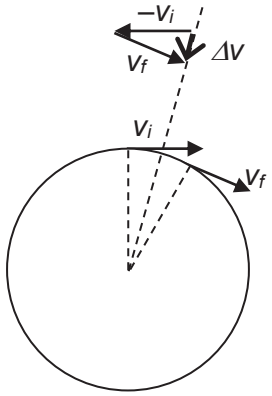
**Anderson Serangoon Junior College 2019 H2 Physics Prelim Mark Scheme**

**Paper 3 (100 marks)**

**1a**




Velocity $v_i$ represents the object's velocity at one instant and $v_f$ its velocity at a later instant.

In the vector triangle, the change in velocity $\Delta v$ ($=v_f - v_i$), is due to a change in the velocity's direction, while the magnitude of $v_i$ and $v_f$ are the same.

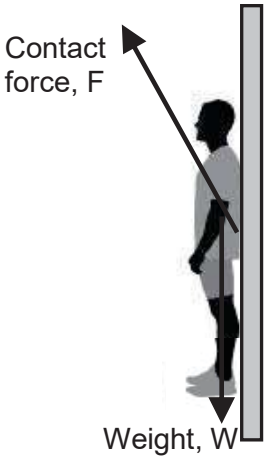
The direction of this change in velocity $\Delta$v is towards the centre of the circle, resulting in a centripetal acceleration perpendicular to velocity. Hence, the object is accelerating.

- Vector diagram showing that velocity changes direction, with brief description.
- State that force or acceleration is perpendicular to velocity, and relate a change in direction of velocity to acceleration.

**1bi**

- gravitational force by earth on man (vertically downwards)
- contact force by wall on man (diagonal to the left. Vertical component of contact force to be equal in magnitude to weight).

Accept: Contact force represented by Friction and Normal Reaction in correct direction and magnitude




**1bii**

The <u>upward frictional force is equal and opposite to the downward gravitational force</u> acting on the rider. Hence, the rider would not fall off.
The <u>normal contact force by the wall on the rider provides for the centripetal force</u> necessary for him to move together with the barrel in a circular path.

**1biii**

acceleration = $r\omega^2 = r(2\pi f)^2 = 2.5(2\pi)^2(33/60)^2$
$= 29.9$ m s$^{-2}$

**1biv**

Work done = <u>0 J</u>
because the <u>net force acting on the man</u> (normal contact force) is <u>always perpendicular to the velocity (or direction of motion) of the man</u> at any instant. As the instantaneous velocity is in the same direction of instantaneous displacement, hence, work done which is the product of force and the displacement in the direction of the force would be zero.

Or

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| | From the work-energy theorem, since there is no change in kinetic energy of the rider, there is no work done on the rider. |

| | |
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| **2a** | The **increase in internal energy** $\Delta U$ of a system is **equal** to the **sum** of the **heat supplied** $Q$ **to** the system and the **work done** $W$ **on** the system. |
| **2bi** | Work done on gas = $-p(V_2 - V_1)$<br>$= -(1.04 \times 10^5)(4.0 \times 10^{-4} - 2.9 \times 10^{-4})$<br>$= -11.4$ J<br>(1 mark if answer is not negative) |
| **2bii** | $\Delta U = Q + W$<br>$= 28.5 + (-11.4)$<br>$= 17.1$ J |
| **2biii** | $\frac{V}{T} = \frac{V'}{T'}$<br>$T' = \frac{V'}{V}T = \frac{4.00 \times 10^{-4}}{2.9 \times 10^{-4}}(314)$<br>$= 433$K |
| **2biv** | ½ m $\langle c^2 \rangle$ = 3/2 kT<br>$\sqrt{\langle c^2 \rangle} = \sqrt{(3kT/m)}$<br><br>Since k and m are constant,<br><br>Ratio = $\sqrt{(T_f/T_i)} = \sqrt{(433/314)} = 1.17$ |

| | |
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| **3a** | A transverse wave is a wave in which the displacement of the particles in the wave are at right angles to the direction of transfer of energy of the wave.<br><br>A longitudinal wave is a wave in which the displacement of the particles in the wave are along the direction of transfer of energy of the wave. |
| **3bi** | $\Delta t = 0.78 - 1.5(0.50)$<br>$= 0.03$ ms<br><br>OR $\Delta t = 0.50 - (0.78 - 1.5(0.50))$<br>$= 0.47$ ms<br><br>Phase difference = $\Delta t / T \times 360°$<br>$= 0.03/0.50 \times 360°$<br>$= 21.6$<br>$= 22°$<br>OR<br>Phase difference = $0.47/0.50 \times 360°$<br>$= 338°$ |


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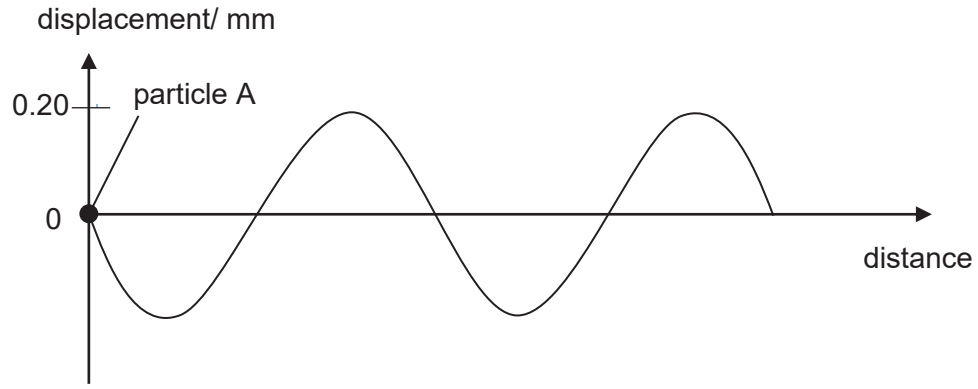
| **3bii** |  <br>Correct shape of graph<br>Correct labelling of amplitude |

| | |
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| **4a** | Using<br>$R = \frac{\rho l}{A}$<br>$= \frac{7.9 \text{ x } 10^{-7}(l)}{\pi(6.0 \text{ x } 10^{-6})^2}$<br>$l$ = 0.137 m |
| **4bi** | The resistance at a point on the curve can be determined using the ratio of voltage to the current at that point. |
| **4bii** | As $V$ increases, temperature increases, the no. of charge carriers (positive holes and/or negative electrons) per unit volume increases.<br><br>At the same time, the amplitude of vibration of atomic cores also increases, resulting in more frequent collisions with the atomic cores.<br><br>The increase in conductivity due to more charge carriers is more significant than the decrease in conductivity due to increased thermal vibration.<br><br>Hence resistance of thermistor decreases. |
| **4biii 1.** | $R_{\square\square} = (\frac{1}{960} + \frac{1}{1250})^{-1} = 543\Omega$ |
| **4bii 2.** | *By Potential Divider Principle*,<br>$V_{\square\square} = \frac{R_{\square\square}}{R_{\square\square} + 7800} \times 1.5$<br>$= \frac{543}{543 + 7800} \times 1.5$<br>$= 0.0976$ V |
| **4bii 3.** | When temperature drops, resistance of thermistor increases.<br><br>Hence, the effective resistance of XY increases.<br><br>By Potential Divider Principle, the potential difference across XY increases. |

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| | Since power is proportional to $V^2$ for constant lamp resistance, the power dissipated in the filament lamp increases. Thus, the bulb is brighter. |

| | |
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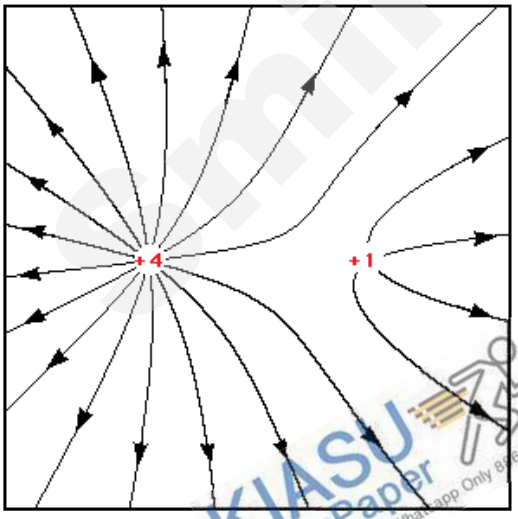
| **5a** | Zero electric field strengths in<br>sphere A (between $x$ = 0 and $x$ = 1.4 cm) and in<br>sphere B (between $x$ = 11.4 and $x$ = 12.0 cm) |
| **5bi** | Since the field strength is zero at a point between the spheres OR the electric fields are in opposite directions,<br>the charges on the spheres are of the same sign. |
| **5bii** | At $x$ = 0.08 m, the electric field strength due to sphere A cancels out the electric field strength due to sphere B.<br><br>$E_A = E_B$<br><br>$\frac{Q_A}{4\pi\varepsilon_o (0.08)^2} = \frac{Q_B}{4\pi\varepsilon_o (0.04)^2}$ (substitution of distances required for credit of mark)<br><br>$\frac{Q_A}{Q_B} = \left(\frac{0.08}{0.04}\right)^2 = 4$<br><br>Allow estimation from graph, 7.8 cm < $x$ < 8.2 cm |
| **5biii** | Diagram<br><br>  <br><br>• Correct field line direction (either all inwards or all outwards) and shape, and location of neutral point nearer to sphere B.<br>• More field lines radiating out of sphere A with closer spacing than sphere B, perpendicularly from the spheres<br>E1: Incorrect number and spacing of field lines |

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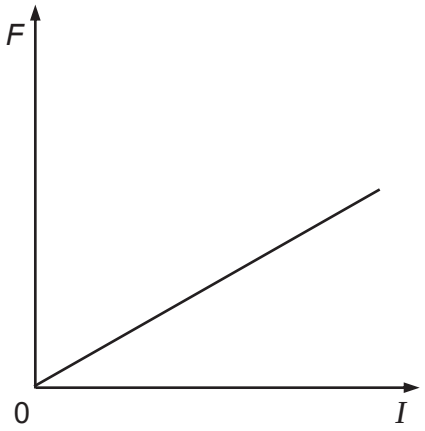
**6ai**

$F = B_{\perp}Il = BIl\sin\theta$

$F \propto I$ for B, l and $\theta$ constant

straight line with positive gradient through origin



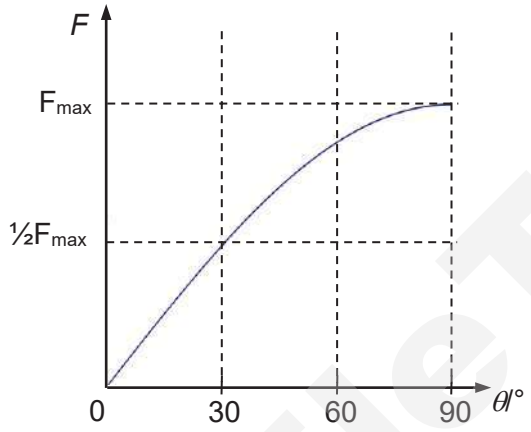

**6aii**

$F \propto \sin\theta$ for B, I and l constant

Curve with decreasing gradient from 0° to 90°. Max force at $\theta$ = 90° and zero force at $\theta$ = 0°.

sine curve with zero gradient $\theta$ = 90°

$\frac{1}{2}F_{max}$ at $\theta$ = 30°




**6bi**

There is a (magnetic) force acting on electron due to magnetic field.
By applying Fleming's Left Hand Rule, this force is directed towards QR. Hence, electron moves towards QR.

**6bii**

Initially, electrons accumulate on side QR. This sets up an electric field from side PS to side QR.
After some time, the electric force acting on subsequent electrons is equal and opposite to the magnetic force acting on these electrons.
Hence, subsequent electrons travel undeflected.

**7ai**

Power dissipated in the resistor is due to the non-zero root-mean-square current.

Accept: $I^2$ is always positive, therefore P(=$I^2R$) is always positive.

**7aii**

either maximum power = $I_0^2 R$ or average power = $I_{RMS}^2 R$
$I_0 = \sqrt{2} \times I_{RMS}$

maximum power = 2 × average power
Thus, ratio = 0.5

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| **7bi** | Improve flux linkage between primary and secondary coil, and strengthen the magnetic flux density. |
| **7bii** | Magnetic flux in the core is changing, causing induced e.m.f. or current in the core. Current in core causes heating effect. |
| **7biii** | The iron core is made of laminated sheets to reduce power loss due to induced current. |

| | |
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| **8ai** | initial speed is zero, constant acceleration, straight line motion (any 2) |
| **8aii1** | $s = \frac{1}{2}at^2$<br>$0.79 = \frac{1}{2}(9.81)t^2$<br>$t = 0.401\,s$ (accept 2 or 3sf) |
| **8aii2** | Distance travelled by end of time interval = 90 cm<br>$0.90 = \frac{1}{2}(9.81)t^2$<br>t = 0.428 s<br>time interval = 0.428 – 0.401 = 0.027 s |
| **8aii3** | % difference = $\frac{0.033 - 0.027}{0.033} = 18\%$<br>Since the percentage difference is larger than 5%, it is significant, hence the test does not confirm this time. (accept different stated criteria). |
| **8aiii** | The speed/acceleration of a less dense ball affected by air resistance will be lesser than the denser one as net force acting on the less dense ball decreases.<br>Hence, length of image is shorter. |
| **8bi** | force = rate of change of momentum (allow symbols if defined) |
| **8bii1** | change in momentum of the ball, $\Delta p = 140 \times 10^{-3} \times (5.5 + 4.0)$<br>$= 1.33$ kg m s$^{-1}$ |
| **8bii2** | $F_{net} = 1.33 / 0.04$<br>= 33.25 N<br>= 33 N<br><br>Average contact force on bar due to ball<br>$= F_{net} + W_{ball}$<br>$= (1.33/0.04) + (9.81 \times 140 \times 10^{-3})$<br>= 34.6<br>= 35 N |
| **8bii3.** | Taking moments about B<br>$(35 \times 0.75) + (0.450 \times 9.81 \times 0.25) = F_A \times 0.20$<br>$F_A$ = 137 N |
| **8biii** | The change in momentum of the ball on hitting the bar decreases,<br>the duration of contact increases, |


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| | hence, average contact force on bar at point D decreases. |

| | |
|---|---|
| **9a** | **Half-life** is the <u>average</u> time taken for the ***<u>activity</u>*** of a particular radioactive <u>nuclide</u> to fall to half its initial value |
| **9bi** | Initial N = 5.6<br>At ½N, t = 4.6 hours<br>At ¼N, t = 9.2 hours<br><br>Take average to find half-life<br><br>Half-life = $\frac{4.6+4.6}{2}$ = 4.6 |
| **9bii** | $\frac{\text{number of X nuclei}}{\text{number of P nuclei}} = 6$<br><br>$\frac{\text{number of } P \text{ nuclei after time t}}{\text{intial number of P nuclei}} = \frac{1}{7}$<br><br>$(\frac{1}{2})^n = \frac{1}{7}$<br>$n = \frac{\lg(\frac{1}{7})}{\lg(\frac{1}{2})}$<br>$= 2.81$<br><br>Hence, t = n × half-life = 2.81 × 4.6 = 13 hours |
| **9biii** | (Negative) gradient of graph<br>represents <u>activity / rate of</u> decay |
| **9biv** | Mtd 1:<br>At t = 4.0, N = $3.05 \times 10^{10}$<br>A = λN = $\frac{\ln 2}{t_{\frac{1}{2}}}$ N<br>= $\frac{\ln 2}{4.6 \times 3600}(3.05 \times 10^{10})$<br>= $1.28 \times 10^6$ Bq<br><br>OR<br><br>Mtd 2:<br><br>tangent drawn and gradient calculated<br>Gradient = $\frac{(0.7-4.5)\times 10^{10}}{(9.4-0.8)\times 3600}$ |

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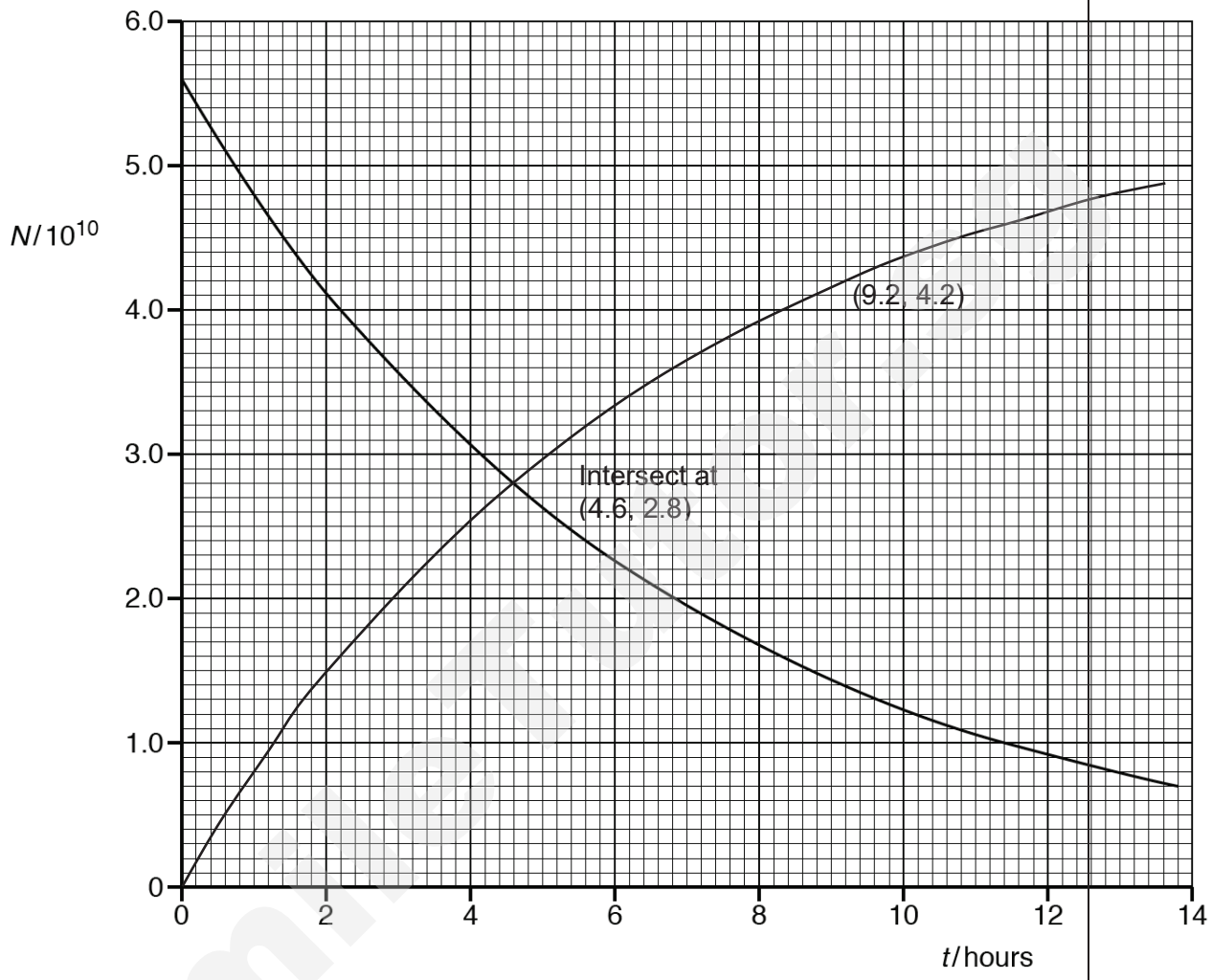
| | |
|---|---|
| | $= 1.23 \times 10^6$ Bq |
| **9bv** | Correct trend<br>Intersect at (4.6, 2.8) and Pass through (9.2, 4.2)<br>  <br> |
| **9bvi** | A neutrino is produced and has energy.<br>Q has kinetic energy.<br>Mass–energy and momentum must be conserved in the decay.<br>The missing energy must have been carried away by other particles in the decay. |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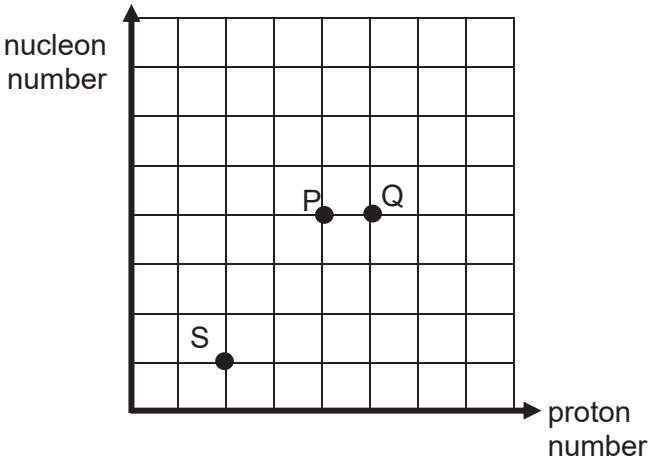
**9ci and ii**




$^{A_p}_{\square_p}P \rightarrow {}^{A_x}_{\square_x}\square + {}^{0}_{-1}e$

By conservation of mass:

$A_p = A_x + 0 \Rightarrow A_p - A_x = 0$

By conservation of charge:

$\square_p = \square_x - 1 \Rightarrow \square_p - \square_x = -1$

$^{A_{Sr}}_{\square_{Sr}}Sr + {}^{4}_{2}He \rightarrow {}^{A_P}_{\square_P}P + {}^{1}_{0}n$

By conservation of mass:

$A_{Sr} + 4 = A_P + 1 \Rightarrow A_{Sr} - A_P = -3$

By conservation of charge:

$\square_{Sr} + 2 = \square_P \Rightarrow \square_{Sr} - \square_P = -2$

**9cii**

Total linear momentum of the system must be conserved throughout the process.
Since initial total momentum of S and $\alpha$ is non-zero, final total momentum of them at closest approach must be non-zero.
Hence, not possible for them to be at rest simultaneously.

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Name: _____ (  )  Class: 19 /____

# ANDERSON SERANGOON JUNIOR COLLEGE

## 2019 JC2 Preliminary Examination

## PHYSICS Higher 2 9749/04

**Paper 4 Practical** **Monday 2 September 2019**

**2 hours 30 minutes**

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

---

**READ THESE INSTRUCTIONS FIRST**

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

Answer **all** questions.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| **Paper 4 (55 marks)** | |
| **1** | |
| **2** | |
| **3** | |
| **4** | |
| **Total (55 marks)** | |

---

This document consists of **15** printed pages and **5** blank pages.


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**1** In this experiment, you will investigate the motion of a sphere launched from a ramp.

**(a)** Set up the apparatus as shown in Fig. 1.1. Adjust the height of the clamp so that the launch angle $\phi$ is approximately 15°. **Do not bend the ramp throughout the experiment**.

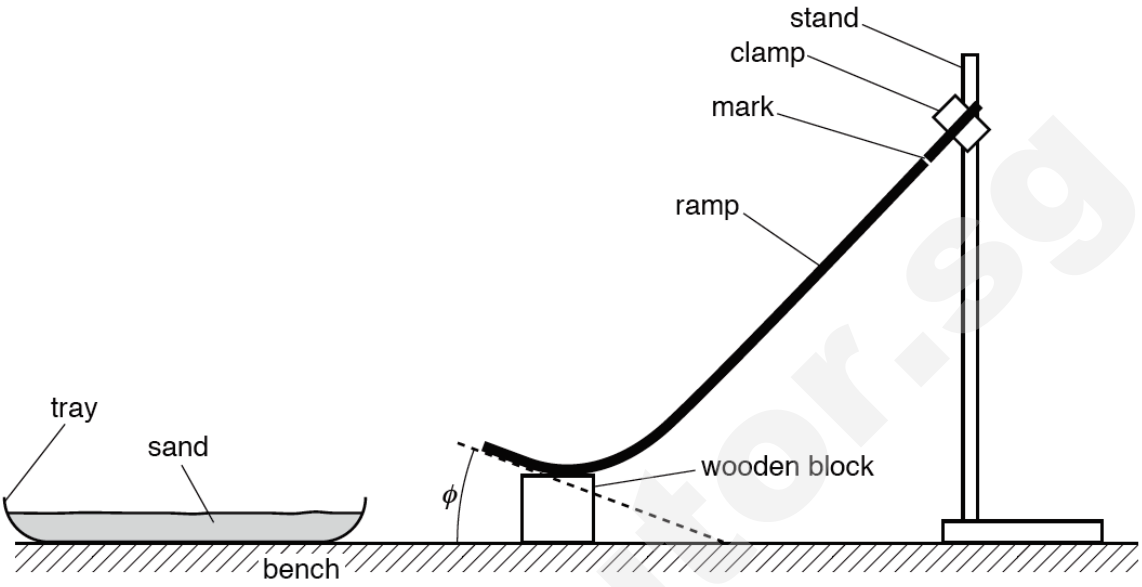


**Fig. 1.1** (not to scale)

**(b)** **(i)** Measure and record $\phi$, as shown in Fig. 1.1.

$\phi$ = 15° .....[1]

M1

**(ii)** Measure and record the height $h_1$ of the mark above the bench, as shown in Fig. 1.2.

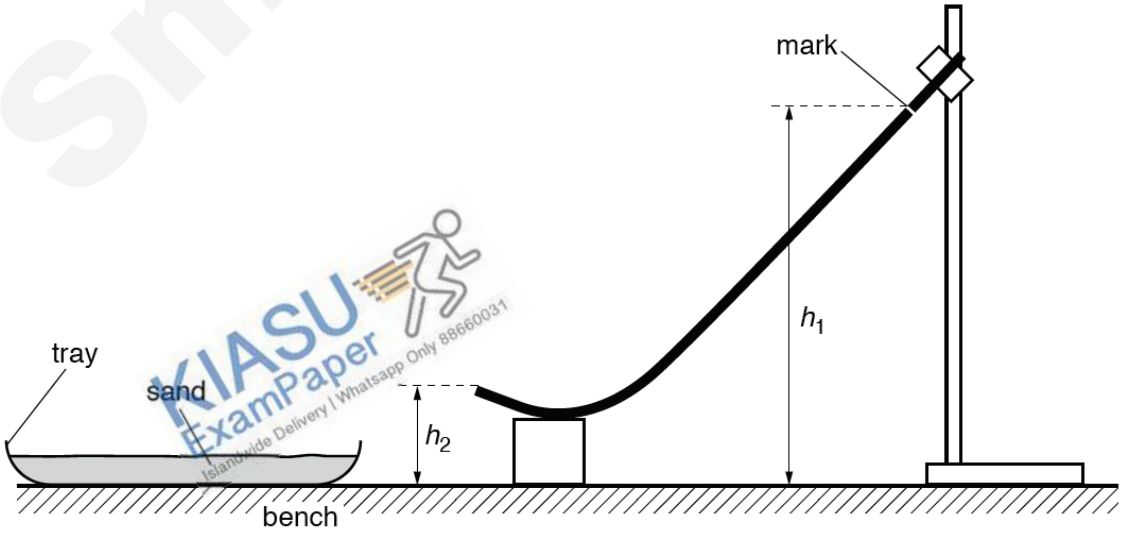


**Fig. 1.2** (not to scale)

$h_1$ = 0.280 m .....



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**(iii)** Measure and record the height $h_2$ of the end of the ramp, as shown in Fig. 1.2.

$h_2$ = 0.085 m .....[1]

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M2

**(iv)** Calculate the speed $v$ of the sphere when it leaves the ramp using the expression

$$v = \sqrt{2g(h_1 - h_2)}$$

where $g$ = 9.81 m s$^{-2}$.

v = $\sqrt{2(9.81)(0.280 - 0.085)}$

= 1.96 m s$^{-1}$

$v$ = 1.96 m s$^{-1}$ .....[1]

A1

**(c)** Justify the number of significant figures you have given for your value of $v$.

Since the number of s.f. for ($h_1 - h_2$) is 3, hence $v$ is 3 s.f.

..... [1]

P1

**(d)** **(i)** Place the sphere on the ramp at the mark. Release the sphere.

**(ii)** Measure and record the horizontal distance $R$ from the end of the ramp to the landing position of the sphere, as shown in Fig. 1.3.

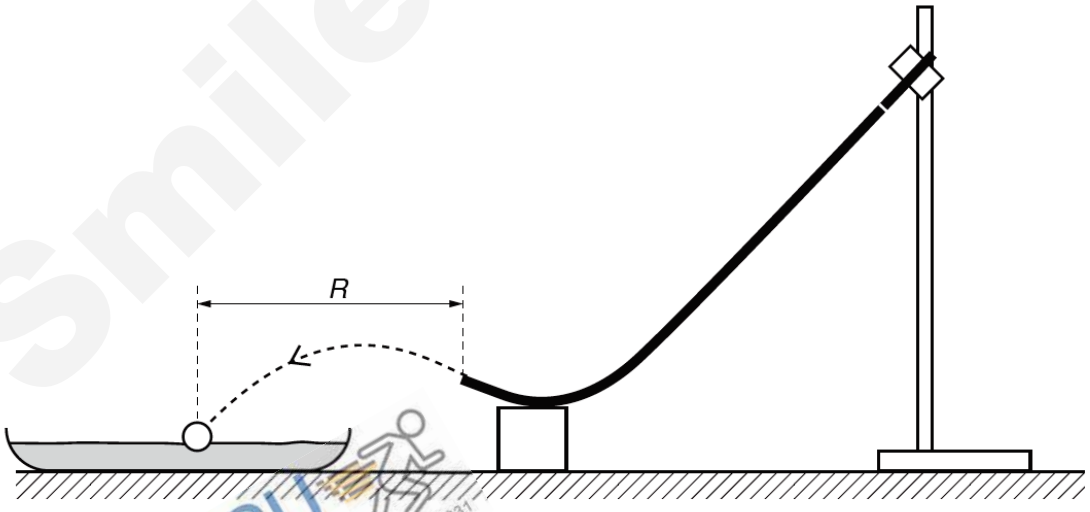


**Fig. 1.3** (not to scale)

$$R = \frac{R_1 + R_2}{2}$$

$$= \frac{0.230 + 0.250}{2}$$

$$= 0.240 \text{ m}$$

$R$ = 0.240 m ..... [2]

M3

M4



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**(e)** Estimate the percentage uncertainty in your value of $R$.

$$\text{percentage uncertainty} = \frac{0.005}{0.240} \times 100\%$$
$$= 2.1\ \%$$

percentage uncertainty = 2.1 % ..... [1]

**(f)** By lowering the clamp, increase the launch angle $\phi$ to approximately 25°. Repeat **(b)** and **(d)** using the sphere.

$\phi$ = 25° .....

$h_1$ = 0.210 m .....

$h_2$ = 0.089 m .....

$$v = \sqrt{2(9.81)(0.210 - 0.089)}$$
$$= 1.54\ \text{m s}^{-1}$$

$v$ = 1.54 m s$^{-1}$ .....

$$R = \frac{0.185 + 0.195}{2}$$
$$= 0.190\ \text{m}$$

$R$ = 0.190 m .....[2]

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A2

M5

M6

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**(g)** It is suggested that the relationship between $R$, $v$ and $\phi$ is

$$R = k\, v \cos \phi$$

where $k$ is a constant.

**(i)** Using your data, calculate two values of $k$.

$$k = \frac{R}{v \cos \phi}$$

first $k$

$$k = \frac{0.240}{1.96 \cos 15°} = 0.126\,\text{s}$$

second $k$

$$k = \frac{0.190}{1.54 \cos 25°} = 0.136\,\text{s}$$

first value of $k$ = 0.126 s

second value of $k$ = 0.136 s

[1] A3

**(ii)** Explain whether your results support the suggested relationship.

Percentage difference in k = $\frac{\Delta k}{k} \times 100\% = \frac{0.136 - 0.126}{0.126} \times 100\% = 7.9\%$

The criterion is percentage difference in k ≤ percentage uncertainty in $R$.

Since the % difference in $k$ value is more than the % uncertainty in $R$, the suggested relationship is not valid. [1] A4

**(iii)** It is not accurate to draw a conclusion based on only two readings as in **g(ii)**. Suggest a way the method can be changed.

Take 6 sets of readings by varying $\phi$ and plot a graph of $R$ against $v \cos\phi$ to test the relationship. If the graph is a straight line passing through the origin, the relationship is valid. [1] A5



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

It is difficult to measure $R$ as the sphere rolls after landing / the landing mark is unclear. This will affect the accuracy of $R$.

.....[1]

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A6

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

Use sticky surface (e.g. duct tape) to stop rolling/ dye on ball to mark paper/ clay to show landing mark so as to improve the accuracy of $R$.

.....[1]

A7

**(i)** A student is investigating the motion of a sphere launched horizontally from the ramp with a range of different speeds $v$.

It is suggested that the square of the horizontal distance $R$ from the end of the ramp to the landing position of the sphere is proportional to $v$.

Explain how you would investigate this relationship using the **same apparatus**.

Your account should include:
- your experimental procedure
- control of variables
- how you would use your results to test the relationship.

1. Decrease the launch angle $\phi$ to zero by raising the clamp.
2. Fix the clamp position to keep $\phi$ constant throughout the experiment.
3. Vary the speed $v$ by releasing the sphere at different position on the ramp (or at different height $h_1$) to obtain 6 sets of readings of $v$ and $R$.
4. Plot a graph of $R^2$ against $v$. If the graph is a straight line passing through the origin, the relationship is valid.

.....[4]

PL1
PL2
PL3
PL4

[Total: 18]


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**Question 2 begins on the next page.**

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**2** In this experiment, you will investigate the oscillatory motion of a loaded metre rule supported at one end by a spring.

**(a)** Secure the cork in the clamp so that the pin is mounted horizontally. Suspend one end of the rule from the pin by passing the pin through the hole in the rule. The rule should be able to pivot around the pin.

Hook one end of the spring to the rod of another clamp. Suspend the other end of the rule through the small loop of string. The string should be at the 0.5 cm marking of the rule as shown in Fig. 2.1.

The clamps should be adjusted so that the rule is approximately horizontal.

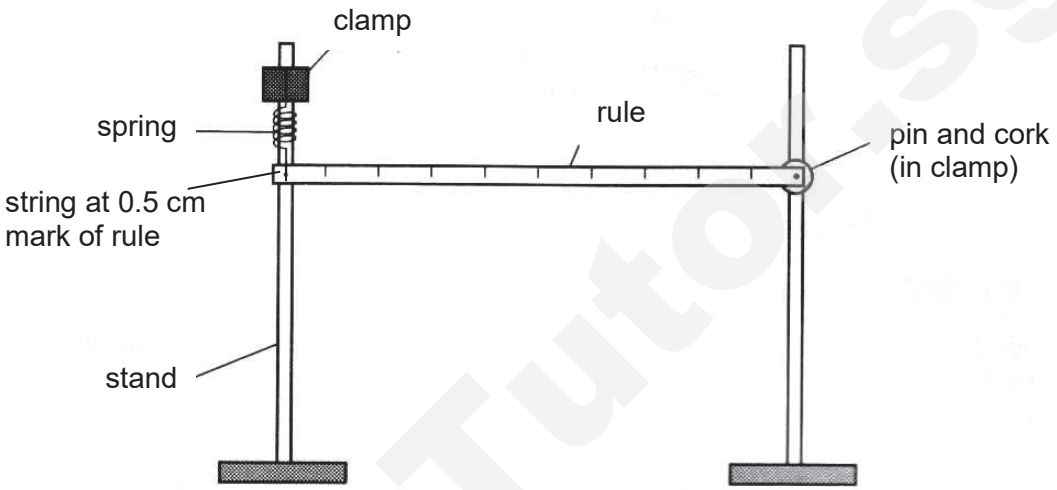


**Fig. 2.1**

**(b)** Tie a loop of string on the rule to suspend a mass of 350 g a distance *d* from the pin as shown in Fig 2.2. The mass should be about halfway along the rule. Adjust the position of the clamps to make the rule approximately horizontal again.

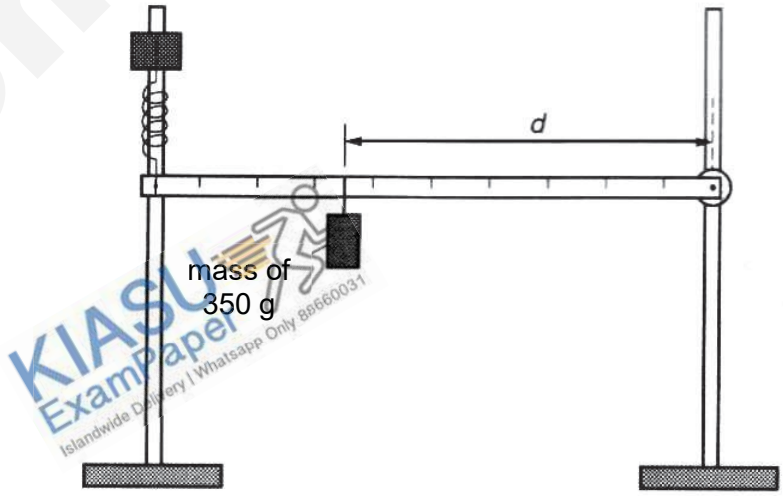


**Fig. 2.2**

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**(c)** Measure and record the value of $d$.

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$d$ = 0.495 m

**(d)** Gently displace the end of the rule so that it performs small oscillations in a vertical plane.

Determine the period $T$ of the oscillations.

$$T = \frac{t_1 + t_2}{2N} = \frac{14.5 + 15.1}{2(30)} = 0.493 \text{ s}$$

| | |
|---|---|
| M1 | |
| A1 | |

$T$ = 0.493 s [2]

**(e)** The equation that relates $T$ and $d$ for this oscillator is

$$T^2 = \frac{4\pi^2}{kL^2}(Md^2 + C)$$

where $k$ is 28.0 N m$^{-1}$, $M$ is the mass of the load, $L$ is the length of the rule and $C$ is a constant.

Calculate $C$.

$$0.493^2 = \frac{4\pi^2}{(28.0)(1.000)^2}\left[(0.350)(0.495)^2 + C\right]$$

C = 0.0866 kg m$^2$

| | |
|---|---|
| A2 | |
| A3 | |
| A4 | |

$C$ = 0.0866 kg m$^2$ [3]

[Total: 5]

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**Question 3 begins on the next page.**

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**3** In this experiment, you will investigate how the current through a milliammeter varies as the resistance of a resistor is changed.

**(a)** Set up the circuit as shown in Fig. 3.1.

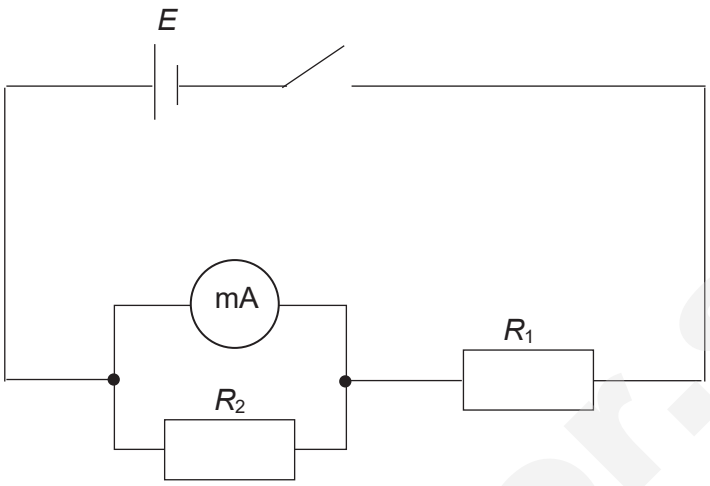


**Fig. 3.1**

**(b)** The resistor of resistance $R_2$ can be made using any combination of the resistors provided. The resistance of each resistor is 100 Ω.

**(c)** Set the value of $R_2$ to 100 Ω and close the switch. Record the current $I$ through the digital milliammeter.

$I$ = ..3.88 x $10^{-3}$.....A [1]

M1

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**(d)** Change the value of $R_2$ and repeat step **(c)** to obtain further sets of values for $R_2$, and the corresponding values of $I$.

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| $R_2$ / Ω | $I$ / $10^{-3}$A | $\frac{1}{R_2}$ / $10^{-3}\,\Omega^{-1}$ | $\frac{1}{I}$ / $A^{-1}$ |
|---|---|---|---|
| 33.3 | 3.25 | 30.0 | 308 |
| 50.0 | 3.54 | 20.0 | 282 |
| 66.7 | 3.72 | 15.0 | 269 |
| 100 | 3.90 | 10.0 | 256 |
| 150 | 4.03 | 6.67 | 248 |
| 200 | 4.10 | 5.00 | 244 |
| 300 | 4.18 | 3.33 | 239 |

| | |
|---|---|
| M2 | |
| M3 | |
| P1 | |
| P2 | |
| P3 | |
| A1 | |

[7]

**(e)** It is suggested that $I$ and $R_2$ are related by the equation,

$$\frac{1}{I} = \frac{k}{R_2} + C$$

where $k$ and $C$ are constants.

Plot a suitable graph to determine values of $k$ and $C$.

Plot a graph of $\frac{1}{I}$ against $\frac{1}{R_2}$ where $k$ is the gradient and $C$ is the y-intercept.

gradient = $\frac{307.0 - 240.0}{(30.0 - 3.5)\times 10^{-3}} = 2530 = 2.53\times 10^3$

k = 2.53 x $10^3$ $A^{-1}\,\Omega$

From graph y-intercept, c = 231.5
C = 232 $A^{-1}$ (allow 231.5 $A^{-1}$)

Or
Substitute (30.0 x $10^{-3}$, 307.0) into y = mx+c,
y-intercept, c = 307.0– (2530 × 30.0$\times 10^{-3}$ ) = 307.0 – 75.9
= 231.1 (allow 231)
C = 231 $A^{-1}$

$k$ = 2530 $A^{-1}\,\Omega$

$C$ = 232 $A^{-1}$

[7]

| | |
|---|---|
| A2 | |
| A3 | |
| A4 | |
| A5 | |


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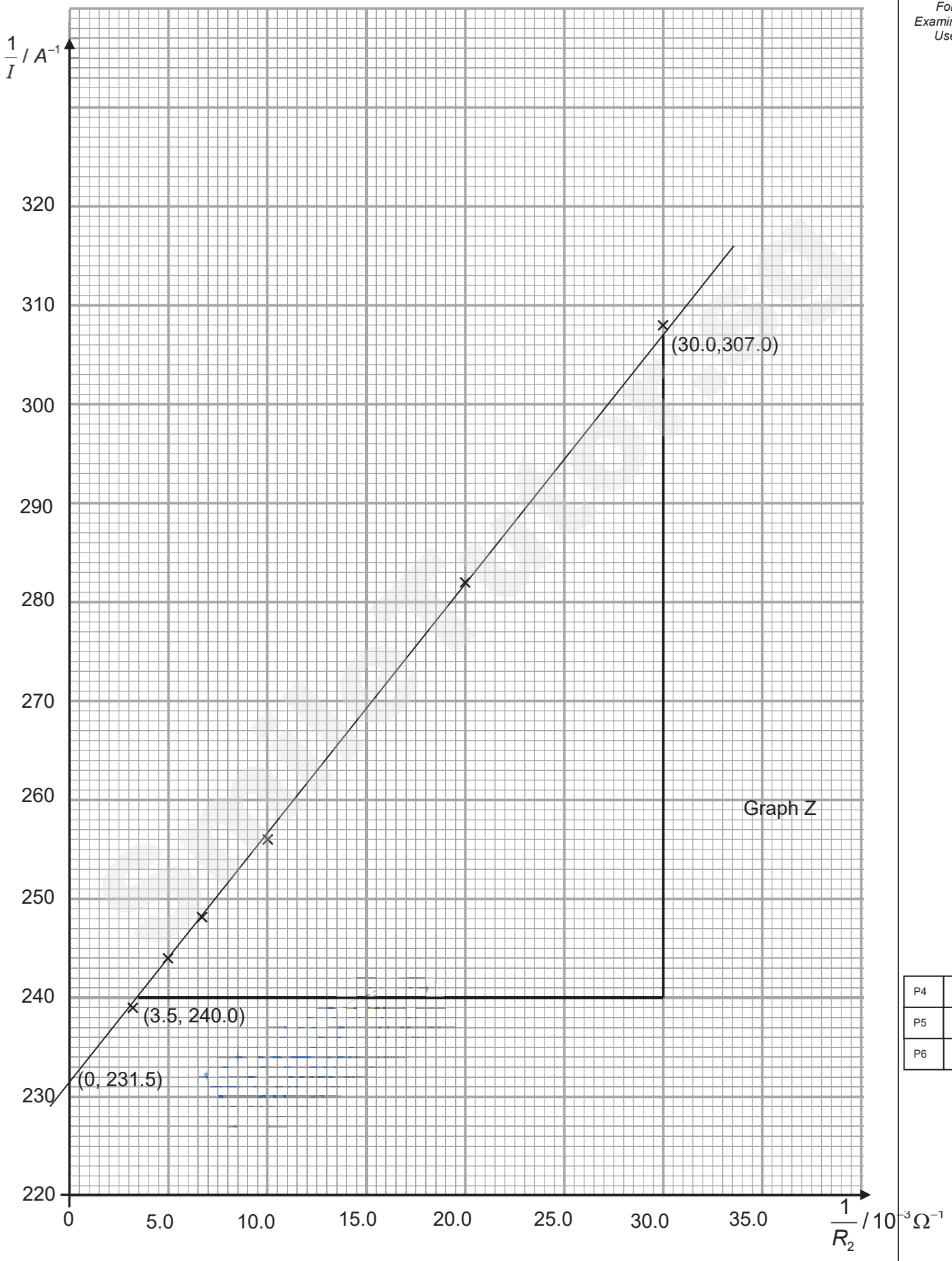


| | |
|---|---|
| P4 | |
| P5 | |
| P6 | |


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

There is no anomalous point as all the points are close to the best fit line.

.....[1]

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M4

**(ii)** Measure and record a value of the e.m.f. $E$ of the power supply using the analogue voltmeter.

$E$ = 2.15 V .....[1]

M5

**(g)** Theory suggests that $k = \frac{R_1 S}{E}$

where $S$ is the resistance of the digital milliammeter.

Given that $R_1$ = 470 Ω, together with your answers to **(e)** and **(f)(ii)**, determine a value for $S$.

$$k = \frac{R_1 S}{E}$$

$$S = \frac{kE}{R_1} = \frac{2530\ (2.15)}{470} = 11.6\ \Omega$$

A6

$S$ = 11.6 Ω ..... [1]

**(h)** $C$ is inversely proportional to $E$.

On the graph grid on page 13, sketch a second graph to represent the results if $E$ is increased. Label this graph Z.

[2]

A7

A8

[Total: 20]



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**Question 4 begins on the next page.**

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**4** Two identical light sources are viewed from a distance, as shown in Fig 4.1. When the angle $\theta$ between the light sources is large, they are seen as separate.

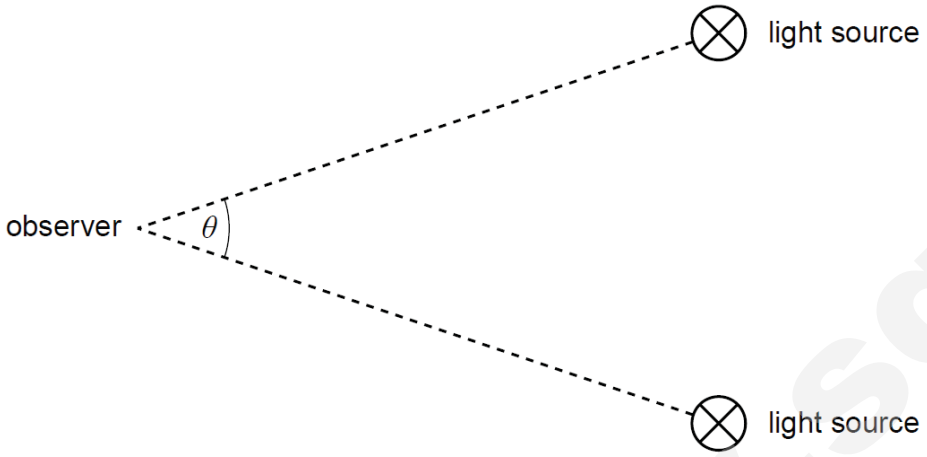


**Fig. 4.1** (not to scale)

The sources are moved closer together. At a particular angle $\theta_1$ the two sources appear as a single source.

The relation between $\theta_1$ and the wavelength $\lambda$ of the light from the sources may be written in the form of

$$\theta_1 = \frac{\lambda}{b}$$

where $b$ is a constant.

It is inappropriate to measure $\theta_1$ using a protractor as it is a small angle.

Design a laboratory experiment using two light sources to determine the value of $b$.

You should draw a diagram to show the arrangement of your apparatus and you should pay particular attention to

**(a)** the equipment you would use
**(b)** the procedure to be followed
**(c)** how the wavelength $\lambda$ and angle $\theta_1$ would be determined
**(d)** the control of variables
**(e)** any precautions that should be taken to improve the accuracy and safety of the experiment.


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**2019 ASRJC JC2 Prelim H2 Physics P4 MS**

| Q1 | Answer | Mark | Code |
|---|---|---|---|
| (b)(i) MMO | ***Measurement of $\phi$***<br>$\phi$ in range 10° to 20°, with unit and to nearest degree. | 1 | **M1** |
| (b)(ii) MMO | ***Measurement of $h_1$ and $h_2$***<br>Values of $h_1$ and $h_2$ to nearest mm. | 1 | **M2** |
| (b)(iv) ACE | ***Calculation of v***<br>Correct calculation of $v$ with correct unit. | 1 | **A1** |
| (c) PDO | ***Calculated quantities (appropriate no. of significant figures)***<br>Justification based on number of significant figures in $(h_1 - h_2)$.<br>*Note: no credit if ans in b(iv) not in 3.s.f.* | 1 | **P1** |
| (d)(ii) MMO | ***Measurement of R***<br>Value of $R$ to nearest mm<br>Evidence of repeat readings of $R$. | 1<br>1 | **M3**<br>**M4** |
| (e) ACE | ***Estimating uncertainties***<br>Percentage uncertainty in $R$ calculated correctly to 2 s.f using sensible value of $\Delta R$ (e.g. 2 mm ≤ $\Delta R$ ≤ 10 mm).<br>*Note: If $\Delta R$ = 10 mm, then R has to be recorded to 2 d.p in metre for d(ii)* | 1 | **A2** |
| (f) MMO | ***Measurement of second values***<br>$\phi$ in range 20° to 30°. Second $h_2$ greater than first $h_2$. Second $h_1$ less than first $h_1$.<br>Second $R$ less than first $R$. | 1<br>1 | **M5**<br>**M6** |
| (g)(i) ACE | ***Calculation of k***<br>Two values of $k$ calculated correctly with unit<br>*Note: k has to be recorded to* 2 s.f. or 3 s.f. | 1 | **A3** |
| (g)(ii) ACE | ***Conclusion***<br>Valid conclusion relating to the calculated values of $k$, testing against a criterion | 1 | **A4** |
| (g)(iii) ACE | ***Modification***<br>Take 6 sets of readings and plot a graph of $R$ against $v\cos\phi$.<br>If the graph is a straight line passing through the origin, the relationship is valid. | 1 | **A5** |
| (h)(i) ACE | ***Sources of errors***<br>1. It is difficult to measure $R$ as the sphere rolls after landing / the landing mark is not clear/distinct. This will affect the accuracy of $R$.<br>2. It is difficult to measure $R$ as the centre of sphere is determined by estimation. This will affect the accuracy of $R$.<br>3. It is difficult to measure $\phi$ as the ramp in contact with the block is curve/ the alignment of the zero marking of protractor is uncertain. This will affect the accuracy of $\phi$.<br>4. It is difficult to release marble from same position each time as alignment of the lowest point of the sphere on the mark is uncertain. This will affect the accuracy of $h_1$. | 1 | **Any 1**<br>**A6** |


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| Q1 | Answer | Mark | Code |
|---|---|---|---|
| (h)(ii)<br>ACE | ***Improvement***<br>1. Use sticky surface (e.g. duct tape) to stop rolling/ dye on ball to mark paper/ clay to show landing mark so as to improve accuracy of *R.*<br>2. Measure to edge of sphere and add half diameter (diameter of sphere can be measured using micrometer screw gauge) so as to improve accuracy of *R.*<br>3. Hold ruler as tangent so as to improve accuracy of $\phi$.<br>4. Use a card as a stop on ramp to ensure marble is released from same position | 1 | **A8** |
| (i) | ***Planning***<br>1. Decrease the launch angle $\phi$ to zero by raising the height of clamp,<br>2. Fix the clamp position to keep $\phi$ constant throughout the experiment.<br>3. Vary the speed *v* by releasing the sphere at different position on the ramp /different height $h_1$ to obtain 6 sets of readings *v* and *R*.<br>4. Plot a graph of $R^2$ against *v*. If the graph is a straight line passing through the origin, the relationship is valid. | 1<br>1<br>1<br><br>1 | **PL1**<br>**PL2**<br>**PL3**<br><br>**PL4** |

| Q2 | Answer | Mark | Code |
|---|---|---|---|
| (c)<br>MMO<br>ACE | ***Calculation of T***<br>Evidence of repeated reading of raw time and *NT* more than 10.0 s.<br>*Correct calculation of T* to 3 s.f. with units. | 1<br>1 | **M1**<br>**A1** |
| (d)<br>ACE | ***Calculation of C***<br>Correct substitution of values (with correct units) into equation<br>Correct calculation of *C* with correct range 0.0650 □ *C* □ 0.0960 and sf.<br>Correct units of *C* | 1<br>1<br>1 | **A2**<br>**A3**<br>**A4** |

| Q3 | Answer | Mark | Code |
|---|---|---|---|
| (c)<br>MMO | ***Measurement of $I$***<br>Value of $I$ in the range 3.45 x $10^{-3}$ A ≤ $I$ ≤ 4.05 x $10^{-3}$ A, with precision to 0.01 mA | 1 | **M1** |
| (d)<br>MMO | ***Set up apparatus from a circuit diagram and follow of written instructions***<br>• Award 2 marks if the student has successfully collected 6 or more sets of data ($R_2$, $I$), without assistance/intervention.<br>• Award 1 mark if student has successfully collected 5 sets of data ($R_2$, $I$), without assistance/intervention.<br>• Award zero mark if student has successfully collected 4 or fewer sets of data ($R_2$, $I$), without assistance/intervention.<br>• Deduct 1 mark if student requires some assistance/intervention but has been able to do most of the work independently. Indicate the nature of any assistance.<br>• Deduct 2 marks if student has been unable to collect data without substantial assistance/intervention.<br><br>Minimum mark for **M2** = 0. | 2 | **M2** |


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| Q3 | Answer | Mark | Code |
|---|---|---|---|
| (d)<br>MMO | ***Values of $R_2$***<br>Correct values of $R_2$ (ie: 33.3, 50.0, 66,7, 100, 150, 200, 300) | 1 | **M3** |
| (d)<br>PDO | ***Layout: Column headings (raw data & calculated quantities: $R_2$, $I$, $1/R_2$, $1/I$)***<br>Each column heading must contain an appropriate quantity and a unit. Ignore units in the body of the table. There must be some distinguishing mark between the quantity and the unit i.e. solidus is expected. | 1 | **P1** |
| (d)<br>PDO | ***Table of results: raw data (appropriate degree of precision)***<br>All $I$ *values* to nearest 0.01 mA. | 1 | **P2** |
| (d)<br>PDO | ***Table of results: calculated quantities (appropriate no. of significant figures)***<br>For each calculated value of $R_2$,$1/R_2$ and $1/I$, the number of s.f. should be the same or one more than the number of s.f. in the raw data.<br><br>*Note: No marks if $1/R_2$ and / or $1/I$ not present.* | 1 | **P3** |
| (d)<br>ACE | ***Table of results: calculated quantities***<br>Correctly calculated values of $1/R_2$ and $1/I$.<br><br>*Note: No marks if $1/R_2$ and / or $1/I$ not present.* | 1 | **A1** |
| (e)<br>ACE | ***Linearising Equation***<br>Linearising equation and deriving expressions that equate e.g. gradient to *k* and y-intercept to *C*. | 1 | **A2** |
| (e)<br>PDO | ***Graph: Layout, choice of scale and labeling of axes***<br>Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions.<br>Axes must be labelled with the quantity which is being plotted. | 1 | **P4** |
| (e)<br>PDO | **Graph: plotting of points**<br>All observations must be plotted. Check any 3 points and put ticks if correct. Work to an accuracy of half a small square. | 1 | **P5** |
| (e)<br>PDO | **Graph: trend line and ability to draw best fit line**<br>Straight line of best fit – judge by scatter of points about the student's line. There must be a fair scatter of points on either side of the line. | 1 | **P6** |
| (e)<br>ACE | ***Interpretation of graph – gradient***<br>Gradient – the hypotenuse of the triangle must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square. Check for $\Delta y/\Delta x$ (do not allow $\Delta x/\Delta y$).<br><br>*Note: Factor of $10^{-3}$ for calculation (ie: x values) or included in units for k.* | 1 | **A3** |
| (e)<br>ACE | ***Interpretation of graph – intercept***<br>y-intercept – must be read off to nearest half a small square or determined from $y = mx + c$ using a point on the line. | 1 | **A4** |


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| Q3 | Answer | Mark | Code |
|---|---|---|---|
| (e)<br>ACE | ***Drawing conclusion***<br>Values of *k* and *C* calculated correctly with units. | 1 | **A5** |
| (f)(i)<br>MMO | ***Identification of anomaly***<br>Anomalous data/results, if any, must be identified. Appropriate justification must be given. Otherwise, comment of absence of anomalous data.<br><br>*Note: Can award if student correctly identified more than one anomalous point.* | 1 | **M4** |
| (f)(ii)<br>MMO | ***Measurement of E***<br>*E* measured to the correct precision with unit. (Raw data last digit must be 0 or 5)<br><br>*Note: Range of E must be between 1.80 V to 2.20 V* | 1 | **M5** |
| (g)<br>ACE | ***Calculation of S***<br>*S* calculated with correct substitution of values (*E* from f(ii) and *k* value from (e) and $R_1$).<br><br>*Range of S between 5 Ω and 20 Ω* | 1 | **A6** |
| (h)<br>ACE | ***Interpretation of graph – underlying principles***<br>When E increases, the gradient decrease<br>and y-intercept decrease | 1<br>1 | **A7**<br>**A8** |

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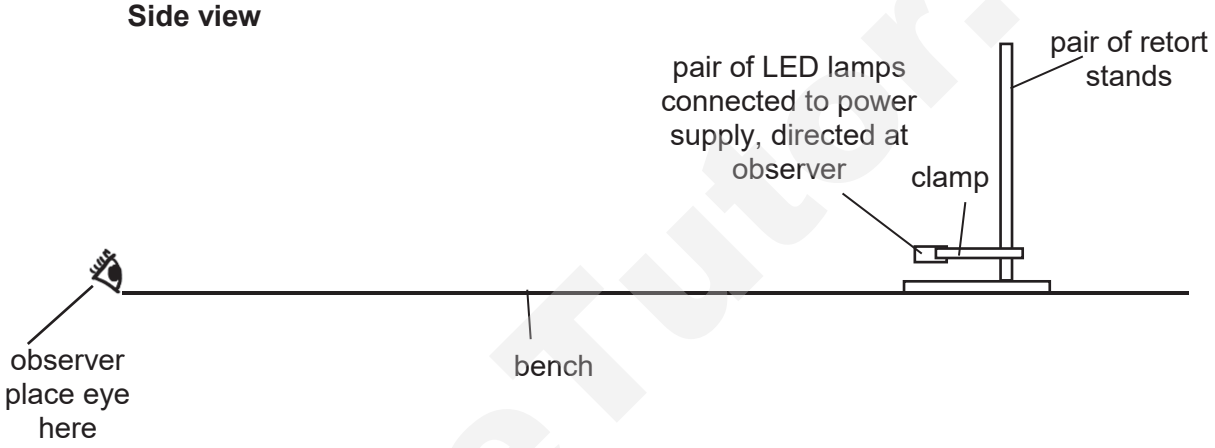
**Suggested Solution to Q4**

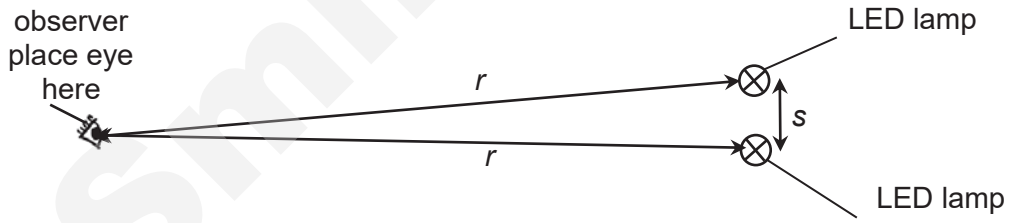
| Independent variable | Dependent variables | Control variables |
|---|---|---|
| **What?**<br>$\lambda$ of monochromatic light produced by LED | $\theta_1$ | Intensity of both LED lamps |
| **How?**<br>Measure $\lambda$ using Young's double slit expt<br>Change type of LED to vary $\lambda$ | *s* using metre rule, r using vernier calipers<br>$\theta_1$ = s/r. | Fix power input to both lamps |

**Diagram**

**Side view**




**Top view**




**Procedure**

1. Setup the experiment as shown in the diagram above with two identical monochromatic LED lamps.
2. With the observer looking at the lamps, gradually reduce the separation *s* between the lamps by bringing them closer together until the two sources appear as a single source to the observer.
3. Measure and record the distance *r* between the observer and one of the lamps using a metre rule.
4. Measure and record *s* using vernier calipers.
5. Calculate $\theta_1$ using $\theta_1 = s/r$.
6. Using the Young's Double Slit Experiment, pass light from one LED lamp through a single slit, followed by a double slit, and allow fringes to form on a screen.
7. Calculate $\lambda$ using $\lambda = ax/D$, where *a* is the slits separation, *x* is the fringe separation, *D* is the distance between the double slits and the screen.
8. Repeat experiment using different LED lamps of different colours to vary $\lambda$ to obtain 6 sets of readings of $\lambda$ and $\theta_1$.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**Control of variables**

1. Keep both light sources to be the same intensity by fixing the power input.

**Analysis**

1. Plot a graph of $\theta_1$ against $\lambda$. The equation $\theta_1 = \frac{\lambda}{b}$ is valid if the graph is a straight line through the origin.
2. Determine the gradient of the graph. Calculate $b$ using $b$ = 1/gradient.

**Safety and Accuracy**

1. Take preliminary readings of $\lambda$, $s$ and $r$ to obtain measurable values of $\theta_1$.
2. Keep the observer equidistant to both light sources by measuring with rule and adjusting for every set of reading.
3. View with same eye to ensure consistency in resolving power of observer.
4. Light may damage eyes, therefore wear dark glasses when looking at the lamps.

(refer to MS for other accepted answers)

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**Q4 Planning MS (12 marks)**

| | | |
|---|---|---|
| **Diagram** | | |
| D1 | Labelled diagram showing observer, light sources with method of producing monochromatic light e.g. filter / coloured LED.<br>Do not accept laser as light source as it may damage eyes. | [1] |
| | | |
| **Procedure** | | |
| P1 | Method to measure wavelength: quote either Young's double slit or diffraction grating equation with symbols defined. | [1] |
| P2 | Use a rule to measure r, r must be described or shown in diagram. | [1] |
| P3 | Method to determine θ, e.g. θ (or sin θ or tan θ) = s/r or<br>tan (θ/2) = s / (2 × r)<br>r can either be distance between observer and one of the sources, or perpendicular distance between observer and centre of the two sources<br>Do not allow protractor methods. | [1] |
| P4 | Repeat experiment by appropriate method (change filter or LED lamp of different colours/frequency/wavelength) to vary λ to obtain 6 sets of readings | [1] |
| | | |
| **Control** | | |
| C1 | Keep both light sources to be the same intensity by fixing the power input, OR<br>Keep intensity of light sources constant throughout by fixing the power input. | [1] |
| | | |
| **Analysis** | | |
| G1 | Plot a graph of $\theta_1$ against $\lambda$ | [1] |
| G2 | $b$ = 1 / gradient | [1] |
| | | |
| **Additional detail and safety (3A + 1S)** | | |
| A1 | Take preliminary readings of $\lambda$, distances r and separation s to obtain measurable values of $\theta_1$. | [4] |
| A2 | Use vertical lamps or slits to reduce the uncertainty in separation. | |
| A3 | Young's double slit method: pass light from source through a single slit, followed by a double slit, and allow fringes to form on a screen.<br>Diffraction grating method: pass light from source through a diffraction grating, allow the bright spots to form on a screen. | |
| A4 | View with same eye to ensure consistency in resolving power of observer. | |
| A5 | Ensure the pair of light sources is in a plane perpendicular with the line of sight of observer by aligning the light sources using a set square. OR<br>Keep the observer equidistant to both light sources by measuring with rule and adjusting after every set of reading. | |
| A6 | Repeat experiment for each $\lambda$ and average readings to reduce the random error. | |
| A7 | Conduct experiment in a dark room to prevent other light sources from interfering and affecting the experiment. | |
| A8 | Use vernier caliper to measure s, as it is very small (for small angle $\theta_1$). s must be described or shown in diagram. | |
| | Do not allow vague computer methods. | |
| S1 | Lamp becomes hot, therefore do not touch/switch off when not in use or use gloves when moving hot lamp. | |
| S2 | Light may damage eyes, therefore wear dark glasses or do not look at unprotected lamps. (accept if light source is laser.) | |


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NAME _____ CLASS 2T

# Catholic Junior College
## JC2 Preliminary Examinations
## Higher 2

# PHYSICS 9749/01

Paper 1: Multiple Choice

**4 September 2019**
**1 hour**

Additional Materials: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Write your name and tutorial group on this cover page.
Write and/or shade your name, NRIC / FIN number and HT group on the Answer Sheet (OMR sheet), unless this has been done for you.
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all 30 questions** in this paper.
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 (OMR sheet).

**Read the instructions on the Answer Sheet carefully.**

Each correct answer will be awarded 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 permitted, where appropriate.

This document consists of **15** printed pages and **one** blank page.

**[Turn over**

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**PHYSICS 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$^{-1}$ |
| | | | $\approx (1/(36\pi)) \times 10^{-9}$ 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 | $k$ | = | $1.38 \times 10^{-23}$ mol$^{-1}$ |
| gravitational constant | $G$ | = | $6.67 \times 10^{-11}$ N m$^2$ kg$^{-2}$ |
| acceleration of free fall | $g$ | = | 9.81 m s$^{-2}$ |

**PHYSICS FORMULAE:**

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

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**1** The table below shows the estimates of some physical quantities.

Which row is **not** a reasonable estimate?

| | quantity | value |
|---|---|---|
| **A** | current used in an electric kettle | 8 A |
| **B** | mass of an adult male | 70 kg |
| **C** | speed of an Olympic sprint runner | 10 m $s^{-1}$ |
| **D** | water pressure at the bottom of a public swimming pool | $10^4$ Pa |

**2** A potential difference (p.d.) is carefully measured with a high-quality instrument and found to be 2.321 V.

Two students, using two different methods to measure the p.d., quote the p.d. as 2.33 V and 2.344 V respectively.

Which statement is correct?

**A** The reading 2.33 V is more accurate and more precise than the reading 2.344 V.
**B** The reading 2.33 V is more accurate but less precise than the reading 2.344 V.
**C** The reading 2.33 V is less accurate but more precise than the reading 2.344 V.
**D** The reading 2.33 V is less accurate and less precise than the reading 2.344 V.

**3** A man is parachuting towards the Earth. According to Newton's third law of motion, the force which makes an action-reaction pair with the gravitational force on the man is

**A** the gravitational force on the Earth due to the man.
**B** the viscous force of the man and his parachute on the air.
**C** the viscous force of the air on the man and his parachute.
**D** the tension in the harness of the parachute.

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**4** A non-uniform rod XY is balanced horizontally on top of a triangular wedge. The top of the wedge O is at a distance 1.10 m from the end X of the rod.

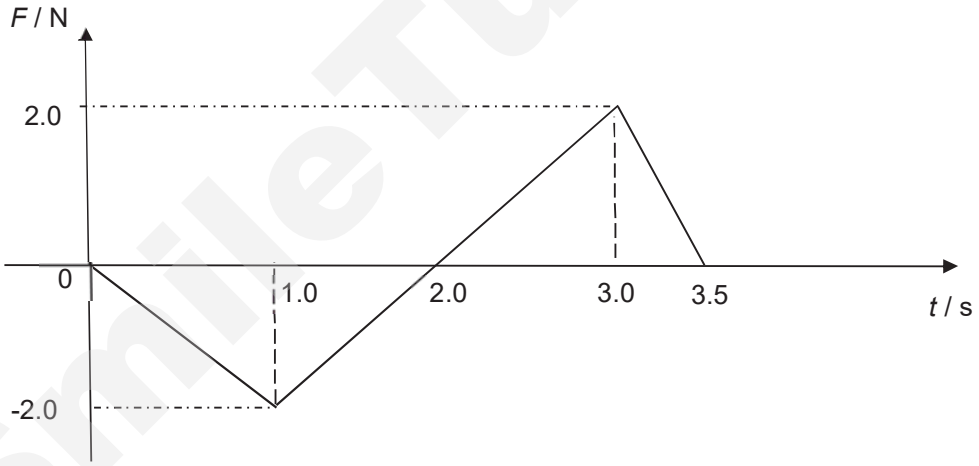



A 1500 g mass is hung at a distance of 0.20 m from X. The rod now needs to be moved 0.25 m to the right to balance horizontally.

What is the mass of the rod?

**A** 1.2 kg **B** 3.9 kg **C** 6.6 kg **D** 7.8 kg

**5** A resultant force *F* acts on a mass of 150 g. The variation with time *t* of *F* is shown on the diagram below.




At time $t$ = 0 s, the mass is moving with a velocity of 2.0 m $s^{-1}$.

What is the speed of the mass at $t$ = 3.0 s?

**A** 2.7 m $s^{-1}$
**B** 4.7 m $s^{-1}$
**C** 6.7 m $s^{-1}$
**D** 8.7 m $s^{-1}$

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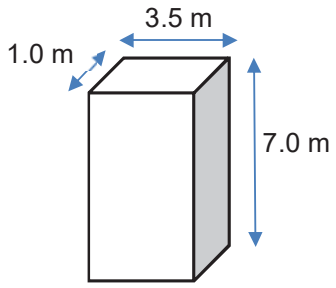
**6** The diagram below shows a wooden block in its upright position, with length 1.0 m, width 3.5 m and height 7.0 m. The density of wood is 850 kg $m^{-3}$.




What is the submerged depth of the wooden block when it floats upright in water?

Density of water is 1000 kg $m^{-3}$.

**A** 0.85 m **B** 5.6 m **C** 6.0 m **D** 7.0 m

**7** A block starts to slide down a 30° slope from rest as shown in the figure below.




Assume that the friction on the block is negligible. What is the final speed of the block after it has travelled 10 m down the slope?

**A** 4.9 m $s^{-1}$ **B** 8.5 m $s^{-1}$ **C** 9.9 m $s^{-1}$ **D** 13 m $s^{-1}$

**8** A body of mass 90 kg travels along a horizontal road at a speed of 5.0 m $s^{-1}$. It then accelerates at 1.5 m $s^{-2}$. At the time it begins to accelerate, the total resistive force acting on the car is 200 N.

What total output power is developed by the car as it begins the acceleration?

**A** 680 W
**B** 1700 W
**C** 4400 W
**D** 5400 W

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**9** A car is making a circular turn of radius $r$ with speed $v$. The centripetal force on the car is $F$.

What is the centripetal force on the car when it makes the same turn at speed $2v$?

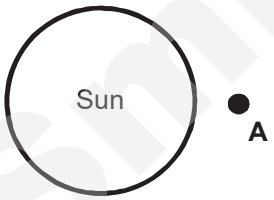
**A** $\frac{F}{2}$
**B** $F$
**C** $2F$
**D** $4F$

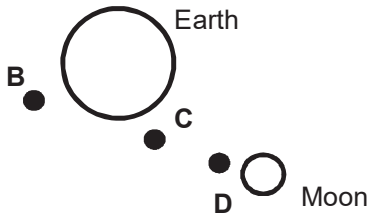
**10** A small sphere is moving in a vertical circle at constant speed.

The magnitude of the resultant force on the sphere
**A** at the bottom of the circle is greater than the resultant force at the top.
**B** at the top of the circle is greater than the resultant force at the bottom.
**C** decreases as the sphere moves from the bottom to the top of the circle.
**D** is the same at the top of the loop as it is at the bottom of the circle.

**11** The neutral point in the gravitational field between the Sun, the Earth and the Moon is the point at which the resultant gravitational field due to the three bodies is zero. The mass of the Earth is about 80 times the mass of the Moon.

At what position is it possible for the neutral point to be? (The diagram is not drawn to scale)




**12** Which statement about two satellites of different masses in the geostationary orbit around the Earth is ***incorrect***?

**A** The gravitational forces acting on the two satellites are different.
**B** The centripetal acceleration of each satellite is different.
**C** The total energy of each satellite is different.
**D** The angular velocities of the two satellites are the same.

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**13** Two monoatomic gases, X and Y, are in thermal equilibrium in a mixture. The molecular mass of gas Y is half the molecular mass of gas X.

The root mean square speed of the molecules of gas Y is $v$. What is the root mean square speed of the molecules of gas X?

**A** $\frac{v}{2}$

**B** $\frac{v}{\sqrt{2}}$

**C** $v$

**D** $2v$

**14** The piston is pushed very slowly into a metal cylinder containing an ideal gas.

If the temperature of the gas does not change in the process. Which of the following statements is ***incorrect***?

**A** The work done on the gas is equal to the heat lost by the gas.
**B** The pressure of the gas increases.
**C** The average kinetic energy of the gas molecules increases due to the work done on the gas.
**D** The internal energy of the gas remains constant.

**15** A small mass undergoes simple harmonic motion about a point O with amplitude $x_o$ and period $T$. Its displacement $x$ from O at time $\frac{1}{6}T$ after passing through O is

**A** $\frac{x_o}{6}$

**B** $\frac{x_o}{2\sqrt{3}}$

**C** $\frac{x_o}{2}$

**D** $\frac{\sqrt{3}x_o}{2}$

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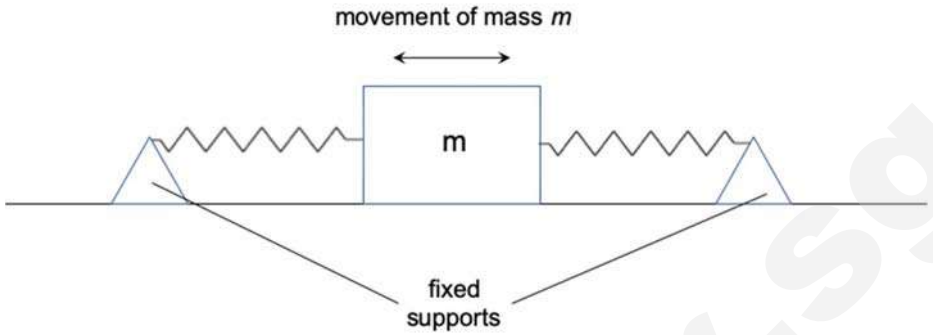
**16** A mass *m* on a smooth horizontal table is attached by two light springs to two fixed supports as shown below. The mass executes simple harmonic motion of amplitude *a* and period *T*.




The total energy of oscillation is

**A** $2\pi ma^2/T^2$
**B** $2\pi m^2a^2/T$
**C** $\pi^2 ma^2/T^2$
**D** $2\pi^2 ma^2/T^2$

**17** A sound wave of frequency 400 Hz is travelling in air at a speed of 320 m $s^{-1}$.

What is the difference in phase between two points on the wave 0.2 m apart in the direction of travel?

**A** $\frac{\pi}{4}$ rad **B** $\frac{\pi}{2}$ rad **C** $\frac{2\pi}{5}$ rad **D** $\frac{4\pi}{5}$ rad

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**18** Fig. 1 shows how the displacement of a wave varies with distance along the wave at one particular time.

Fig. 2 shows how the displacement of one particular point P of the same wave varies with time.

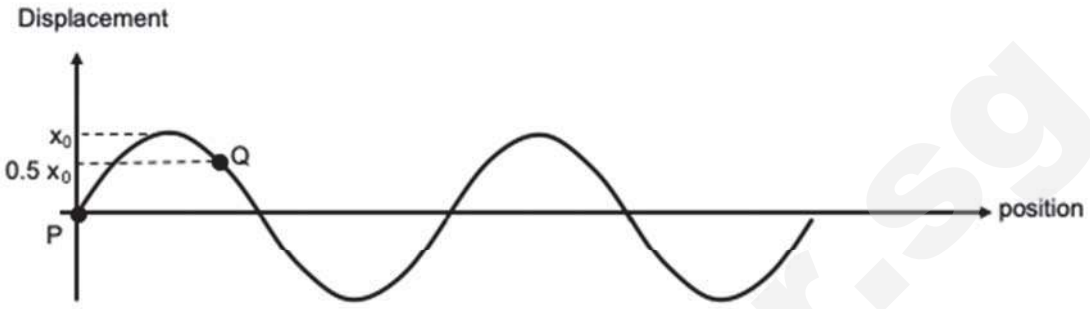



Fig. 1

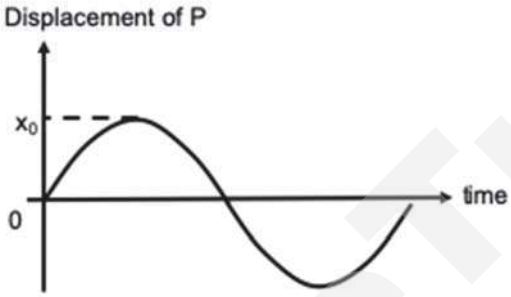
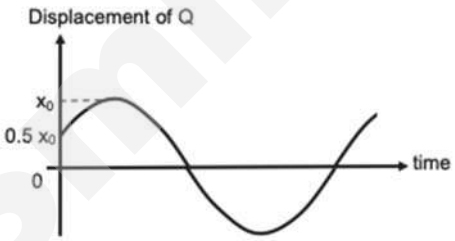


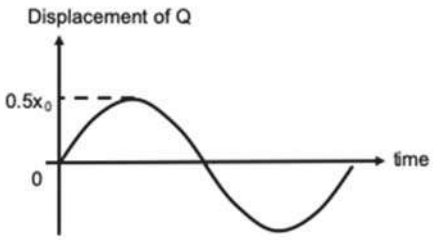

Fig. 2

Which of the following graphs correctly depicts the displacement-time graph for point Q?

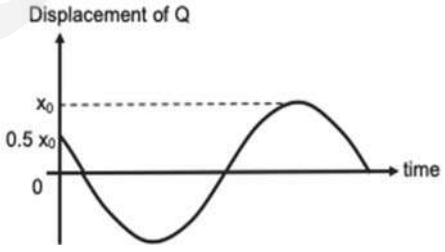
**A**



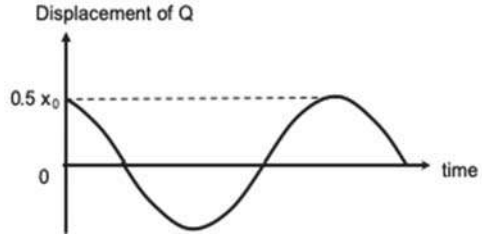

**B**




**C**




**D**

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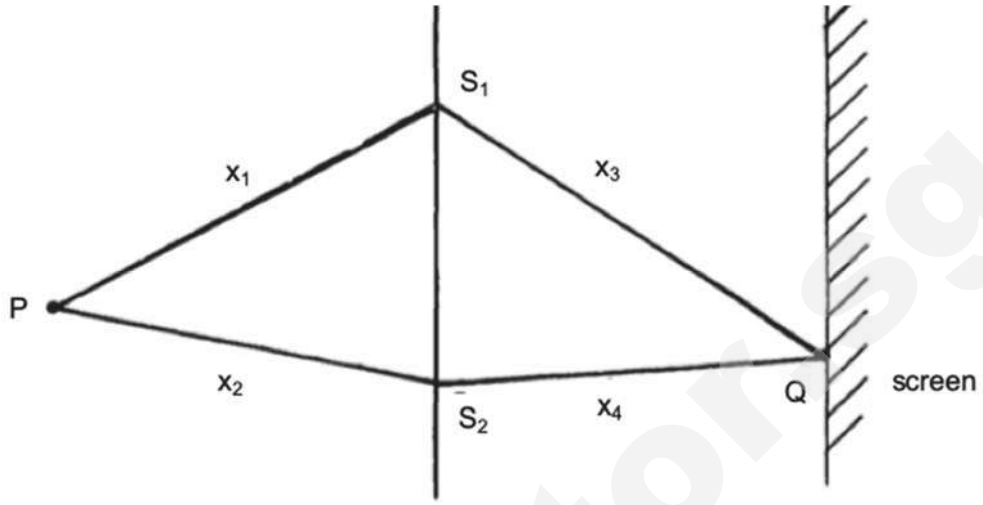
**19** Two identical narrow slits $S_1$ and $S_2$ are illuminated with light of wavelength $\lambda$ from a point source P.




If, as shown in the diagram above, the light is then allowed to fall on a screen, and if $m$ is a positive integer, the condition for constructive interference at Q is

**A** $x_1 - x_2 = (2m+1)\frac{\lambda}{2}$

**B** $x_3 - x_4 = (2m+1)\frac{\lambda}{2}$

**C** $x_3 - x_4 = m\lambda$

**D** $(x_1 + x_3) - (x_2 + x_4) = m\lambda$

**20** A beam of light that consists of all wavelengths between 480 nm and 600 nm is projected onto a diffraction grating that contains 500 lines per millimeter.

What is the maximum number of complete continuous spectra that can be observed emerging from the grating?

**A** 6 **B** 7 **C** 8 **D** 9

**21** The charge of a uranium nucleus is $1.5 \times 10^{-17}$ C.

What is the potential at the mid-point between a uranium nucleus and an alpha particle if they are separated by a distance of $1.0 \times 10^{-13}$ m?

**A** $2.2 \times 10^{-13}$ V

**B** $4.3 \times 10^{-13}$ V

**C** $2.8 \times 10^{6}$ V

**D** $5.5 \times 10^{6}$ V

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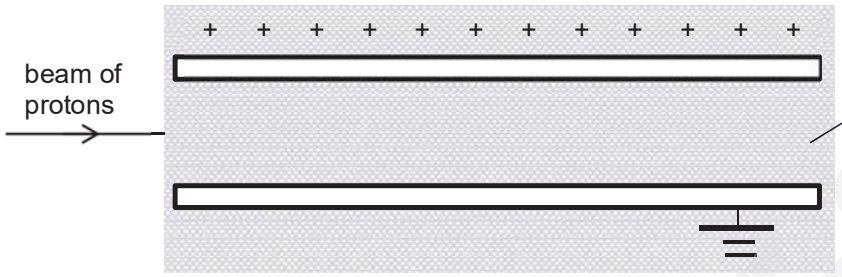
**22** A velocity selector for protons has an electric field of strength 3.0 x $10^5$ V $m^{-1}$, produced by two horizontal plates. The upper plate is connected to a positive potential and the lower plate is earthed. A magnetic field of flux density 1.5 x $10^{-2}$ T, directed into the plane of the paper, is at right-angle to the electric field as shown in the diagram.




Which of the following could be the possible speed of a proton and its observation?

| | speed | observation |
|---|---|---|
| **A** | 1.8 x $10^7$ m $s^{-1}$ | undeflected |
| **B** | 2.0 x $10^7$ m $s^{-1}$ | deflected downwards |
| **C** | 2.2 x $10^7$ m $s^{-1}$ | deflected downwards |
| **D** | 2.4 x $10^7$ m $s^{-1}$ | deflected upwards |

**23** When four identical resistors are connected as shown in diagram 1, the ammeter reads 1.0 A and the voltmeter reads zero.

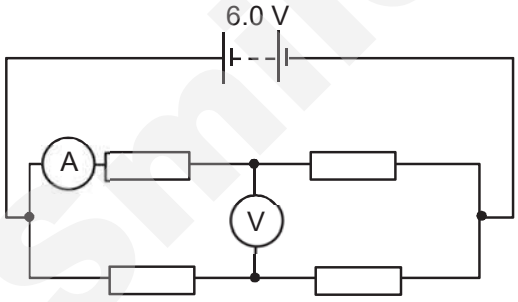



diagram 1

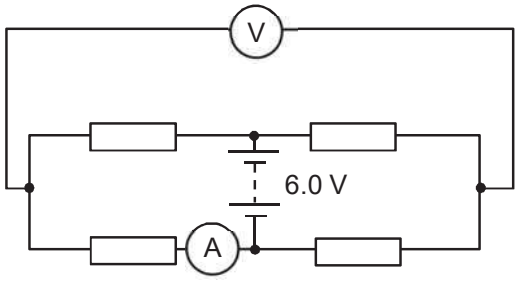



diagram 2

The resistors and meters are reconnected to the supply as shown in diagram 2.

What are the meter readings in diagram 2?

| | voltmeter reading / V | ammeter reading / A |
|---|---|---|
| **A** | 0 | 1.0 |
| **B** | 0 | 0.5 |
| **C** | 3.0 | 1.0 |
| **D** | 6.0 | 0.5 |

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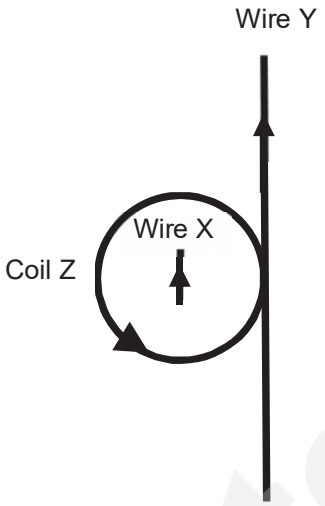
**24** The diagram below shows a setup of two current-carrying wires X and Y, and a single-turn coil Z.




Wire X has length 0.050 m with a current of 1.0 A flowing through it. Wire Y has length 2.0 m with a current of 0.50 A. Coil Z has a diameter of 0.20 m with a current of 1.5 A.

What is the resultant force on wire X if the centre of coil Z is on wire X?

**A** $5.0 \times 10^{-8}$ N
**B** $4.2 \times 10^{-7}$ N
**C** $5.2 \times 10^{-7}$ N
**D** $9.4 \times 10^{-6}$ N

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**25** Diagram A shows an aluminium rod moving away from point O, at right angle to a uniform magnetic field.

Diagram B shows the variation with time *t* of its displacement *s* from O.

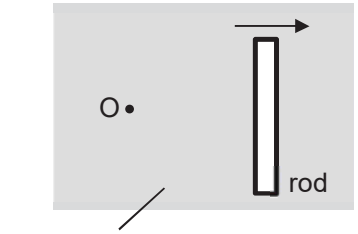



Diagram A

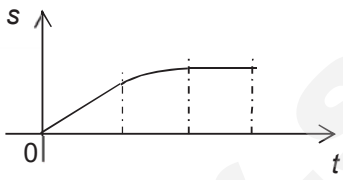
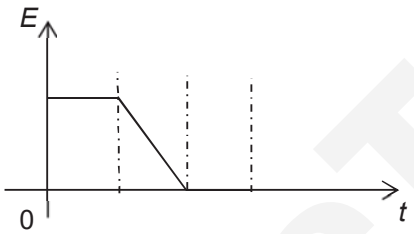


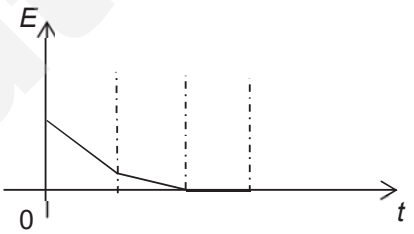

Diagram B

Which graph best shows the variation with *t* of the e.m.f. *E* induced in the rod?

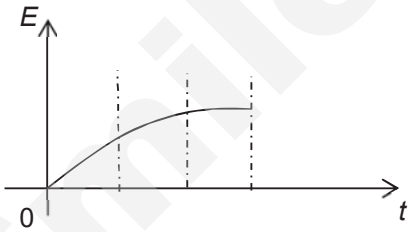
**A**



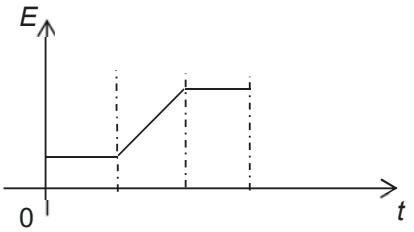

**B**




**C**




**D**

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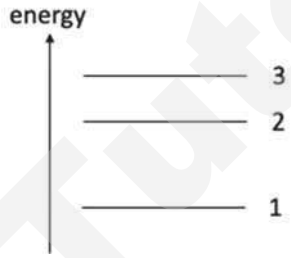
**26** A sinusoidal current is represented by the equation

$$I = I_o \sin(\omega t)$$

Which equation represents the sinusoidal current with both its period and amplitude doubled?

**A** $2I = I_o \sin(2\omega t)$
**B** $I = 2I_o \sin(2\omega t)$
**C** $I = \frac{1}{2} I_o \sin(2\omega t)$
**D** $I = 2I_o \sin(\frac{1}{2}\omega t)$

**27** Part of the energy level diagram of a certain atom is shown below. The energy spacing between levels 1 and 2 is three times that between 2 and 3. If an electron makes a transition from level 3 to level 2, the radiation of wavelength $\lambda$ is emitted.




What possible radiation wavelengths might be produced by other transitions between the three energy levels?

**A** only $\frac{\lambda}{3}$
**B** both $\frac{\lambda}{3}$ and $\frac{\lambda}{4}$
**C** only $3\lambda$
**D** only $4\lambda$

**28** Which one of the following statements, referring to a photoelectric emission, is true?

**A** No emission of electrons occurs for very low intensity illumination, even if the illumination's frequency is above the threshold frequency.
**B** For a given metal there is a minimum frequency of radiation below which no emission occurs.
**C** The velocity of the emitted electrons is proportional to the intensity of the incident radiation.
**D** The number of electrons emitted per second is dependent on the threshold frequency of the given metal if the frequency of the incident photon is higher than the threshold frequency.

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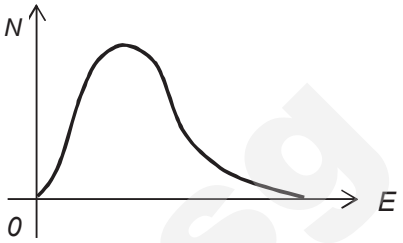
**29** Which one of the following best represents the number *N* of alpha-particles emitted from a given radioactive source possessing energy *E* ?

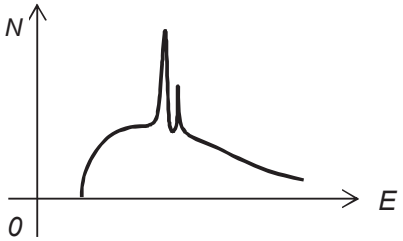
**A**



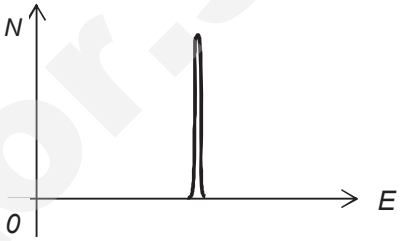

**B**




**C**




**D**




**30** Which nuclide has the greatest initial activity?

| | nuclide | amount/mole | half-life/day |
|---|---|---|---|
| **A** | $^{228}_{88}Ra$ | 0.7 | 2100 |
| **B** | $^{225}_{89}Ac$ | 0.002 | 10 |
| **C** | $^{228}_{90}Th$ | 0.09 | 400 |
| **D** | $^{241}_{94}Pu$ | 0.09 | 4800 |

**-- END OF PAPER 1 –**

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# Catholic Junior College

## JC2 Preliminary Examinations

## Higher 2

| | |
|---|---|
| **CANDIDATE NAME** | |
| **CLASS** | **2T** |

# PHYSICS

**9749/02**

Paper 2: Structured Questions

**26 August 2019**

**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 in the space provided. **[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 Paper 2.

| FOR EXAMINER'S USE | | DIFFICULTY | | |
|---|---|---|---|---|
| | | L1 | L2 | L3 |
| Q1 | / 10 | | | |
| Q2 | / 11 | | | |
| Q3 | / 11 | | | |
| Q4 | / 12 | | | |
| Q5 | / 8 | | | |
| Q6 | / 8 | | | |
| Q7 | / 20 | | | |
| PAPER 2 | / 80 | | | |

This document consists of **22** printed pages and **zero** blank page.

**[Turn over**

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**PHYSICS 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$^{-1}$ |
| | | | $\approx (1/(36\pi)) \times 10^{-9}$ 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 | $k$ | = | $1.38 \times 10^{-23}$ mol$^{-1}$ |
| gravitational constant | $G$ | = | $6.67 \times 10^{-11}$ 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 | $\phi$ | = | $-\frac{Gm}{r}$ |
| temperature | $T/K$ | = | $T/^{\circ}C + 273.15$ |
| pressure of an ideal gas | $p$ | = | $\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E$ | = | $\frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x$ | = | $x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v$ | = | $v_0 \cos \omega t$ |
| | | = | $\pm \omega \sqrt{{x_0}^2 - x^2}$ |
| electric current | $I$ | = | $Anvq$ |
| resistors in series | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R$ | = | $1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V$ | = | $\frac{Q}{4\pi\varepsilon_o r}$ |
| alternating current / voltage | $x$ | = | $x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B$ | = | $\frac{\mu_o I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B$ | = | $\frac{\mu_o N I}{2r}$ |
| magnetic flux density due to a long solenoid | $B$ | = | $\mu_o n I$ |
| radioactive decay | $x$ | = | $x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda$ | = | $\frac{\ln 2}{t_{\frac{1}{2}}}$ |

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

**1** **(a)** A truck is accelerated from rest by a constant driving force. It experiences a drag force which is proportional to its speed. Eventually, the truck travels at a constant velocity.

Explain why the truck reaches a constant velocity.

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..... [2]

**(b)** On Fig. 1.1 sketch a graph to show how the acceleration of the truck varies with time from the time when it was at rest to the time when it reaches the constant velocity.

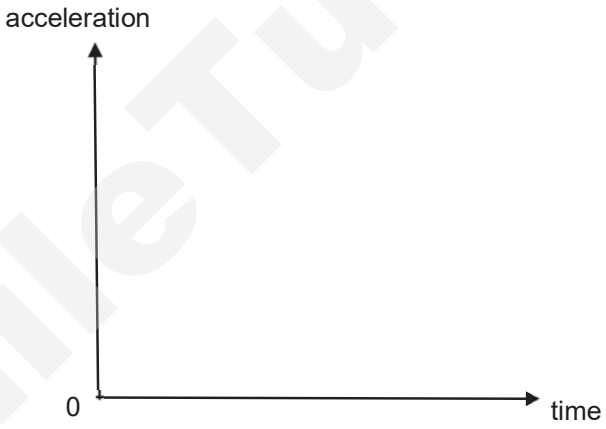


**Fig. 1.1**

[1]

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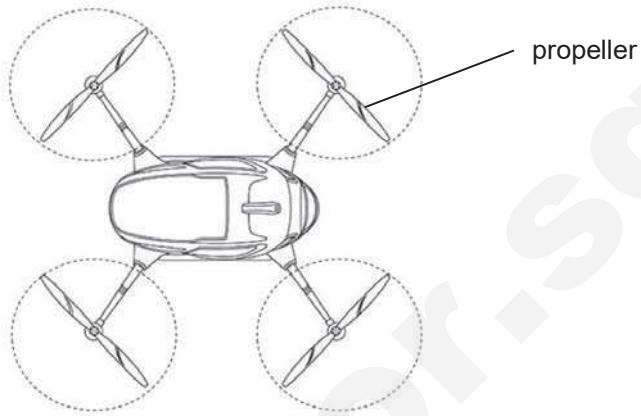
**(c)** Fig. 1.2 shows a drone that is able to hover by rotating the four horizontal propellers attached to its body. The propellers push the air downwards and impart the air with a certain speed. The mass of the drone is 0.50 kg and each of the propellers has a radius of 15.0 cm.




Top view of a drone

**Fig. 1.2**

**(i)** Calculate the upward force by the air on the drone.

upward force = ..... N [1]

**(ii)** State, with a reason, the magnitude of the downward force exerted by all of the drone's propellers on the air.

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..... [2]

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**(iii)** The density of air is 1.3 kg $m^{-3}$.

Determine using Newton's second law of motion the speed imparted to the air by the propellers.

speed = ..... m $s^{-1}$ [4]

**2** **(a)** State the *first law of thermodynamics*.

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..... [2]

**(b)** A fixed mass of monatomic ideal gas undergoes a cycle of changes A → B → C → A as shown in Fig. 2.1.

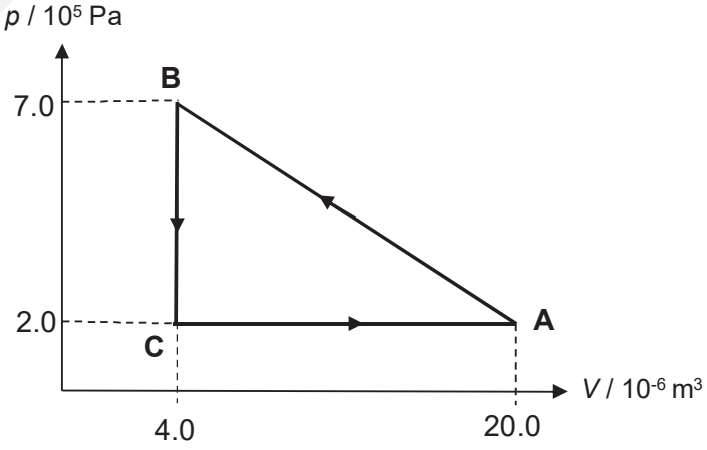


**Fig. 2.1**

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**(i)** Explain why the change in internal energy of the ideal gas during a complete cycle A → B → C → A is zero.

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..... [2]

**(ii)** Calculate the work done on the gas during the process from A to B.

work done on gas = ..... J [2]

**(iii)** Calculate the change in internal energy of the gas when it undergoes the process from A to B.

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

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**(iv)** Calculate the heat supplied to the ideal gas during the process from A to B.

heat supplied = ..... J [2]

**(v)** In a car engine, the expanding combustion gases push the piston which causes the car to move.

Suggest, with a reason, whether the cycle of changes A → B → C → A could be the cycle in the piston engine of a car.

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..... [1]

**3** **(a)** Two light identical springs are joined in series and a 120 g bar magnet is hung from the lower end as shown in Fig. 3.1. The effective spring constant of the combined springs is 11 N $m^{-1}$.

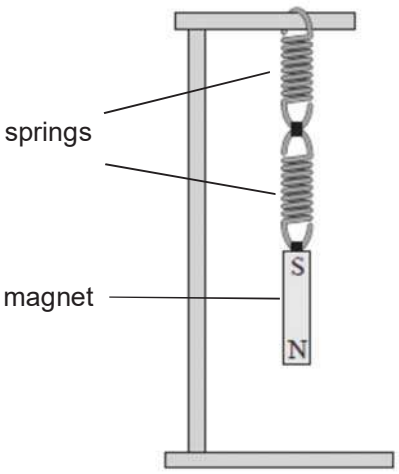


**Fig. 3.1**

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The bar magnet is displaced a small distance vertically downward from its equilibrium position and released. It then oscillates in simple harmonic motion.

**(i)** By considering the forces on the magnet at its equilibrium position, and also at a small displacement $x$ downward from its equilibrium position, show that the oscillation is a simple harmonic motion where the acceleration $a$ is given by the equation

$$a = -92x$$

[4]

**(ii)** Hence calculate the frequency at which the magnet oscillates.

frequency = _____ Hz [2]

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**(b)** Two systems in part **(a)** are now suspended with the North pole of their magnets located inside a coil of wire. The two coils are connected together with conducting leads as shown in Fig. 3.2.

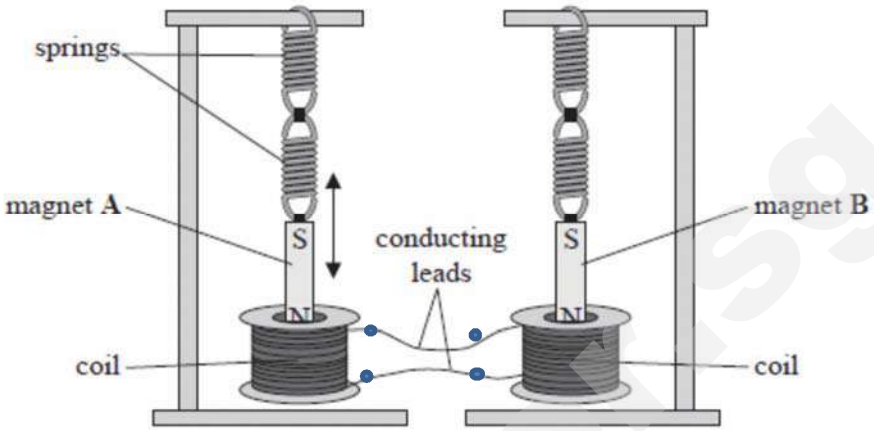


**Fig. 3.2**

Magnet A is displaced so that it oscillates vertically. The North pole of magnet A moves into and out of the coil of wire with simple harmonic motion. As this motion continues, magnet B starts to oscillate. The amplitude of oscillation of magnet B increases over time.

Explain why magnet B starts to oscillate with an increasing amplitude.

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..... [5]

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**4** **(a)** Define *electromotive force* of a cell, and explain its difference from the *terminal potential difference* across the terminals of the cell.

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..... [2]

**(b)** The variation with current $I$ of terminal potential difference $V$ across a battery with e.m.f. $E$ and internal resistance $r$ is shown in Fig. 4.1.

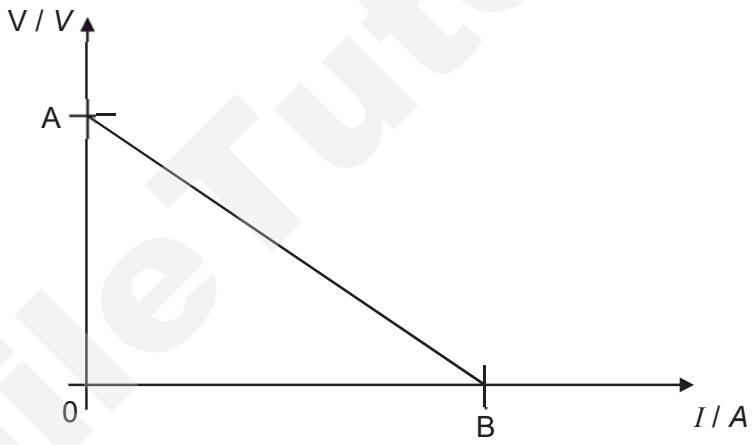


**Fig. 4.1**

In Fig. 4.1, state and explain the significance of the values of

**(i)** the vertical intercept, A;

.....

.....

..... [2]

**(ii)** the horizontal intercept, B.

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..... [2]

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**(c)** In an attempt to obtain the graph of Fig. 4.1 for the battery, a student sets up a circuit as shown in Fig. 4.2.

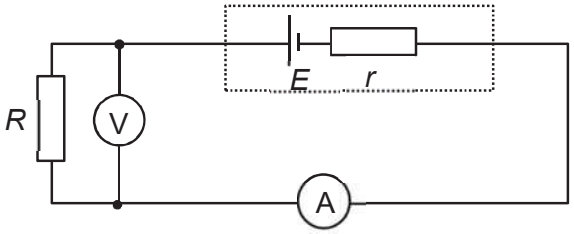


**Fig. 4.2**

State and explain why the circuit shown in Fig. 4.2 is inappropriate for obtaining data for the full range of values in Fig. 4.1.

[4]

**(d)** In the space below draw a circuit diagram, using the appropriate components, from which the full range of values in Fig. 4.1 may be obtained.

[2]

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**5** Fig. 5.1 shows a point source S emitting continuous waves at a distance *h* from a plane reflector R. As a result, regions of high intensity such as C, C' and C" are produced.

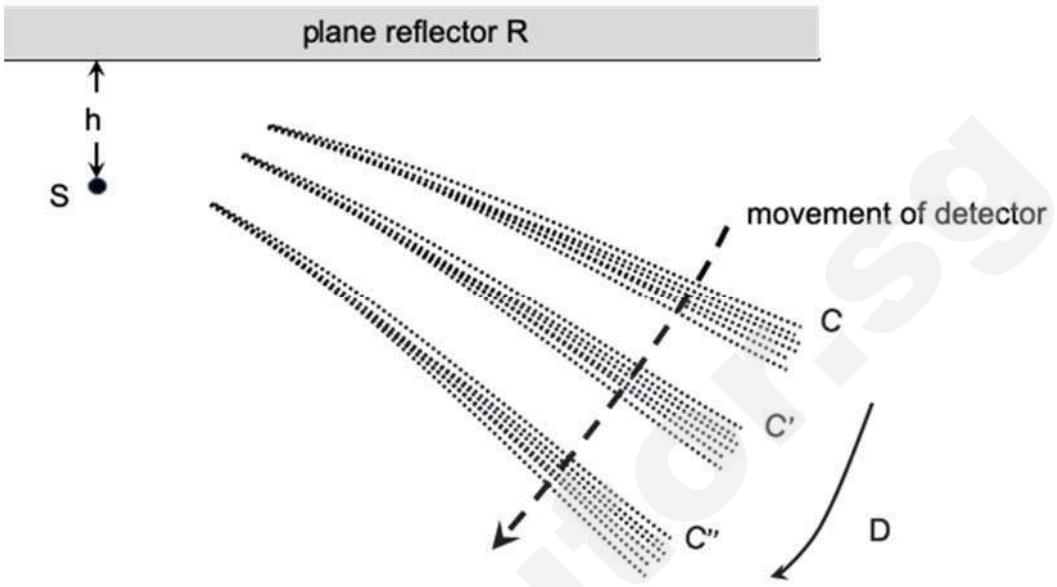


**Fig. 5.1**

**(a)** Explain why regions of high intensity such as C, C' and C'' are produced.

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..... [3]

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**(b)** A detector is moved in the direction indicated by the dotted arrow in Fig. 5.1. Explain how the detected intensity of the waves would vary.

[3]

**(c)** When the frequency of S is decreased slowly, the regions C, C' and C" move in the direction D as shown in Fig. 5.1. Explain this phenomenon.

[2]

**6** **(a)** A simple a.c. generator which consists of a rectangular coil with 40 turns is rotating at 50 revolutions per second in a uniform magnetic field of flux density 50 mT. The coil is 50 cm long and 35 cm wide, as shown in Fig. 6.1.

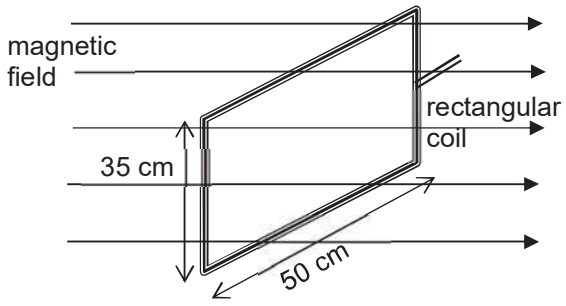


**Fig. 6.1**

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**(i)** Define *magnetic flux*.

.....

.....

..... [1]

**(ii)** Calculate the maximum e.m.f. induced in the coil.

maximum e.m.f. = ..... V [2]

**(b)** The output from the generator in part **(a)** is connected to the input of a transformer. The transformer has 40 turns on its primary coil and 10 turns on its secondary coil. The transformer may be considered to be ideal. The output from the transformer is connected to a resistor of resistance 100 Ω and a diode, as shown in Fig. 6.2.

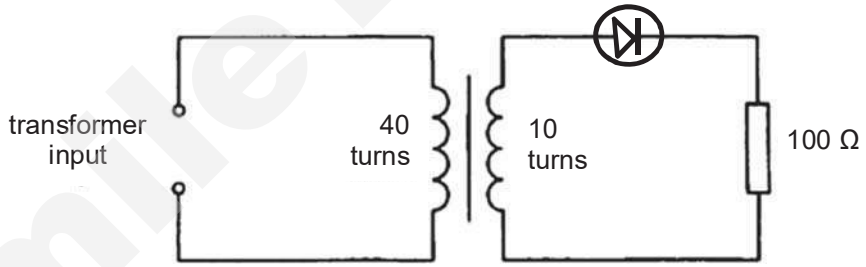


**Fig. 6.2**

Calculate the root-mean-square voltage across the resistor.

root-mean-square voltage = ..... V [3]

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**(c)** In an attempt to draw the circuit diagram that represents the system in part **(b)**, a student drew Fig. 6.3 instead.

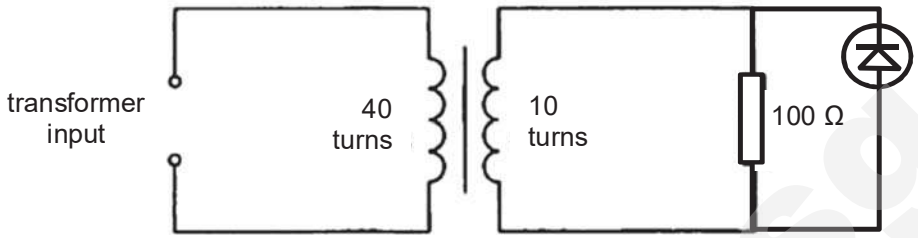


**Fig. 6.3**

Suggest, with a reason, what will happen if the circuit is set up according to Fig. 6.3.

.....

.....

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.....

.....

..... [2]

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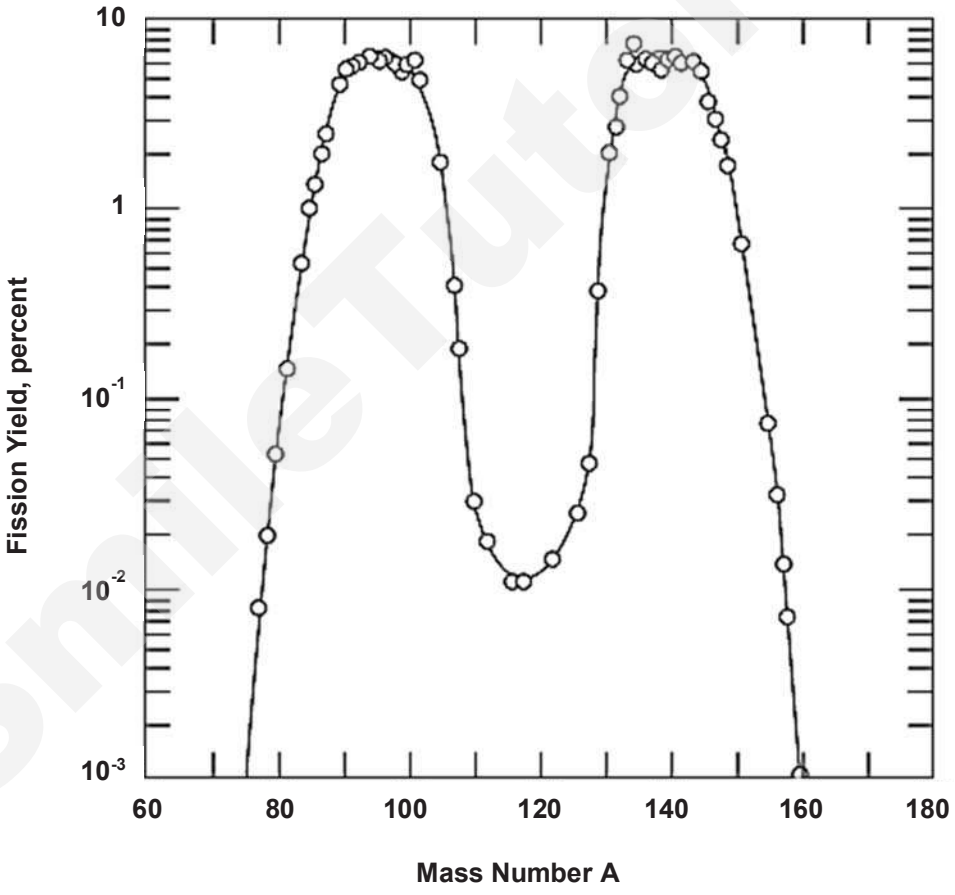
**7** When a very strong earthquake of magnitude 9.0 hit Japan on 11 March 2011, the accompanying tsunami caused the devastation of the Fukushima Dai-ichi Nuclear Power Plant (Fk-1). A large amount of radioactive material leaked out of Fk-1 as a result, mainly through cracks made by the quake on some reactors, explosions, intentional vents to relieve pressure, and leakage of cooling water that was contaminated with the melted fuel rod debris.

Fk-1 was capable of generating up to 4.7 gigawatts of power through neutron-induced fissions of Uranium-235 ($^{235}$U) nuclei. Fission resulting from neutron absorption is called *induced* fission. Some nuclides can also undergo *spontaneous* fission, but that is quite rare. Nuclear fission is a decay process in which an unstable nucleus splits into two fragments of comparable mass, although nearly equal mass is unlikely. Over 100 different nuclides, representing more than 20 different elements, have been found among the fission products. Fig. 7.1 shows the distribution of mass numbers for fission fragments from the fission of $^{235}$U. Fission yield refers to the percentage of a nuclide of a fission fragment produced per fission. Two or three free neutrons usually appear along with the fission fragments.




Source: https://www.quora.com/Why-is-promethium-produced-from-uranium-235

**Fig. 7.1**

The induced fission of $^{235}$U may be represented by a nuclear equation of the form

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{a}_{b}\mathrm{P} + {}^{c}_{d}\mathrm{Q} + (2 \text{ or } 3)\,{}^{1}_{0}\mathrm{n} + \text{energy}$$

where P represents the lower mass number fission fragment, and Q represents the higher mass number fission fragment.

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One day after the earthquake, elevated levels of Iodine-131, Cesium-134 and Cesium-137, which are common fission fragments of Uranium-235, were detected near the nuclear plant site. Fig. 7.2 shows some general information of the three fission fragments.

| Isotope | Symbol | Half-life |
|---|---|---|
| Iodine-131 | $^{131}_{53}\mathrm{I}$ | 8.0197 days |
| Cesium-134 | $^{134}_{55}\mathrm{Cs}$ | 2.065 years |
| Cesium-137 | $^{137}_{55}\mathrm{Cs}$ | 30.17 years |

**Fig. 7.2**

**(a)** Explain the difference between *induced* and *spontaneous* fission.

.....

.....

..... [1]

**(b)** Suggest why the *percentage fission yield* in Fig. 7.1 is shown on a logarithmic scale.

.....

.....

..... [1]

**(c)** Deduce the two most common ranges of mass numbers of the fission fragments (P and Q) of $^{235}\mathrm{U}$.

most common range of mass numbers of P: ..... [1]

most common range of mass numbers of Q: ..... [1]

**(d)** **(i)** Uranium-235 undergoes nuclear fission to produce Rubidium-97 and Cesium-137. Write down the nuclear equation to represent this reaction. Use the chemical symbol Rb to represent Rubidium.

[2]

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**(ii)** With reference to Fig. 7.1, state the percentage fission yield of
**1.** Cesium-137;
**2.** Rubidium-97.
Indicate clearly on Fig. 7.1, the points that you read off.

percentage yield of Cesium-137= ..... %

percentage yield of Rubidium-97 = ..... % [1]

**(iii)** Comment on the similarity of your answers in **(d)(ii)**.

.....

.....

.....

.....

..... [1]

**(iv)** State the mass number of the other fission fragment produced if one of the fragments has a mass number of 81 in the nuclear fission of Uranium-235.

mass number = ..... [1]

**(e)** Deduce which isotope in Fig. 7.2 will be about 47% as radioactive after 33 years.

isotope is ..... [2]

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**(f)** The release of Iodine-131, Cesium-134 and Cesium-137 into the air, ground and seawater were monitored closely by the Japanese authority because they readily decay by emitting beta-particles and gamma-rays. For example, Cesium-137 decays into Barium-137 (Ba) through beta-emission.

95% of Cesium-137 decays to a metastable excited nuclear energy state (Barium -137m) and is responsible for all emission of gamma-rays, while the other 5% directly decays to the ground state (Barium-137) of the nucleus. Fig. 7.4 illustrates the decay scheme of Cesium-137.

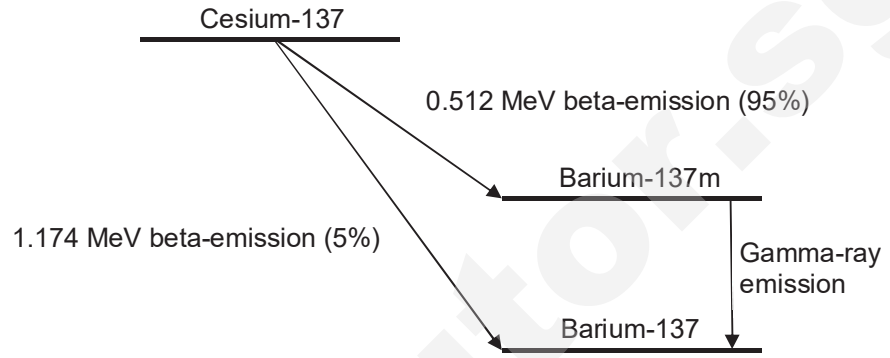


**Fig. 7.4**

Determine the photon energy of the gamma-rays emitted during Cesium-137 decay.

energy = ..... MeV [1]

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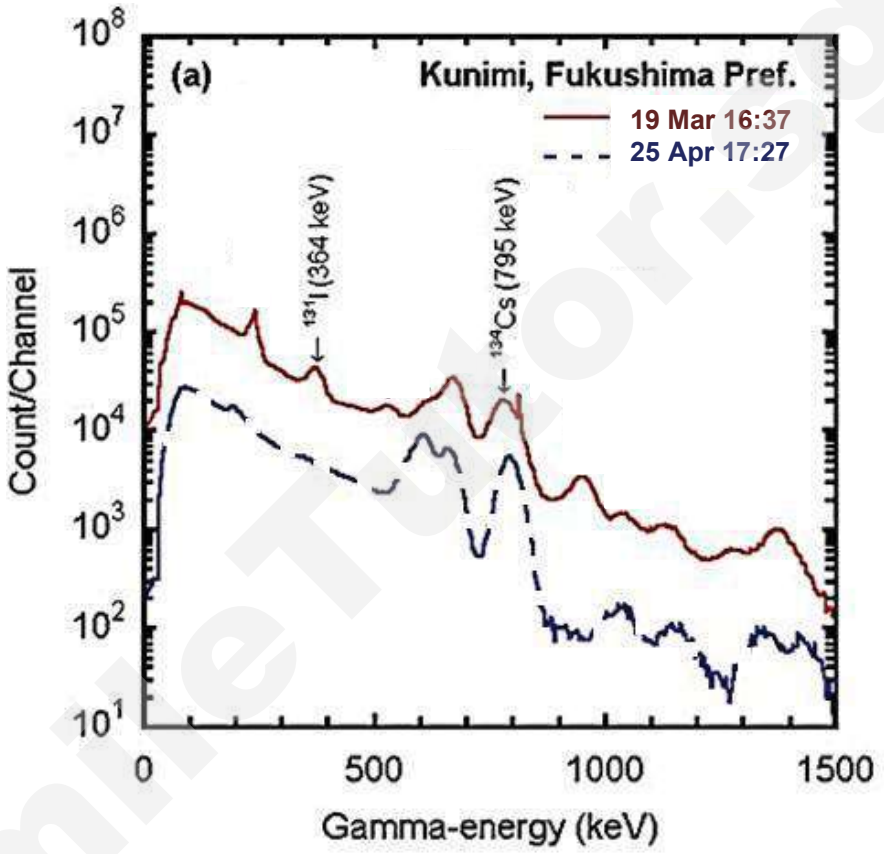
**(g)** Gamma spectroscopy is a technique used by scientists to identify specific radioactive products from the many possible products that can be produced from the nuclear fission of Uranium-235. Fig. 7.5 shows the gamma spectra measured at Kunimi, Fukushima Prefecture on both 19 March 2011 and 25 April 2011. Photon peaks generated by Tellurium-132, Iodine-131, -132, and Cesium-134, -136 and -137 were observed in the spectra given in Fig. 7.5. The photon peaks corresponding to Iodine-131 and Cesium-134 are indicated in Fig. 7.5.




Source: https://www.nature.com/articles/srep00087 (modified)

**Fig. 7.5**

**(i)** Using your answer from **(f)**, indicate on Fig. 7.5 the position of Cesium-137 in the gamma spectra. [1]

**(ii)** Suggest why no photon peak of Iodine-131 was observed on 25 April 2011.

.....

.....

.....

..... [1]

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**(h)** The sievert (Sv) is the SI unit of effective radiation dose. It is a measure of the biological effects of radiation. One sievert carries with it a 4% chance of developing a fatal cancer in an adult, and a 0.8% chance of hereditary defects in his or her future offspring. Doses greater than one sievert received over a short time period are likely to cause radiation poisoning, possibly leading to death within weeks.

Fig. 7.6 shows the dose rate of gamma-rays recorded by a monitoring car at Fukushima Daiichi Nuclear Power Station during the incident.

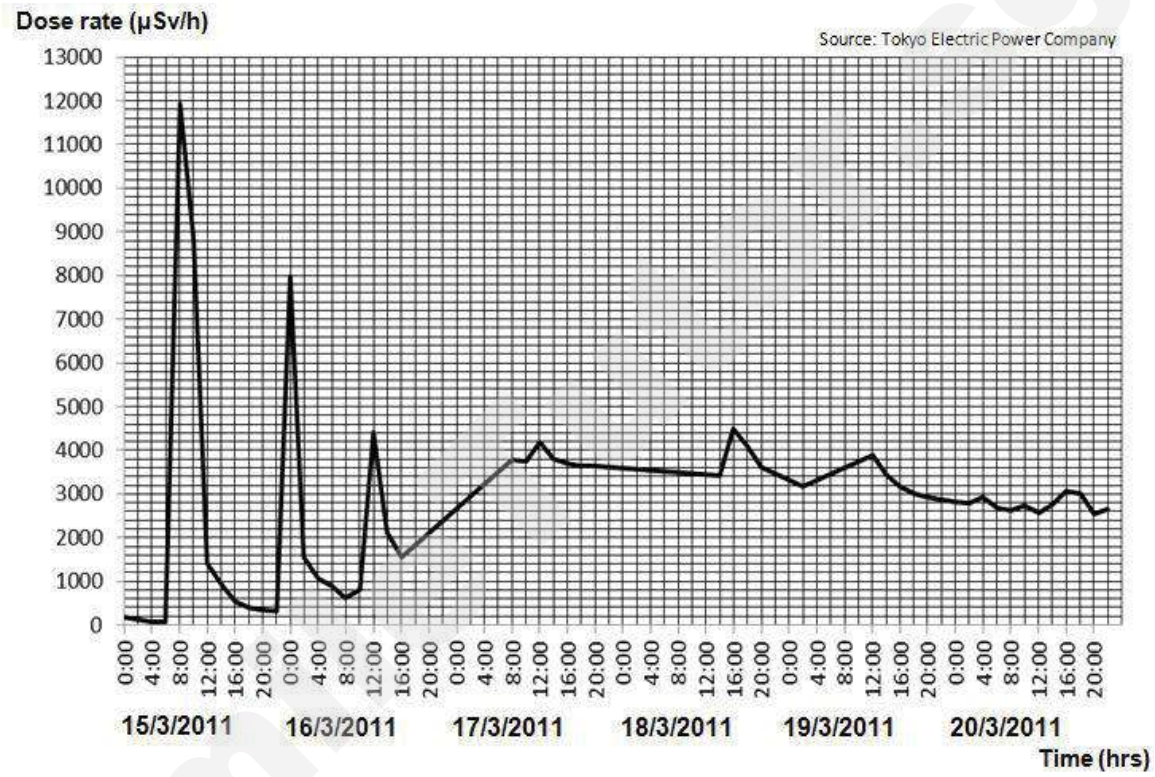


**Fig. 7.6**

On 15 March 2011, the Japanese Health and Labour Ministry increased the maximum permissible dose for Japanese nuclear workers from 100 mSv per year to 250 mSv per year for emergency situations.

If a worker was at the nuclear site from 16:00 hrs on 16/3/2011, estimate the time that he must be evacuated from the site before his life is in danger. Assume that the worker does not leave the site.

time : ..... hrs
date: ..... [2]

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**(i)** Compare the three types of radioactive decay: alpha-decay, beta-decay and gamma-decay. Explain which of the three poses the greatest health risk if the source is:

**1.** outside the body;

.....

.....

.....

.....

..... [2]

**2.** ingested and enters the body.

.....

.....

.....

.....

[2]

.....

**-- END OF PAPER 2 --**

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# Catholic Junior College

## JC2 Preliminary Examinations

## Higher 2

| | |
|---|---|
| **CANDIDATE NAME** | |
| **CLASS** | **2T** |

# PHYSICS 9749/03

Paper 3: Longer Structured Questions

**29 Aug 2019**
**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 in the space provided. **[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.

**Section A:** Answer **all** questions.

**Section B:** Answer **one** question only. **Circle** the question number attempted in Section B.

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

| FOR EXAMINER'S USE | | DIFFICULTY | | |
|---|---|---|---|---|
| | | L1 | L2 | L3 |
| SECTION A | | | | |
| Q1 | / 4 | | | |
| Q2 | / 9 | | | |
| Q3 | / 9 | | | |
| Q4 | / 14 | | | |
| Q5 | / 6 | | | |
| Q6 | / 11 | | | |
| Q7 | / 7 | | | |
| SECTION B | | | | |
| Q8 | / 20 | | | |
| Q9 | / 20 | | | |
| PAPER 3 | / 80 | | | |
| PAPER 2 | / 80 | | | |
| PAPER 1 | / 30 | | | |
| TOTAL FOR THEORY | / 190 | | | |

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

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**PHYSICS 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$^{-1}$ |
| | | | $\approx (1/(36\pi)) \times 10^{-9}$ 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 | $k$ | = | $1.38 \times 10^{-23}$ mol$^{-1}$ |
| gravitational constant | $G$ | = | $6.67 \times 10^{-11}$ 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 | $\phi$ | = | $-\frac{Gm}{r}$ |
| temperature | $T/K$ | = | $T/^{\circ}C + 273.15$ |
| pressure of an ideal gas | $p$ | = | $\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E$ | = | $\frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x$ | = | $x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v$ | = | $v_0 \cos \omega t$ |
| | | = | $\pm \omega \sqrt{{x_0}^2 - x^2}$ |
| electric current | $I$ | = | $Anvq$ |
| resistors in series | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R$ | = | $1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V$ | = | $\frac{Q}{4\pi\varepsilon_o r}$ |
| alternating current / voltage | $x$ | = | $x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B$ | = | $\frac{\mu_o I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B$ | = | $\frac{\mu_o N I}{2r}$ |
| magnetic flux density due to a long solenoid | $B$ | = | $\mu_o n I$ |
| radioactive decay | $x$ | = | $x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda$ | = | $\frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

**1** **(a)** State *Newton's second law of motion*.

.....

.....

.....

..... [2]

**(b)** Use Newton's second law of motion to deduce the principle of conservation of linear momentum.

.....

.....

.....

..... [2]

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**2** A student constructs a potentiometer as shown in Fig. 2.1. The driver battery has negligible internal resistance and an e.m.f. of $E_1$ = 2.0 V. Wire PQ has a total length of 50.0 cm and resistivity $\rho$. Wire PQ also has a total resistance of 10.0 Ω. Unfortunately, there is a defect in wire PQ (shaded in Fig. 2.1) where that part of the wire has a cross-sectional area, $S$, that is half of the rest of the wire. This defective portion has a length that is denoted by $x$.

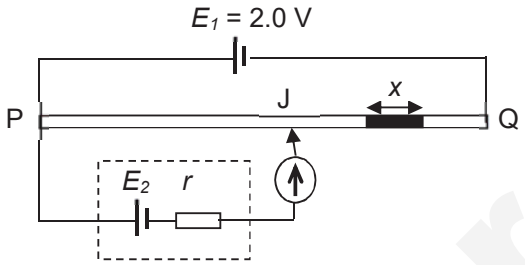


**Fig. 2.1**

The student carried out an experiment and determined that the e.m.f. $E_2$ was 1.01 V. The balance length PJ which did not include the defective portion, was 25.5 cm.

**(a)** When the potentiometer is balanced, determine the current $I_{PQ}$ in the wire PQ.

current, $I_{PQ}$ = _____ A [1]

**(b)** **(i)** Using your answer from **(a)**, obtain an expression for

**1.** $V_{PJ}$, the potential difference between points P and J, in terms of $S$ and $\rho$;

[1]

**2.** $V_{PQ}$, the potential difference between points P and Q, in terms of $\rho$, $S$ and $x$.

[1]

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**(ii)** Hence determine the defective length, *x*.

defective length, *x* = _____ cm [2]

**(c)** In a further experiment, the student swaps the connections to the wire PQ and repeats the measurement, as shown in Fig. 2.2.

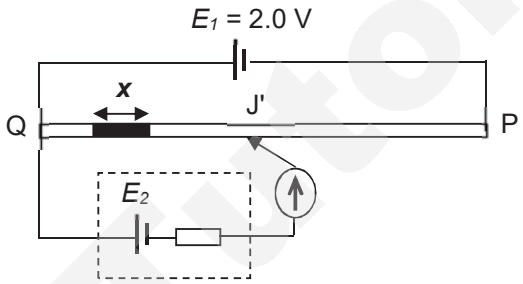


**Fig. 2.2**

State and explain if the new balance length QJ' would be shorter, longer or unchanged from the set-up in Fig. 2.1.

.....

.....

.....

.....

.....

.....

..... [4]

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**3** A binary star system shown in Fig. 3.1 consists of two stars orbiting around their common centre of mass, P. One such binary star system is known as Sirius where the mass of Sirius A is twice the mass of Sirius B. The mass of Sirius B is $1.99 \times 10^{30}$ kg.

Sirius A is at a distance of $\frac{1}{3}D$ from P. Sirius B is at a distance of $\frac{2}{3}D$ from P.

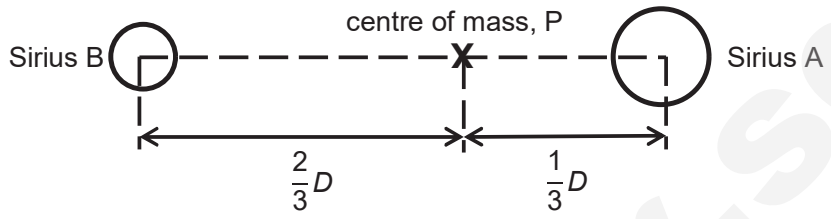


**Fig. 3.1**

**(a)** State *Newton's law of gravitation*.

.....

.....

.....

..... [2]

**(b)** The orbital period of this binary star system is 50 years. Determine the distance *D* between the binary stars, assuming that the stars move in circular orbits.

distance *D* = _____ m [4]

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**(c)** Determine the speed of a probe, originally at rest at infinity, when it reaches the centre of mass of the star system.

speed = _____ $m\ s^{-1}$ [3]

**4** **(a)** Fig. 4.1 shows two identical small positive charged spheres A and B, each having a mass of $5.0 \times 10^{-4}$ kg in equilibrium. Sphere A is fixed in position by an insulated rod while sphere B is free to move and attached to the ceiling by a string with length 0.20 m.

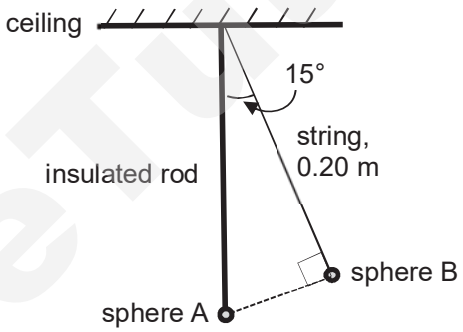


**Fig. 4.1**

The string suspends at an angle of 15° to the vertical insulating rod and it also makes a right angle with the straight line connecting the two spheres.

Calculate

**(i)** the repulsive force acting on sphere B due to sphere A;

repulsive force = _____ N [3]

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**(ii)** the magnitude of the charge on each sphere.

charge = _____ C [2]

**(b)** Sphere B connected with the same string as part **(a)** is now projected into the page at a speed of 0.50 m $s^{-1}$ such that it orbits horizontally around the same vertical insulating rod as shown in Fig. 4.2.

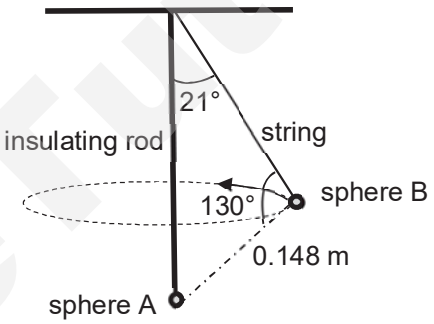


**Fig. 4.2**

The string makes an angle of 21° with the insulating rod. The distance between sphere A and sphere B is now found to be 0.148 m and the angle between the string and this line connecting sphere A and B is now 130°.

**(i)** Show that the resultant horizontal force on sphere B is 1.7 x $10^{-3}$ N.

[2]

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**(ii)** Calculate the tension in the string.

tension = _____ N [3]

**(c)** A uniform magnetic field perpendicular to the motion of sphere B is now introduced to the system in part **(b)** as shown in Fig. 4.3.

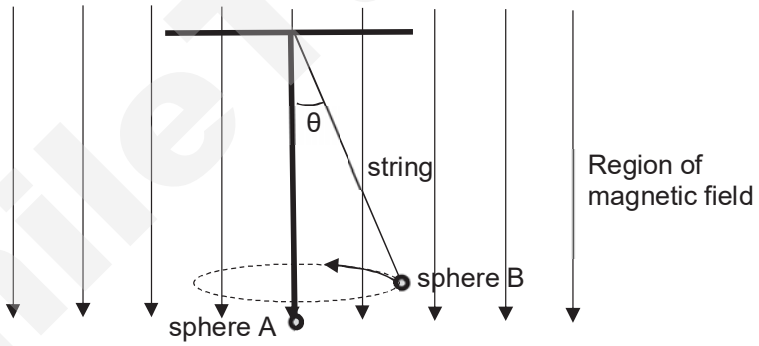


**Fig. 4.3**

Discuss how this might affect the subsequent motion of sphere B.

.....

.....

.....

..... [3]

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**(d)** In the presence of air, sphere A and B will slowly discharge as they ionize the air particles around them.

Describe the path of sphere B when this happens.

.....

.....

..... [1]

**5** **(a)** State two differences between a progressive wave and a stationary wave.

.....

.....

.....

..... [2]

**(b)** Two coherent radiowave sources $S_1$ and $S_2$ that are in phase face each other, separated by a distance of 1.25 m, as shown in Fig. 5.1. Point P is located along line AB, *x* metres away from A.

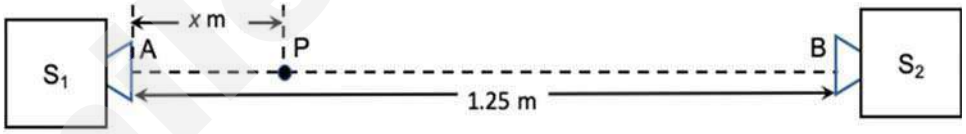


**Fig. 5.1**

**(i)** Show that the positions of minimum intensity along the line AB can be described by the following equation:

$$2L = (2n+1)\lambda$$

where
$L$ is the path difference between the waves from $S_1$ and $S_2$,
$n$ is any integer and
$\lambda$ is the wavelength of the radiowaves.

[1]

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**(ii)** Determine the number of points along AB where minima would be expected when radiowave signals of wavelength 0.429 m are produced.

number of points = _____ [3]

**6** **(a)** A metal plate has work function of 4.5 eV. When ultraviolet radiation of wavelength 120 nm is incident on the plate, a photoelectric current is detected.

**(i)** Calculate the maximum speed of the photoelectrons as a result of this illumination.

maximum speed = _____ $m\ s^{-1}$ [2]

**(ii)** The uncertainty in the speed of the photoelectrons in **(a)(i)** is 0.50%.

Assuming that the photoelectrons are moving in the horizontal direction,

**1.** determine the uncertainty in the horizontal momentum of the photoelectrons;

uncertainty = _____ N s [3]

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**2.** determine the minimum uncertainty in the position of the electron.

uncertainty = _____ m [2]

**(b)** Fig. 6.1 shows an x-ray spectrum.

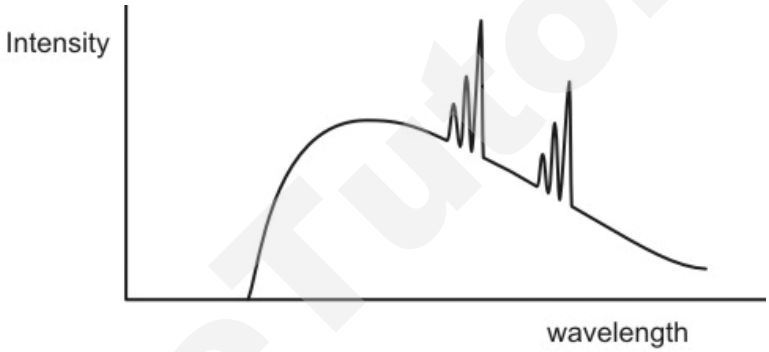


**Fig. 6.1**

Describe how the continuous spectrum is produced.

.....

.....

.....

.....

.....

.....

..... [4]

**7** **(a)** State experimental evidence to suggest that the process of radioactive decay is
**(i)** random;

.....

.....

..... [1]

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**(ii)** spontaneous.

.....

.....

..... [1]

**(b)** A student measured the count rate from a sample of pure iodine-131 at various times. The results are shown in Fig. 7.1. Iodine-131 decays by beta emission to form xenon-131 which is stable.

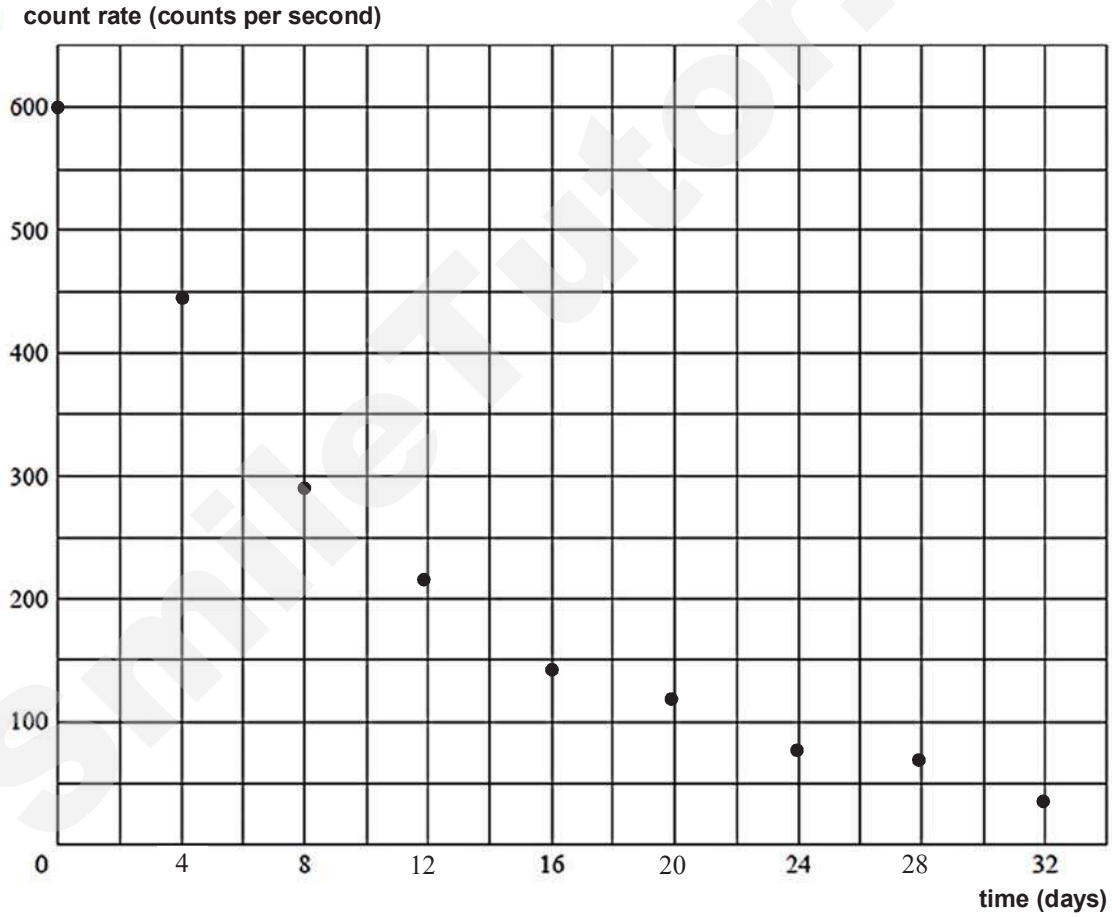


**Fig. 7.1**

Use Fig. 7.1 to determine a value for the half-life, in days, of iodine-131.

half life = ..... days [3]

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**(c)** Explain why the determination of the half-life of iodine-131 by the method in **(b)** requires that the product of the decay is stable.

.....

.....

..... [1]

**(d)** Suggest why the percentage systematic error will not be significant if the student neglected the background radiation.

.....

.....

..... [1]

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## Section B

Answer **one** question in this section in the spaces provided.

**8** In a roller coaster ride, a train of mass 1200 kg and carrying a load of 400 kg is pulled up a smooth slope at a constant speed of 1.5 m $s^{-1}$ by an electric motor to a height of 80.0 m as shown in Fig. 8.1. The train with its load is then released from rest at point A and moved to point B along the curved track.

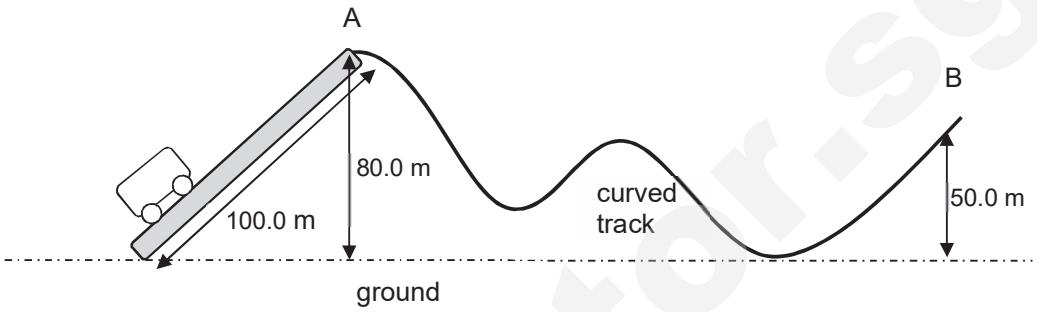


**Fig. 8.1**

**(a)** **(i)** Calculate the minimum force required to pull the train with its load up the slope at the given speed.

minimum force = ..... N [2]

**(ii)** The efficiency of the motor is 80%. Calculate the electrical power that is supplied to the motor to pull the train with its load up the slope to point A.

electrical power = ..... kW [3]

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**(iii)** Between A and B, the train experiences an average resistive force of 3.0 kN. If the train arrives at B with a speed of 8.0 m $s^{-1}$, determine the distance travelled by the train between A and B.

distance travelled = ..... m [3]

**(iv)** Suggest why the resistive force on the train is unlikely to remain constant. (Ignore the resistive force due to air resistance.)

.....

.....

.....

..... [1]

**(b)** In another segment of the ride, the train loop the loop in a circular track as shown in Fig.8.2. The radius of the circular motion is 25 m.

Point D is at the bottom of the circular motion.
Point E is at the right of the circular motion.
Point F is at the top of the circular motion.
Point G is at the left of the circular motion.

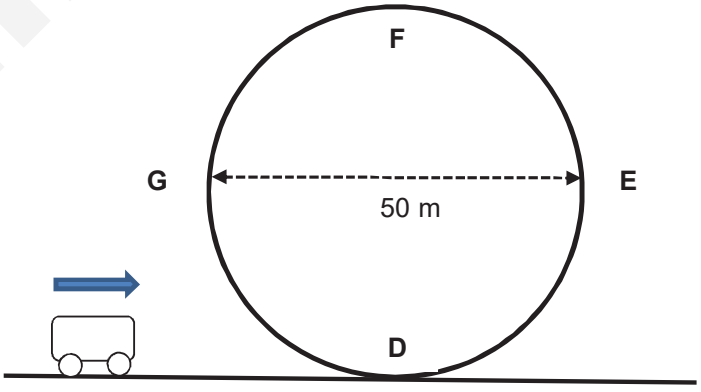


**Fig. 8.2**

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**(i)** On Fig. 8.3 below, draw the free body diagram of the train at point D and point F.




**Fig. 8.3**

[2]

**(ii)** Determine the minimum speed of the train at point D so that it can loop the loop.

minimum speed = _____ m $s^{-1}$ [4]

**(c)** It is suggested to keep the speed of the train constant.

**(i)** On Fig. 8.4, sketch the graph to show how the normal contact force experienced by the train varies as it moves from Point D to G and back to D.

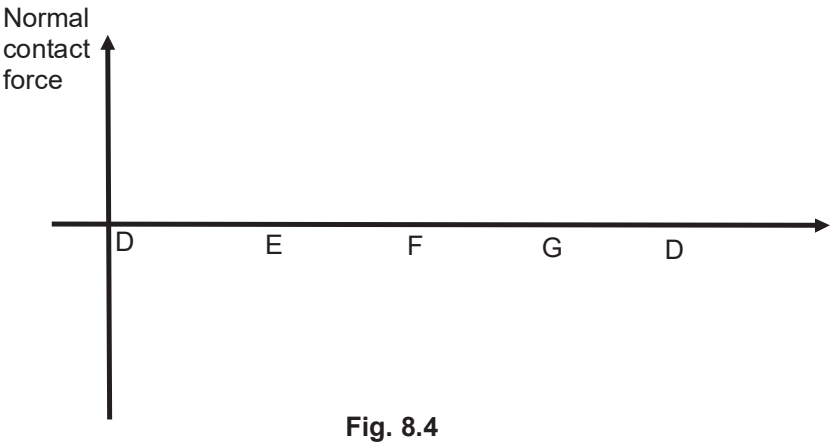


**Fig. 8.4**

[3]

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**(ii)** Discuss why it is difficult to maintain the train at constant speed during the loop the loop.

.....

.....

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..... [2]

**9** **(a)** Define *electric potential*.

.....

.....

..... [2]

**(b)** Two identical point charges, of +*Q* each, are located at a distance 2*d* apart as shown in Fig 9.1.

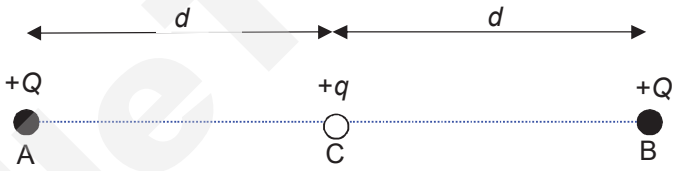


**Fig. 9.1**

A third charge of mass *m*, and charge +*q* is placed at C, midpoint between the two charges.

**(i)** Obtain an expression for the electric potential at point C due to the two point charges at A and B.

electric potential at point C = _____ V [2]

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**(ii)** Sketch in Fig. 9.2 to show how the electric potential varies with the position along AB for the following cases:

1. due to the point charge at A
2. due to the point charge at B
3. due to both point charges at A and B.

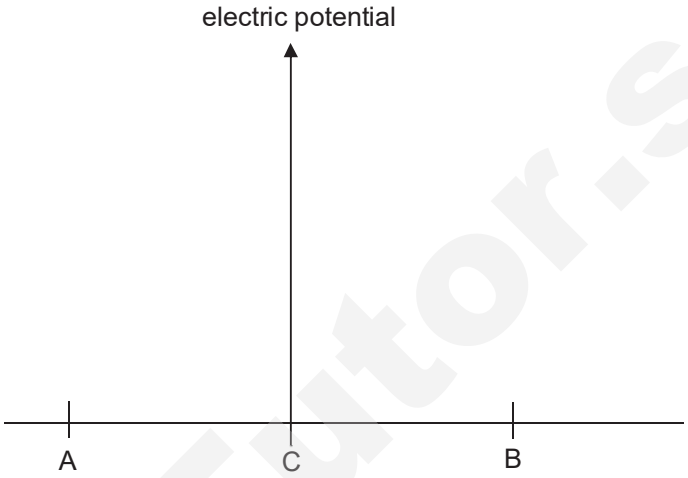


**Fig. 9.2** [3]

**(iii)** The charge $+q$ is then being displaced horizontally and released. It is observed that charge $+q$ exhibits simple harmonic motion with an amplitude of $x_o$, where $x_o$ is significantly smaller than $d$.

**1.** On Fig. 9.3, draw a well-labelled free body diagram to show the electrostatic forces acting on the third charge $+q$ at the instant when it is being displaced at a distance of $x$ to the left of C.

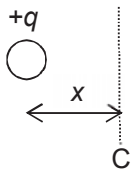


**Fig. 9.3** [2]

**2.** Derive an expression for the magnitude of the resultant electrostatic force experienced by the charge due to the point charges at A and B.

resultant electrostatic force = _____ N [1]

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**3.** The angular frequency of the oscillations can be expressed as follows.

$$\omega = \sqrt{\frac{qQ}{\pi\varepsilon_o md^3}}$$

Determine the period of oscillation using the data provided below:

*m*: 6.8 x $10^{-25}$ kg
*q*: 3.2 x $10^{-19}$ C
*Q*: 1.28 x $10^{-18}$ C
*d*: 8.6 cm

period = ..... s [1]

**4.** On Fig. 9.4, sketch three graphs to show how the *total energy*, *potential energy* and k*inetic energy* of the charge +*q* vary as it oscillates between $-x_o$ and $x_o$, Label each graph.

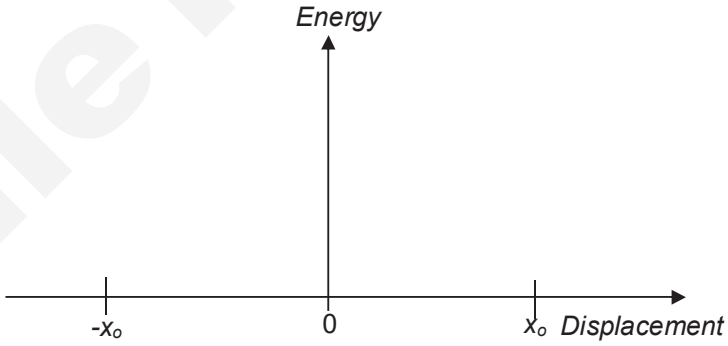


**Fig. 9.4**

[3]

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**(c)** An electron was accelerated from rest with potential difference of 1.0 x $10^4$ V, before entering at right angle into a uniform electric field region provided by a pair of charged parallel plates, separated at a distance of 3.0 cm as shown in Fig. 9.5.

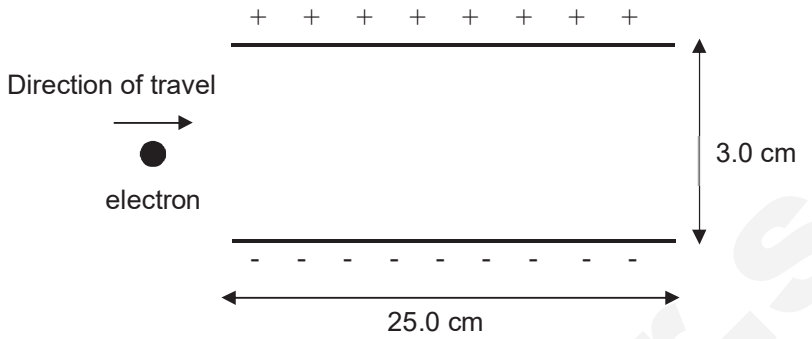


**Fig. 9.5**

**(i)** Determine the speed of the electron when it entered the uniform electric field region.

speed = _____ m $s^{-1}$ [2]

**(ii)** On Fig. 9.5, draw the electric field lines between the pair of charged parallel plates. [1]

**(iii)** The electron entered the uniform electric field region at the midpoint between the two charged parallel plates.

**1.** On Fig. 9.5, sketch the trajectory of the electron within and beyond the parallel plates. [1]

**2.** Show that the electron did not hit any of the parallel plates when it emerged from the uniform electric field region. The electric field strength between the parallel plates is 5.7x$10^3$ N $C^{-1}$.

[2]

**- END OF PAPER –**

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NAME: _____ CLASS: _____

# CATHOLIC JUNIOR COLLEGE
## JC2 Preliminary Examinations
## Higher 2

# PHYSICS
Paper 4: Practical

**9749/04**
**20 August 2019**
**2 hours and 30 minutes**

**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. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use an HB or 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **ALL** questions.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| 1 | / 14 |
| 2 | / 9 |
| 3 | / 20 |
| 4 | / 12 |
| Total | / 55 |

This document consists of **20** printed pages and **zero** blank page.

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**1.** In this experiment, you will investigate the variation of current $I$ with potential difference $V$ of an electrical component Y.

**(a)** Set up the circuit as shown in Fig. 1.1, with the rheostat connected as a potential divider and taking care component Y is connected the right way around.

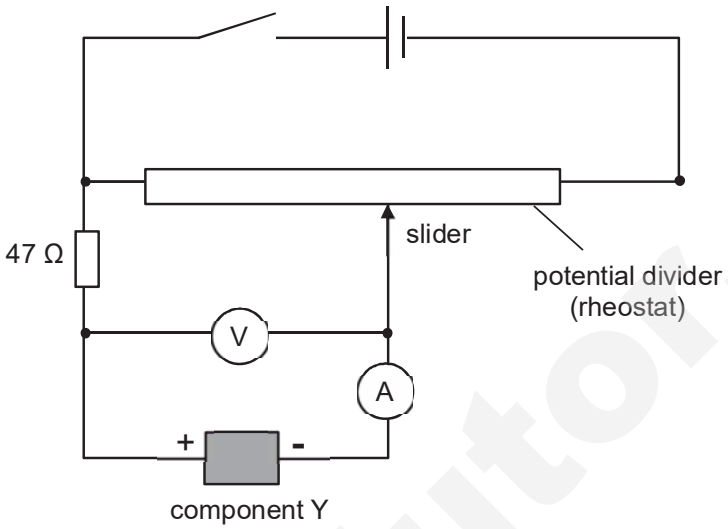


**Fig. 1.1**

**(b)** Place the slider of the rheostat at its mid-point.

**(c)** Close the switch. Record the potential difference across component Y and the current flowing through it.

potential difference = ……..……..[1]

current = ……..……..[1]

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**(d)** Adjust the slider to vary the potential difference $V$, from 0 V to the maximum value, across component Y so as to obtain further readings of the current $I$ through component Y. The current will remain zero for low values of $V$.

Record sufficient readings of $V$ and $I$ so that a curve could be plotted.

[5]



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**(e)** On the graph grid on **page 5,** draw a curve to show how $I$ varies with $V$. [3]

**(f)** **(i)** From the curve drawn on **page 5**, describe how the resistance of component Y varies.

……..

……..

……..

……..[2]

**(ii)** Suggest a practical purpose of using component Y in an electrical circuit.

……..

……..[1]

**(g)** Suggest a reason for connecting the 47 Ω resistor in series to component Y.

……..

……..[1]

**[Total: 14 marks]**

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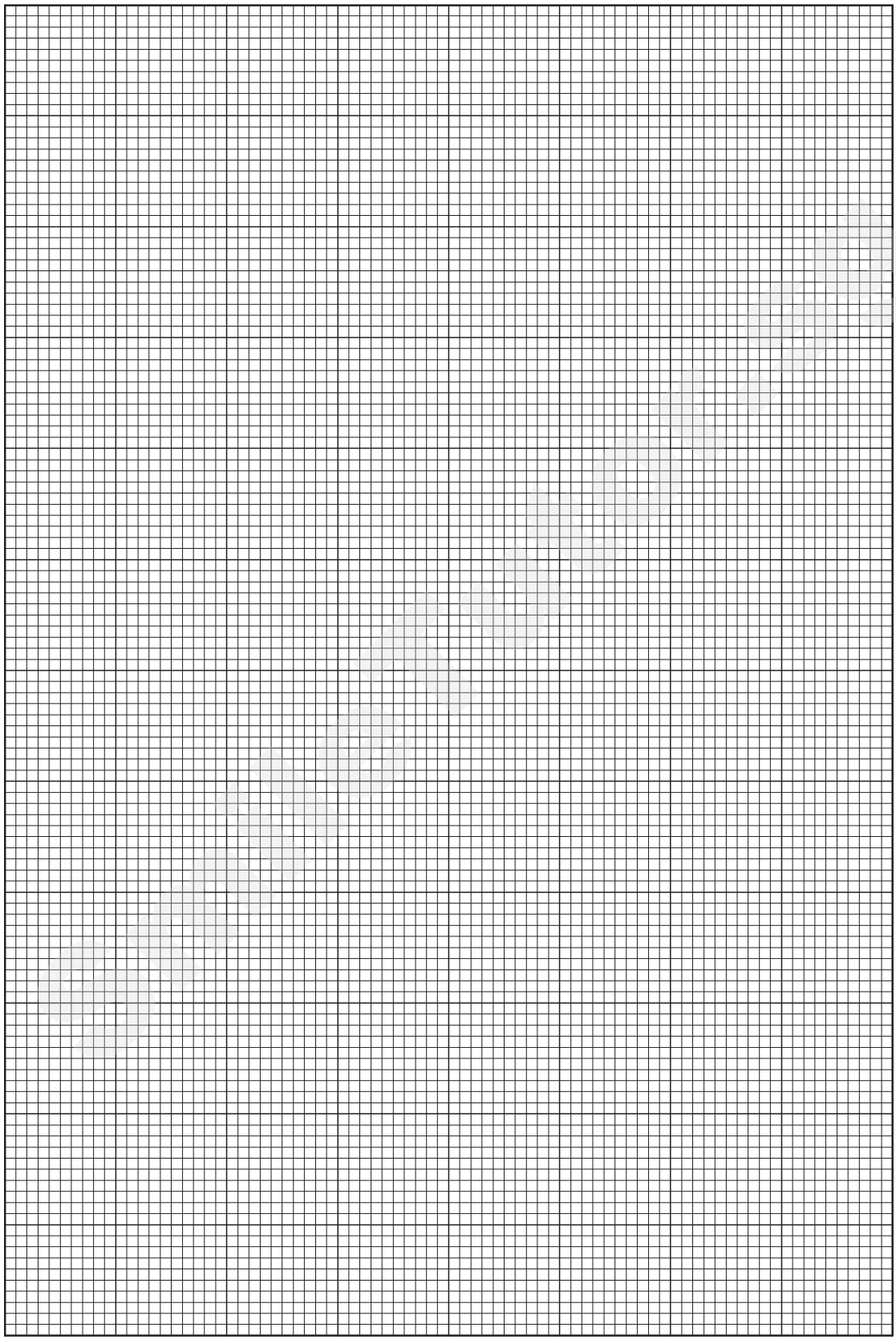



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**2.** In this experiment, you will investigate the extension of a spring.

**(a)** You have been provided with a spring.
Measure and record the length $x_0$ of the unstretched spring, as shown in Fig. 2.1.

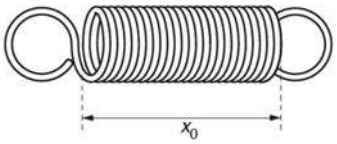


**Fig. 2.1**

$x_0$ = .....

**(b)** Set up the apparatus as shown in Fig. 2.2.

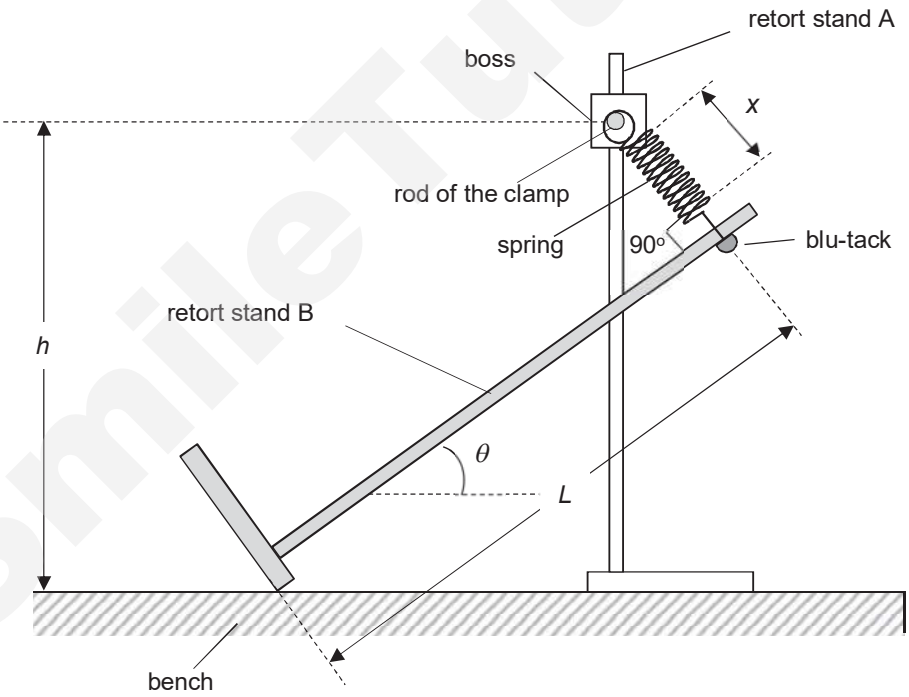


**Fig. 2.2**

The height $h$ of the rod of the clamp above the bench should be approximately 38 cm.

One loop of the spring should be around the rod of the clamp.

The other loop of the spring should be around the rod of retort stand B close to the top of the rod and secured using blu-Tack.

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**(c)** Slide the base of retort stand B until the angle between the rod of retort stand B and the stretched spring is 90°.

The length of the coiled section of the spring is $x$.
The angle between the rod of retort stand B and the horizontal is $\theta$.
The length between the base of the retort stand B and the spring is $L$.

Measure and record $x$, $\theta$ and $L$.

$x$ = .....

$\theta$ = .....

$L$ = .....
[2]

**(d)** Calculate $e$ where

$$e = x - x_0$$

$e$ = .....[1]

**(e)** Estimate the absolute uncertainty of $\theta$.

absolute uncertainty = .....[1]



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**(f)** Reduce the height *h* of the rod of the clamp to approximately 32 cm. Keeping *L* constant, slide the base of retort stand B until the angle between the rod of retort stand B and the stretched spring is again 90°.

Measure and record *x* and $\theta$. Calculate *e*.

*x* = ……

$\theta$ = ……

*e* = ……

**(g)** Theory suggests that the quantities *e* and $\theta$ are related by the equation

$$e + \frac{mp}{L}\tan\theta\cos\theta = \frac{mq}{L}\cos\theta$$

where *p* and *q* are constants and *m* is the mass of retort stand B.

**(i)** Using the values in **(c)**, **(d)**, **(f)** and *m* = 1800 g, calculate *p* and *q*.

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$p$ = ……..……..

$q$ = ……..……..
[2]

**(ii)** It is also found that

$$p = \frac{gy}{k}$$

where $g$ = 9.81 m s$^{-2}$, $y$ = 4.2 cm and $k$ is the spring constant of the spring.

Calculate $k$.

$k$ = ……..……..…N m$^{-1}$
[1]

**(iii)** If you were to repeat this experiment with other values of $\theta$, describe the graph that you would plot to determine $k$.

……

……

……

……..……..[2]

**[Total: 9 marks]**

**[Turn Over**

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**3.** In this experiment, you will investigate the variation of the fundamental frequency *f* of a stretched string with a fixed tension *T*.

**(a)** Fig. 3.1 shows the apparatus which has been set up for this experiment.

The mass M = 1.000 kg.

**Do not dismantle the apparatus during the experiment.**

*L* is the length between the bridges and is initially set to approximately 25 cm.

The paper rider should be placed on the string around the mid-point between the two bridges.

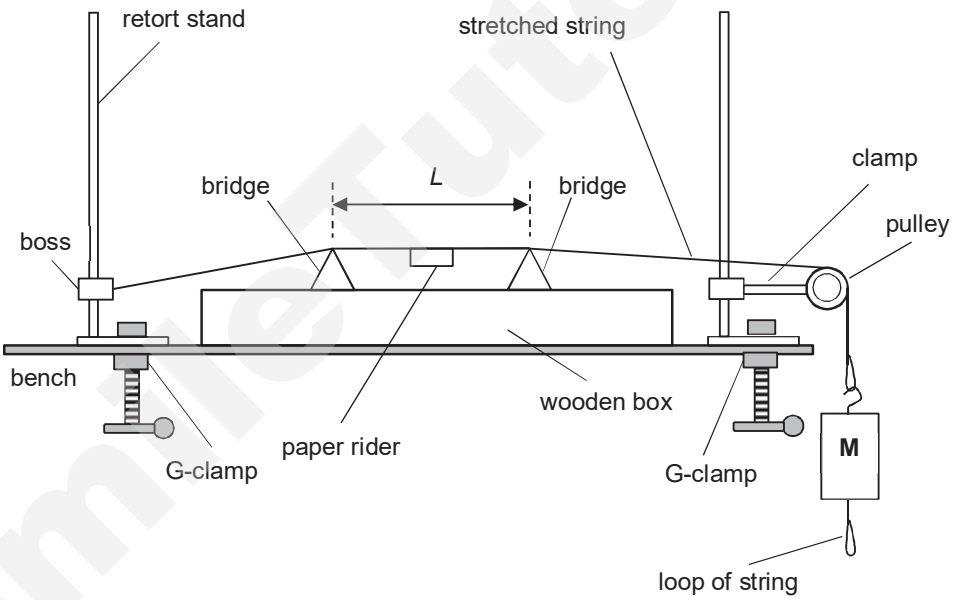


**Fig. 3.1**

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**(i)** Hit the tuning fork against the rubber bung to set the tuning fork into vibration and, immediately, rest its handle gently on the wooden box as shown in Fig. 3.2.

**(ii)** While keeping the handle of the vibrating tuning fork resting on the wooden box, move the bridges gradually to increase the length *L* until you observe the **strongest** vibration of the paper rider or the paper rider jumps off the string. You may need to hit the tuning fork more than once.

The length *L* should not exceed 35 cm.

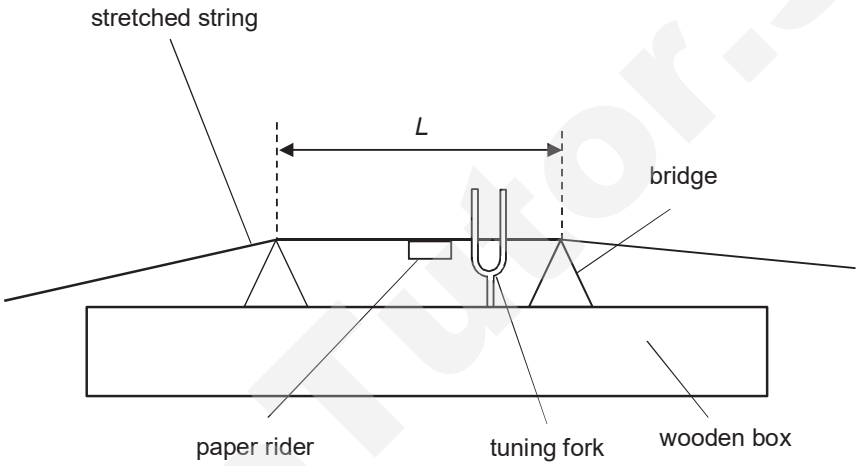


**Fig. 3.2**

**(iii)** Measure and record the length *L* and the frequency *f* of the tuning fork, when the paper rider has the strongest vibration or jumps off the string.

frequency *f* = ……

length *L* = ……
[2]



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**(b)** Estimate the percentage uncertainty in your value of *L*.

percentage uncertainty in *L* = ……..…….[1]

**(c)** Choose another tuning fork of a different frequency and repeat **(a)(i) and (a)(ii)** to obtain another set of readings for *L* and *f*.

Measure and record *L* and *f*.

frequency *f* = ……..……..

length *L* = ……..……..

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**(d)** It is suggested that

$$2Lf = k\sqrt{mg}$$

where $k$ is a constant and $m$ is the total mass hung on the stretched string.

**(i)** Use your values from **(a)(iii)** and **(c)** to determine two values of $k$.

Give your values of $k$ to an appropriate number of significant figures.
Assume $g$ = 9.81 m s$^{-2}$.

first value of $k$ = ……..……..……..

second value of $k$ = ……..……..……..
[2]

**(ii)** State whether the results of your experiment support the suggested relationship in **(d)**.

Justify your conclusion by referring to your values in **(b).**

……...

……..

……..

……..……..[1]



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**(e)** You will now determine two more values of *k* by varying *m* for two different frequencies of tuning fork.

**(i)** Adjust the bridges such that the length *L* is **fixed** at 35.0 cm. **Do not change the length *L* in this part of the experiment**.

**(ii)** Hang the 100 g mass hanger onto the loop of string, shown in Fig. 3.3.

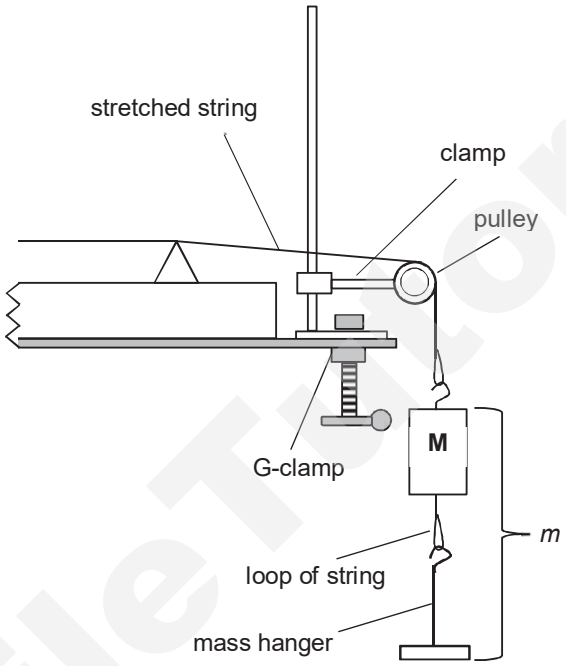


**Fig. 3.3**

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**(iii)** Hit the tuning fork against the rubber bung to set the tuning fork into vibration and, immediately, rest its handle gently on the wooden box. Observe the vibration of the paper rider.

**(iv)** If the paper rider does not show the **strongest** vibration or jump off the string, increase *m* in steps of 100 g slotted mass and repeat step **(iii)**.

**(v)** Stop increasing *m* when you observe the **strongest** vibration of the paper rider or the paper rider jumps off the string.

Measure and record *f* and *m*.

**Repeat for a second tuning fork.**

Tabulate your results of *m* and *f*, including the values of *k*.

[3]



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**(vi)** Comment on your values of $k$ in **(d)(i)** and **(e)(v).**

……..

……..

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……..

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……..

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……..

……..[3]

**(f)** **(i)** State two significant sources of error in this experiment.

1 ……

……

……

2 ……

……

……..[2]

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

……

……

……..[1]

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**(g)** The oscillation of a stretched string depends on the properties of the string.

It is suggested that the fundamental frequency $f$ is inversely proportional to the square root of the diameter $d$ of the string.

Explain how you would investigate this relationship using the same apparatus. In addition, you have access to a set of 12 tuning forks and 6 strings of different diameters.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show inverse proportionality
- why you might not have enough results to reach a valid conclusion.

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……[5]

**[Total: 20 marks]**

**[Turn Over**

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**4.** A student is investigating the force between two charged metal spheres S and T, as shown in Fig. 4.1.

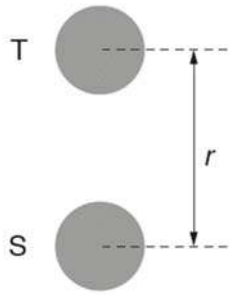


**Fig. 4.1**

Each sphere may be charged by connecting the positive lead from a power supply to the sphere and then removing the lead. The electromotive force (e.m.f.) of the power supply used to charge sphere T is $V$.

The force $F$ between the two charged spheres may be determined by attaching sphere S to an electronic balance.

For a constant charge on sphere S, it is suggested that the relationship between $F$ and $V$ is

$$F = kV^m r^n$$

where $r$ is the distance between the centres of the spheres; and $k$, $m$ and $n$ are constants.

Design an experiment to determine the values of $k$, $m$ and $n$.

You should draw a diagram to show the arrangement of your apparatus and you should pay particular attention to

**(a)** the equipment you would use

**(b)** the procedure to be followed

**(c)** the measurements to be taken

**(d)** the control of variables

**(e)** any precautions that should be taken to improve the accuracy and safety of the experiment.

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**Diagram**

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**[Turn Over**

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**[Total: 12 marks]**

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NAME _____ CLASS 2T

# Catholic Junior College
## JC2 Preliminary Examinations
## Higher 2

# PHYSICS 9749/01

Paper 1: Multiple Choice

**4 September 2019**
**1 hour**

Additional Materials: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Write your name and tutorial group on this cover page.
Write and/or shade your name, NRIC / FIN number and HT group on the Answer Sheet (OMR sheet), unless this has been done for you.
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all 30 questions** in this paper.
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 (OMR sheet).

**Read the instructions on the Answer Sheet carefully.**

Each correct answer will be awarded 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 permitted, where appropriate.

**MARK SCHEME**

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

**[Turn over**

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**PHYSICS 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$^{-1}$ |
| | | | $\approx (1/(36\pi)) \times 10^{-9}$ 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 | $k$ | = | $1.38 \times 10^{-23}$ mol$^{-1}$ |
| gravitational constant | $G$ | = | $6.67 \times 10^{-11}$ N m$^2$ kg$^{-2}$ |
| acceleration of free fall | $g$ | = | 9.81 m s$^{-2}$ |

**PHYSICS FORMULAE:**

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

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| | | | |
|---|---|---|---|
| **1** | The table below shows the estimates of some physical quantities.<br><br>Which row is **not** a reasonable estimate? | | |
| | | quantity | value |
| | **A** | current used in an electric kettle | 8 A |
| | **B** | mass of an adult male | 70 kg |
| | **C** | speed of an Olympic sprint runner | 10 m $s^{-1}$ |
| | **D** | water pressure at the bottom of a public swimming pool | $10^4$ Pa |

**Answer: D**

**Option A: With I = 8 A, and V = 240 V, power rating of kettle = 8 x 240 = 1920 W which is a reasonable estimate.**

**Option B: Typically Singaporean adult weighs between 50 kg and 100 kg. Therefore 70 kg is a reasonable estimate.**

**Option C: The timing for 100 m race is the Olympic is about 10 s; therefore the average speed of 10 m $s^{-1}$ is a reasonable estimate.**

**Option D: Atmospheric pressure = $10^5$ Pa.**
**Assume that the swimming pool has depth of 2 m,**
**Pressure at the bottom pool = Atmospheric pressure + hρg**
**= $10^5$ + (2 x 1000 x 9.81)**
**= $10^5$ + 1.96 x $10^4$ = 1.196 x $10^5$ Pa**

**$10^4$ Pa is less than 1.196 x $10^5$ Pa. Therefore $10^4$ Pa is not a reasonable estimate. Answer is D.**

| | | |
|---|---|---|
| **2** | A potential difference (p.d.) is carefully measured with a high-quality instrument and found to be 2.321 V.<br><br>Two students, using two different methods to measure the p.d., quote the p.d. as 2.33 V and 2.344 V respectively.<br><br>Which statement is correct? | |
| | **A** | The reading 2.33 V is more accurate and more precise than the reading 2.344 V. |
| | **B** | The reading 2.33 V is more accurate but less precise than the reading 2.344 V. |
| | **C** | The reading 2.33 V is less accurate but more precise than the reading 2.344 V. |
| | **D** | The reading 2.33 V is less accurate and less precise than the reading 2.344 V. |

**Answer: B**

**Explanation:**

**The reading 2.33 V has a precision of 0.01 V which is less precise than the reading 2.344 V as the reading 2.344 V has a precision of 0.001 V. Eliminate Option A and C.**

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**True Value = 2.321 V**

**The reading 2.33 V is 0.009 V from the True Value while the reading 2.344 V is 0.023 V from the True Value. Therefore the reading 2.33 V is more accurate than the reading 2.344 V**

**Answer is B**

| | | |
|---|---|---|
| **3** | A man is parachuting towards the Earth. According to Newton's third law of motion, the force which makes an action-reaction pair with the gravitational force on the man is | |
| | **A** | the gravitational force on the Earth due to the man. |
| | **B** | the viscous force of the man and his parachute on the air. |
| | **C** | the viscous force of the air on the man and his parachute. |
| | **D** | the tension in the harness of the parachute. |

**Answer: A**

**Understanding and applying N3L.**

**4** A non-uniform rod XY is balanced horizontally on top of a triangular wedge. The top of the wedge O is at a distance 1.10 m from the end X of the rod.




A 1500 g mass is hung at a distance of 0.20 m from X. The rod now needs to be moved 0.25 m to the right to balance horizontally.

What is the mass of the rod?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **A** | 1.2 kg | **B** | 3.9 kg | **C** | 6.6 kg | **D** | 7.8 kg |

**Answer: B**

As the rod is balanced at O, it can be deduced that the centre of mass of the rod is at 1.10 m away from X (at O).

After the extra mass is added, and balanced distance achieved,

Taking moments about point O,
Sum of clockwise moments = Sum of anticlockwise moments
$0.25 \times m \times 9.81 = (1.10 - 0.20 - 0.25) \times (1500 \times 10^{-3}) \times 9.81$
$m = 3.9$ kg

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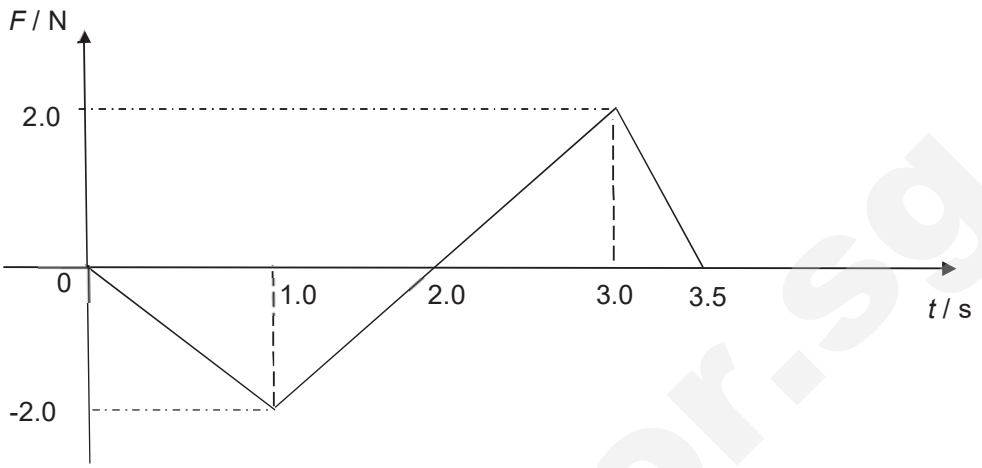
**5** A resultant force $F$ acts on a mass of 150 g. The variation with time $t$ of $F$ is shown on the diagram below.




At time $t$ = 0 s, the mass is moving with a velocity of 2.0 m s$^{-1}$.

What is the speed of the mass at $t$ = 3.0 s?

| | | |
|---|---|---|
| | **A** | 2.7 m s$^{-1}$ |
| | **B** | 4.7 m s$^{-1}$ |
| | **C** | 6.7 m s$^{-1}$ |
| | **D** | 8.7 m s$^{-1}$ |

**Answer: B**

Change in momentum = area under the graph

= - ½ (2) (2) + ½ (2) (1)

= - 1.0 Nm

Therefore, $m\Delta v$ = - 1.0

$\Delta v$ = -1.0 / (150 x 10$^{-3}$)

= - 6.67 m s$^{-1}$

Hence, $V_f - v_i$ = - 6.67

$V_f$ = -6.67 + 2.0 = - 4.67 m s$^{-1}$

Therefore the speed of mass = 4.7 m s$^{-1}$ (2 s.f.)

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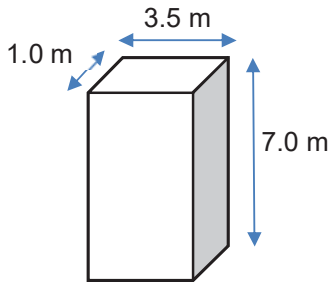
**6** The diagram below shows a wooden block in its upright position, with length 1.0 m, width 3.5 m and height 7.0 m. The density of wood is 850 kg $m^{-3}$.




What is the submerged depth of the wooden block when it floats upright in water?

Density of water is 1000 kg $m^{-3}$.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **A** | 0.85 m | **B** | 5.6 m | **C** | 6.0 m | **D** | 7.0 m |

**Answer: C**

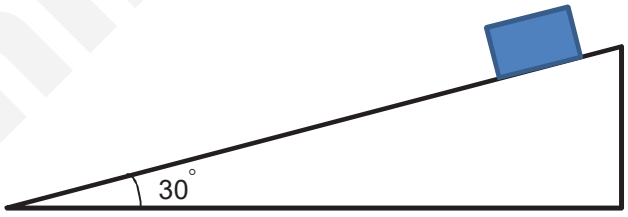
**Weight of water displaced = weight of wooden block**

**$\rho_{water}\ g\ V_{water\ displ.} = \rho_{wood}\ g\ V_{wood}$**

**$1000 \times g \times h_{water\ displ.} \times A = 850 \times g \times 7.0 \times A$**

**$h_{water\ displ.} = 5.95\ m = 6.0\ m$ (2 s.f.).**

**7** A block starts to slide down a 30° slope from rest as shown in the figure below.




Assume that the friction on the block is negligible. What is the final speed of the block after it has travelled 10 m down the slope?

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **A** | 4.9 m $s^{-1}$ | **B** | 8.5 m $s^{-1}$ | **C** | 9.9 m $s^{-1}$ | **D** | 13 m $s^{-1}$ |

**Answer: C**

**Acceleration along the slope = g sin 30° = 4.905 m $s^{-1}$.**

**$v^2 = u^2 + 2as$**

**$v^2 = 0 + 2 \times 4.905 \times 10$**

**$v = 9.9\ m\ s^{-1}$**

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| | | |
|---|---|---|
| **8** | A body of mass 90 kg travels along a horizontal road at a speed of 5.0 m $s^{-1}$. It then accelerates at 1.5 m $s^{-2}$. At the time it begins to accelerate, the total resistive force acting on the car is 200 N.<br><br>What total output power is developed by the car as it begins the acceleration? | |
| | **A** | 680 W |
| | **B** | 1700 W |
| | **C** | 4400 W |
| | **D** | 5400 W |

**Answer: B**

**ma = F – resistive force**

**F = 90 x 1.5 + 200 = 335 N**

**Therefore power required to give the 90 kg, 5.0 m $s^{-1}$ body to accelerate at 1.5 m $s^{-2}$ is**

**F x v**

**= 335 x 5**

**= 1675 W**

**= 1700 W**

| | | |
|---|---|---|
| **9** | A car is making a circular turn of radius *r* with speed *v*. The centripetal force on the car is *F*.<br><br>What is the centripetal force on the car when it makes the same turn at speed 2*v*? | |
| | **A** | $\frac{F}{2}$ |
| | **B** | $F$ |
| | **C** | $2F$ |
| | **D** | $4F$ |
| | | |
| | **Answer : D**<br><br>$F = \frac{mv^2}{r}$<br>$\frac{m(2v)^2}{r} = 4\frac{mv^2}{r} = 4F$ | |
| | | |
| **10** | A small sphere is moving in a vertical circle at constant speed.<br><br>The magnitude of the resultant force on the sphere | |
| | **A** | at the bottom of the circle is greater than the resultant force at the top. |
| | **B** | at the top of the circle is greater than the resultant force at the bottom. |
| | **C** | decreases as the sphere moves from the bottom to the top of the circle. |
| | **D** | is the same at the top of the loop as it is at the bottom of the circle. |
| | | |
| | | |

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**Solution: D**

**Resultant force = Centripetal force, $mv^2 / r$**

**Since the mass, speed and radius remain unchanged throughout, the resultant force is unchanged in magnitude.**

**11** The neutral point in the gravitational field between the Sun, the Earth and the Moon is the point at which the resultant gravitational field due to the three bodies is zero. The mass of the Earth is about 80 times the mass of the Moon.

At what position is it possible for the neutral point to be? (The diagram is not drawn to scale)




**Answer: D**

**The null point should be closest to the body with the smallest mass. In this case, the moon has smallest mass. The null point will be slightly affected by the mass of the Sun so therefore it is slightly off the line joining the centre of mass of the Earth and Moon.**

**12** Which statement about two satellites of different masses in the geostationary orbit around the Earth is ***incorrect***?

| | |
|---|---|
| **A** | The gravitational forces acting on the two satellites are different. |
| **B** | The centripetal acceleration of each satellite is different. |
| **C** | The total energy of each satellite is different. |
| **D** | The angular velocities of the two satellites are the same. |

**Answer: B**

**By equating Gravitational force with centripetal force, show that:**

$T^2 \propto R^3$

**where T is the period and R is the radius of the orbital motion.**

**All geostationary satellites have equal period T, hence all are at the same distance R from Earth.**

**Since $a_c = R\omega^2 = R\left(\frac{2\pi}{T}\right)^2$, all have equal magnitude of centripetal acceleration.**

**[ OR, Since orbital motion is free fall motion, $a_c = g_{\text{due to Earth at R}} = G\frac{M}{R^2}$, all have equal magnitude of centripetal acceleration.]**

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**Hence Option B is false.**

**Option A is true because $F_G = F_c = m\,a_c$. $a_c$ same, but with different m, $F_G$ differs.**
**Option C is true because it can be shown that Total Energy = - ½ GMm/R, which depends on the satellite's mass.**
**Option D is true because geostationary implies same period, hence same angular velocity.**

**13** Two monoatomic gases, X and Y, are in thermal equilibrium in a mixture. The molecular mass of gas Y is half the molecular mass of gas X.

The root mean square speed of the molecules of gas Y is *v*. What is the root mean square speed of the molecules of gas X?

| | |
|---|---|
| **A** | $\frac{v}{2}$ |
| **B** | $\frac{v}{\sqrt{2}}$ |
| **C** | $v$ |
| **D** | $2v$ |

**Solution: B**

**Thermal equilibrium means same temperature.**
**Same temperature means that the mean translational KE is the same.**

**But rms speed need to be $\frac{v}{\sqrt{2}}$ for the mass to be doubled and KE to be still the same.**

$\langle E_K \rangle = \frac{3}{2}kT$

$\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT$

**14** The piston is pushed very slowly into a metal cylinder containing an ideal gas.

If the temperature of the gas does not change in the process. Which of the following statements is ***incorrect***?

| | |
|---|---|
| **A** | The work done on the gas is equal to the heat lost by the gas. |
| **B** | The pressure of the gas increases. |
| **C** | The average kinetic energy of the gas molecules increases due to the work done on the gas. |
| **D** | The internal energy of the gas remains constant. |

**Answer: C**

**Metal → good conductor of heat. There can be heat transfer in/out of the cylinder.**

**A: $\Delta U = \frac{3}{2}nR\Delta T = 0$ . Hence by First Law of thermodynamics, W = -Q. Correct.**

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| | |
|---|---|
| | **B: Ideal gas equation, pV = nRT = constant since T & n are both constants. So since V decreases, p increases. Correct**<br>**C: $\langle E_K \rangle = \frac{3}{2}kT$. Same temperature means that the mean translational KE is the same. Incorrect**<br>**D: internal energy of an ideal gas = 3/2 nRT. For a fixed n, internal energy remains constant at constant T.** |

| | | |
|---|---|---|
| **15** | A small mass undergoes simple harmonic motion about a point O with amplitude $x_o$ and period $T$. Its displacement $x$ from O at time $\frac{1}{6}T$ after passing through O is | |
| | **A** | $\frac{x_o}{6}$ |
| | **B** | $\frac{x_o}{2\sqrt{3}}$ |
| | **C** | $\frac{x_o}{2}$ |
| | **D** | $\frac{\sqrt{3}x_o}{2}$ |
| | **Answer: D**<br><br>Since time is measured starting from the instant when the object is at O, we use the **sine**-function.<br><br>Using<br>$x = x_0 \sin(\omega t)$<br>$x = x_0 \sin\left(\frac{2\pi}{T}t\right)$<br><br>When $t = \frac{T}{6}$,<br><br>$x = x_0 \sin\left(\frac{2\pi}{T} \times \frac{T}{6}\right)$<br>$= x_0 \sin\left(\frac{\pi}{3}\right)$<br>$= \frac{\sqrt{3}x_0}{2}$ | |

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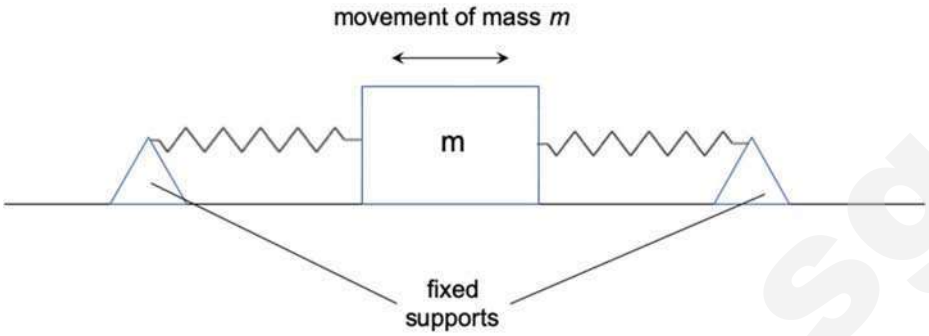
**16** A mass *m* on a smooth horizontal table is attached by two light springs to two fixed supports as shown below. The mass executes simple harmonic motion of amplitude *a* and period *T*.




The total energy of oscillation is

| | | |
|---|---|---|
| | **A** | $2\pi ma^2/T^2$ |
| | **B** | $2\pi m^2a^2/T$ |
| | **C** | $\pi^2 ma^2/T^2$ |
| | **D** | $2\pi^2 ma^2/T^2$ |

**Answer: D**

The total energy of oscillation is equal to the **maximum** KE of the object in the oscillation.

$KE_{max} = \frac{1}{2}mv_0^2$

$= \frac{1}{2}m(x_0\omega)^2$

$= \frac{1}{2}ma^2\left(\frac{2\pi}{T}\right)^2$

$= \frac{1}{2}ma^2\left(\frac{4\pi^2}{T^2}\right)$

$= \frac{2ma^2\pi^2}{T^2}$

**17** A sound wave of frequency 400 Hz is travelling in air at a speed of 320 m $s^{-1}$.

What is the difference in phase between two points on the wave 0.2 m apart in the direction of travel?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **A** | $\frac{\pi}{4}$ rad | **B** | $\frac{\pi}{2}$ rad | **C** | $\frac{2\pi}{5}$ rad | **D** | $\frac{4\pi}{5}$ rad |

**Answer: B**

$\lambda = \frac{v}{f}$

$= \frac{320}{400}$

$= 0.8$ m

$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$

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$= 2\pi\left(\frac{0.2}{0.8}\right)$

$= \frac{\pi}{2}$ rad

**18** Fig. 1 shows how the displacement of a wave varies with distance along the wave at one particular time.

Fig. 2 shows how the displacement of one particular point P of the same wave varies with time.

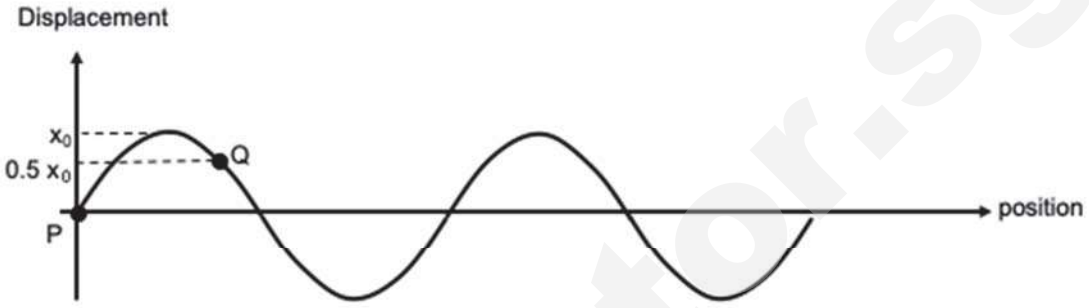



Fig. 1

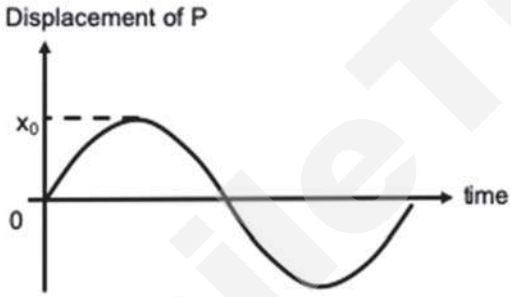
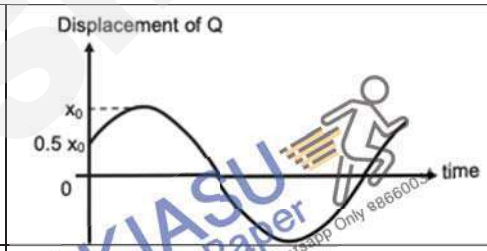


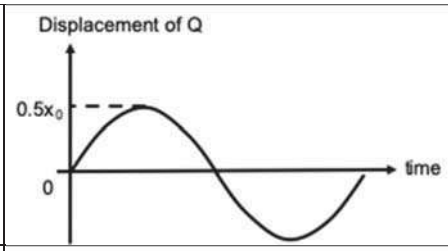

Fig. 2

Which of the following graphs correctly depicts the displacement-time graph for point Q?

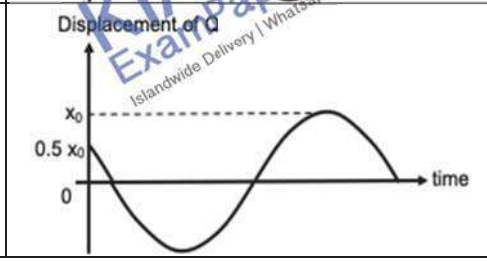
**A**



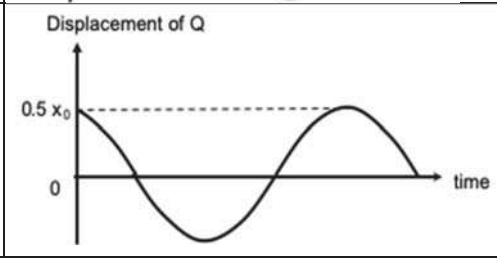

**B**




**C**




**D**




**Answer: C**

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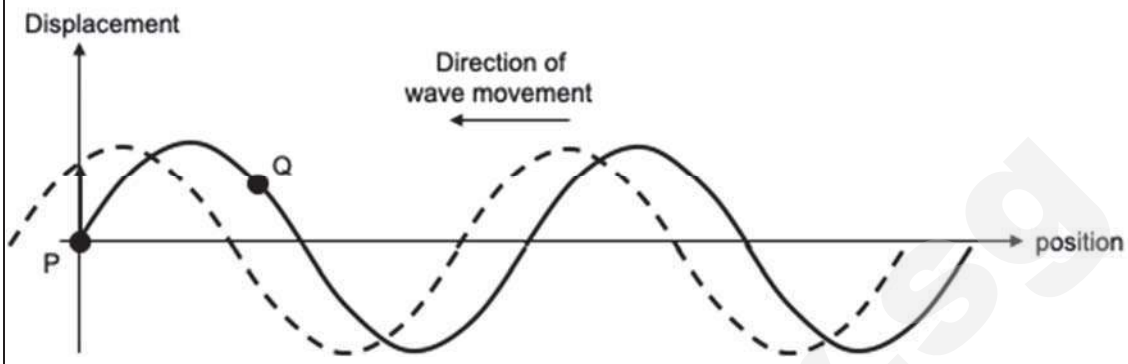
From Fig. 2, we can deduce that the wave is moving in the leftwards direction, as depicted below.

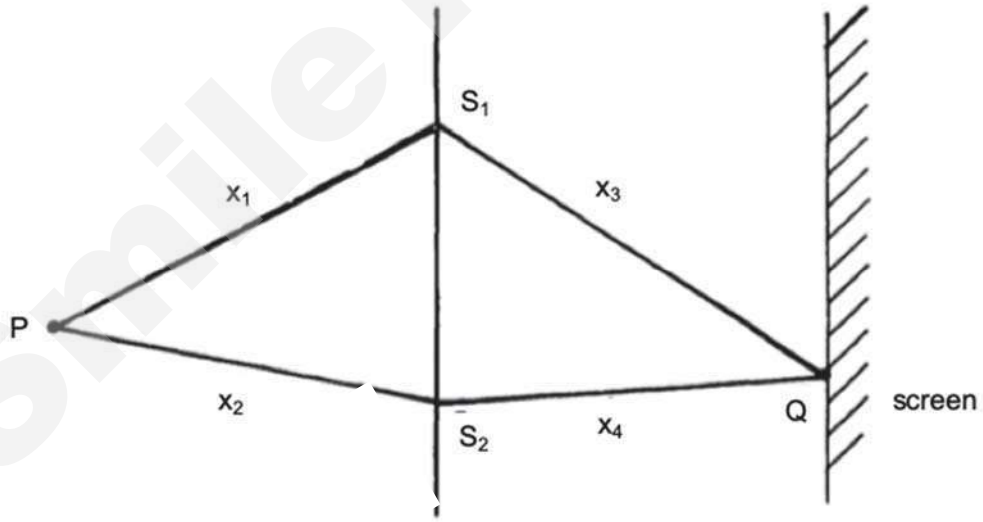



If the wave is travelling to the left, its next position can be represented by the dotted line shown above. A can be seen to be moving from equilibrium to a displacement in the positive direction, and B is moving downwards.

As such, Option A is not correct. In the same light, Option B is also not correct.

Since P and Q are succumbed to the same wave, P and Q will encounter the same amplitude magnitude, which is $x_0$. Therefore, Option D is wrong.

**19** Two identical narrow slits $S_1$ and $S_2$ are illuminated with light of wavelength $\lambda$ from a point source P.




If, as shown in the diagram above, the light is then allowed to fall on a screen, and if $m$ is a positive integer, the condition for constructive interference at Q is

| | | |
|---|---|---|
| | **A** | $x_1 - x_2 = (2m+1)\frac{\lambda}{2}$ |
| | **B** | $x_3 - x_4 = (2m+1)\frac{\lambda}{2}$ |
| | **C** | $x_3 - x_4 = m\lambda$ |
| | **D** | $(x_1 + x_3) - (x_2 + x_4) = m\lambda$ |

**Answer: D**

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| | |
|---|---|
| | For constructive interference to take place, the waves meeting at the point must have a path difference (difference in the lengths of paths from the source to the meeting point) to be a full wavelength, or integers of multiples of the wavelengths of the waves. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **20** | A beam of light that consists of all wavelengths between 480 nm and 600 nm is projected onto a diffraction grating that contains 500 lines per millimeter.<br><br>What is the maximum number of complete continuous spectra that can be observed emerging from the grating? | | | | | | | |
| | **A** | 6 | **B** | 7 | **C** | 8 | **D** | 9 |

**Answer: A**

d sin θ = nλ

For longest wavelength, find the maximum order that can be observed:
$n\lambda / d \leq 1 \rightarrow n \leq (1.0\times10^{-3} / 500) / 600\times10^{-9} = 3.3$
max n = 3
Thus there will be 6 spectra observed. (Zeroth order maximum is not a spectrum.)

| | | |
|---|---|---|
| **21** | The charge of a uranium nucleus is 1.5 x $10^{-17}$ C.<br><br>What is the potential at the mid-point between a uranium nucleus and an alpha particle if they are separated by a distance of 1.0 x $10^{-13}$ m? | |
| | **A** | 2.2 x $10^{-13}$ V |
| | **B** | 4.3 x $10^{-13}$ V |
| | **C** | 2.8 x $10^{6}$ V |
| | **D** | 5.5 x $10^{6}$ V |

**Answer: C**

Alpha particle is a $^4_2He$ nucleus, hence its charge = +2e = 3.2 x $10^{-19}$ C

Using $V = \frac{Q_1}{4\pi\varepsilon_0 r_1} + \frac{Q_2}{4\pi\varepsilon_0 r_2}$

Since the distances from the two charges to mid-point are the same, $r_1 = r_2$.

$V = \frac{1.5\times10^{-17} + 3.2\times10^{-19}}{4\pi(8.85\times10^{-12})(0.5\times10^{-13})}$ = 2.8 x $10^{6}$ V (2 s.f.)

| | |
|---|---|
| **22** | A velocity selector for protons has an electric field of strength 3.0 x $10^{5}$ V $m^{-1}$, produced by two horizontal plates. The upper plate is connected to a positive potential and the lower plate is earthed. A magnetic field of flux density 1.5 x $10^{-2}$ T, directed into the plane of the paper, is at right-angles to the electric field as shown in the diagram. |

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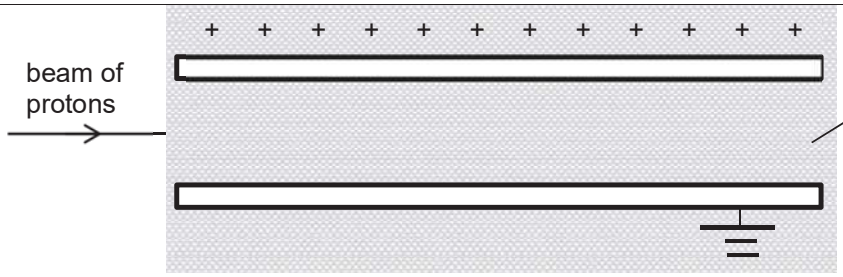


Which of the following could be the possible speed of a proton and its observation?

| | speed | observation |
|---|---|---|
| **A** | $1.8 \times 10^7$ m $s^{-1}$ | undeflected |
| **B** | $2.0 \times 10^7$ m $s^{-1}$ | deflected downwards |
| **C** | $2.2 \times 10^7$ m $s^{-1}$ | deflected downwards |
| **D** | $2.4 \times 10^7$ m $s^{-1}$ | deflected upwards |

**Answer: D**

**Protons entering the velocity have a range of speeds.**

**If protons are undeflected, Upwards magnetic force = Downwards electric force.**

**i.e. Bqv = qE**

**$v = E/B = 3.0 \times 10^5 / 1.5 \times 10^{-2}$**

**$= 2.0 \times 10^7$ m $s^{-1}$.**

**Protons with speeds higher than this value will have a greater magnetic force, but the electric force is constant regardless of speed, hence deflected upwards.**

**Conversely, protons with speeds lower than this value will deflect downwards.**

**23** When four identical resistors are connected as shown in diagram 1, the ammeter reads 1.0 A and the voltmeter reads zero.

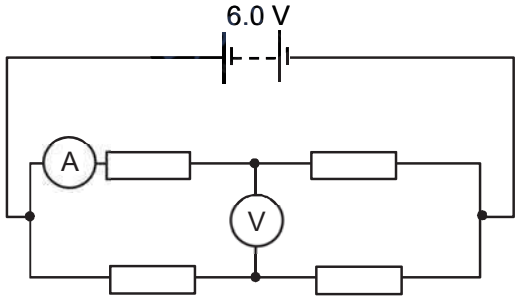


diagram 1

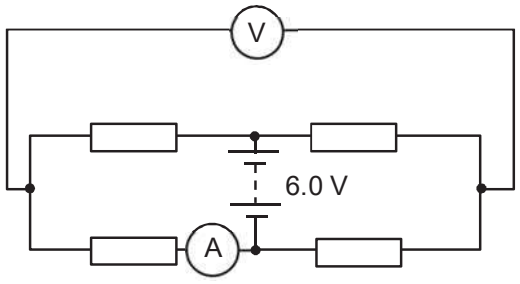


diagram 2

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| | |
|---|---|
| | The resistors and meters are reconnected to the supply as shown in diagram 2.<br><br>What are the meter readings in diagram 2? |

| | | voltmeter reading / V | ammeter reading / A | |
|---|---|---|---|---|
| | **A** | 0 | 1.0 | |
| | **B** | 0 | 0.5 | |
| | **C** | 3.0 | 1.0 | |
| | **D** | 6.0 | 0.5 | |

**Answer: A**

**Moving the battery source and the meters to the new position does not change the effective layout of the circuit. By circuit analysis the 4 resistors are still connected similar to the first i.e. 2 in series with each other and then these 2 in parallel with the other branch.**

**Therefore based on the position of the ammeter it is measuring the current in one branch of the circuit hence the current is still 1.0 A and the voltmeter is now measuring across two points in the circuit where the potentials of these two points are the same. So potential difference is 0 V.**

**OR**

**Based on diagram 1,**

**Let the unknown value of the resistors be R.**

$$(1.0)(R+R) = 6.0 \text{ V}$$
$$2R = 6.0 \text{ V}$$
$$R = 3.0 \ \Omega$$

**Based on diagram 2,**

$$I(6.0) = 6.0 \text{ V}$$
$$I = 1.0 \text{ A}$$

**Since the potential difference is measured after the first resistor in both branches the potentials at these two points are the same. Hence potential difference is 0 V.**

| | |
|---|---|
| **24** | The diagram below shows a setup of two current-carrying wires X and Y, and a single-turn coil Z. |

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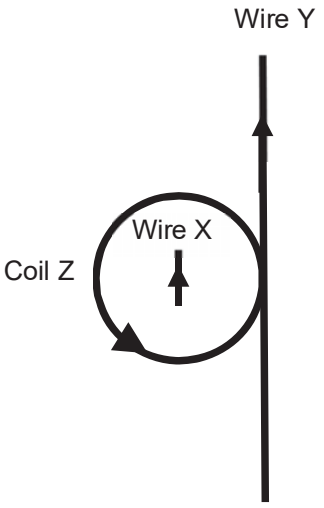


Wire X has length 0.050 m with a current of 1.0 A flowing through it. Wire Y has length 2.0 m with a current of 0.50 A. Coil Z has a diameter of 0.20 m with a current of 1.5 A.

What is the resultant force on wire X if the centre of coil Z is on wire X?

| | | |
|---|---|---|
| | **A** | $5.0 \times 10^{-8}$ N |
| | **B** | $4.2 \times 10^{-7}$ N |
| | **C** | $5.2 \times 10^{-7}$ N |
| | **D** | $9.4 \times 10^{-6}$ N |

**Answer: C**

By right-hand grip rule, the magnetic flux densities due to wire Y and due to coil Z are **both** out of the page.

Hence, the resultant magnetic flux density experienced by wire X

$= \frac{\mu_0 NI}{2r} + \frac{\mu_0 I}{2\pi d} = \frac{4\pi \times 10^{-7} \times 1 \times 1.5}{2(0.1)} + \frac{4\pi \times 10^{-7} \times 0.5}{2\pi(0.1)}$

$= 1.042 \times 10^{-5}$ T

Therefore, the resultant force on wire X = BIL = $1.042 \times 10^{-5} \times 1.0 \times 0.05 = 5.2 \times 10^{-7}$ N

**25** Diagram A shows an aluminium rod moving away from point O, at right angles to a uniform magnetic field. Diagram B shows the variation with time *t* of its displacement *s* from O.

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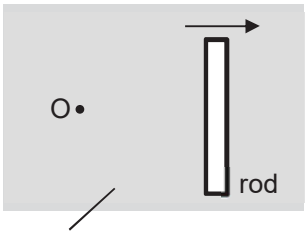



Diagram A

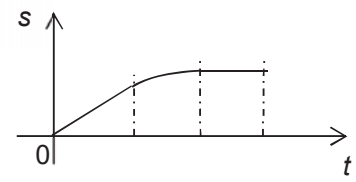
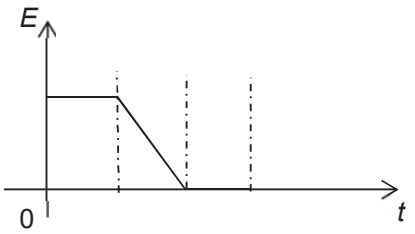


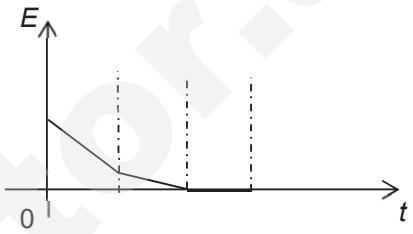

Diagram B

Which graph best shows the variation with $t$ of the e.m.f. $E$ induced in the rod?

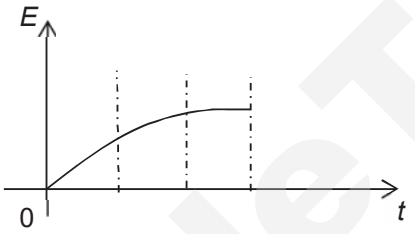
**A**



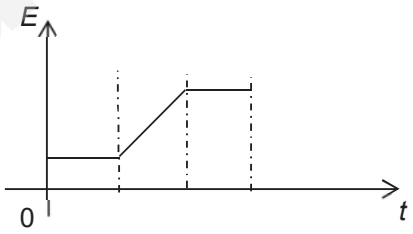

**B**




**C**




**D**




**Answer: A**

By Faraday's law, e.m.f. induced is the rate of change of magnetic flux linkage. Since the rate of change of magnetic flux linkage is proportional to the velocity of the rod, the e.m.f.-time graph has the same shape as the velocity-time graph. i.e. refers to the gradient of s-t graph.

**26** A sinusoidal current is represented by the equation

$$I = I_o \sin (\omega t)$$

Which equation represents the sinusoidal current with both its period and amplitude doubled?

| | |
|---|---|
| **A** | $2I = I_o \sin (2\omega t)$ |
| **B** | $I = 2I_o \sin (2\omega t)$ |
| **C** | $I = \frac{1}{2} I_o \sin (2\omega t)$ |
| **D** | $I = 2I_o \sin (\frac{1}{2}\omega t)$ |

**Answer: D**

$I_0$ is the amplitude and ω is the angular frequency.

With double the period, it means half the angular frequency.

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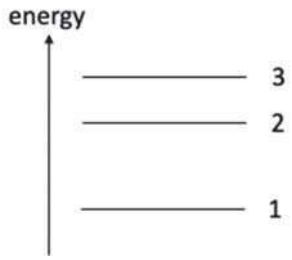
**27** Part of the energy level diagram of a certain atom is shown below. The energy spacing between levels 1 and 2 is three times that between 2 and 3. If an electron makes a transition from level 3 to level 2, the radiation of wavelength $\lambda$ is emitted.




What possible radiation wavelengths might be produced by other transitions between the three energy levels?

| | | |
|---|---|---|
| | **A** | only $\frac{\lambda}{3}$ |
| | **B** | both $\frac{\lambda}{3}$ and $\frac{\lambda}{4}$ |
| | **C** | only $3\lambda$ |
| | **D** | only $4\lambda$ |

**Answer: B**

$E_{3\to2}=\frac{hc}{\lambda}$

Possible transitions:

$E_{2\to1}=3E_{3\to2}$

$=3\frac{hc}{\lambda}$

$=\frac{hc}{(\lambda/3)}$

$E_{3\to1}=4E_{3\to2}$

$=4\frac{hc}{\lambda}$

$=\frac{hc}{(\lambda/4)}$

Therefore, these transitions will produce the wavelengths $\frac{\lambda}{3}$ and $\frac{\lambda}{4}$.

**28** Which one of the following statements, referring to a photoelectric emission, is true?

| | | |
|---|---|---|
| | **A** | No emission of electrons occurs for very low intensity illumination, even if the illumination's frequency is above the threshold frequency. |
| | **B** | For a given metal there is a minimum frequency of radiation below which no emission occurs. |
| | **C** | The velocity of the emitted electrons is proportional to the intensity of the incident radiation. |

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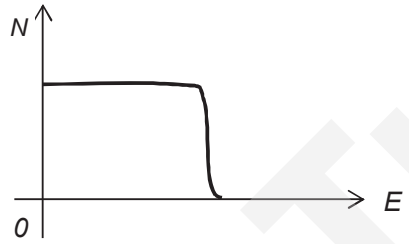
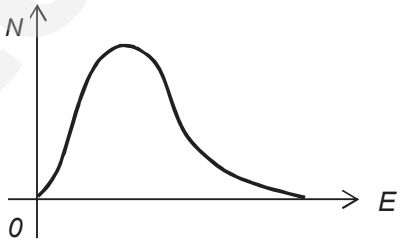
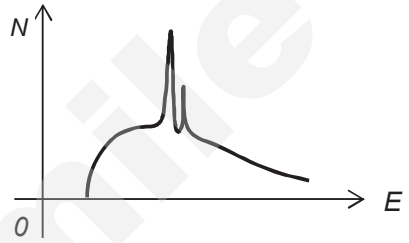
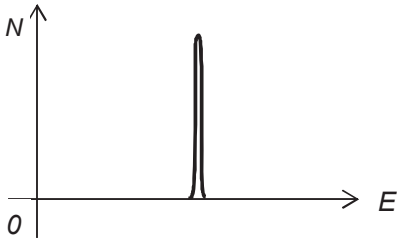
| | | |
|---|---|---|
| | **D** | The number of electrons emitted per second is dependent on the threshold frequency of the given metal if the frequency of the incident photon is higher than the threshold frequency. |
| | **Answer: B**<br><br>**Option A is incorrect: no emissions occurs for frequency lower than the threshold frequency**<br>**Option C is incorrect: The velocity of the emitted electrons is dependent on the photon energy and work function of metal surface**<br>**Option D is incorrect: The number of electrons emitted per second is independent of the threshold frequency.** | |

| | | | | |
|---|---|---|---|---|
| **29** | Which one of the following best represents the number *N* of alpha-particles emitted from a given radioactive source possessing energy *E* ? | | | |
| | **A** |  | **B** |  |
| | **C** |  | **D** |  |

**Answer: D**

**In alpha-decay, there are only 2 products: parent nucleus → daughter nucleus + alpha-particle (only one particular reaction, and no other forms of energy).**
**Hence to ensure conservation of momentum and conservation of energy, each product's speed and kinetic energy would be of fixed values.**

| **30** | Which nuclide has the greatest initial activity? | | | |
|---|---|---|---|---|
| | | nuclide | amount/mole | half-life/day |
| | **A** | $^{228}_{88}Ra$ | 0.7 | 2100 |
| | **B** | $^{225}_{89}Ac$ | 0.002 | 10 |
| | **C** | $^{228}_{90}Th$ | 0.09 | 400 |
| | **D** | $^{241}_{94}Pu$ | 0.09 | 4800 |

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**Answer: A**

**$A = \lambda N = (\ln 2 / t_{1/2})\ N$, where $N = n.N_A$ (i.e. $N \alpha n$)**
**$A \propto \frac{N}{t_{1/2}} \propto \frac{n}{t_{1/2}}$**
**Of the four options, option A gives the largest ratio $\frac{n}{t_{1/2}}$ hence greatest activity.**

**Option A: $3.33 \times 10^{-4}$**
**Option B: 0.0002**
**Option C: 0.000225**
**Option D: 0.00001875**

**-- END OF PAPER 1 –**

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# Catholic Junior College

## JC2 Preliminary Examinations

## Higher 2

**CANDIDATE NAME** **MARK SCHEME**

**CLASS** 2T

# PHYSICS

**9749/02**

Paper 2: Structured Questions

**26 August 2019**

**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 in the space provided. **[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 Paper 2.

| FOR EXAMINER'S USE | | DIFFICULTY | | |
|---|---|---|---|---|
| | | L1 | L2 | L3 |
| Q1 | / 10 | | | |
| Q2 | / 11 | | | |
| Q3 | / 11 | | | |
| Q4 | / 12 | | | |
| Q5 | / 8 | | | |
| Q6 | / 8 | | | |
| Q7 | / 20 | | | |
| PAPER 2 | / 80 | | | |

This document consists of **27** printed pages and **1** blank page.

**[Turn over**

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**PHYSICS 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$^{-1}$ |
| | | | $\approx (1/(36\pi)) \times 10^{-9}$ 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 | $k$ | = | $1.38 \times 10^{-23}$ mol$^{-1}$ |
| gravitational constant | $G$ | = | $6.67 \times 10^{-11}$ 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 | $\phi$ | = | $-\frac{Gm}{r}$ |
| temperature | $T/K$ | = | $T/^{\circ}C + 273.15$ |
| pressure of an ideal gas | $p$ | = | $\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E$ | = | $\frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x$ | = | $x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v$ | = | $v_0 \cos \omega t$ |
| | | = | $\pm \omega \sqrt{{x_0}^2 - x^2}$ |
| electric current | $I$ | = | $Anvq$ |
| resistors in series | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R$ | = | $1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V$ | = | $\frac{Q}{4\pi\varepsilon_o r}$ |
| alternating current / voltage | $x$ | = | $x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B$ | = | $\frac{\mu_o I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B$ | = | $\frac{\mu_o N I}{2r}$ |
| magnetic flux density due to a long solenoid | $B$ | = | $\mu_o n I$ |
| radioactive decay | $x$ | = | $x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda$ | = | $\frac{\ln 2}{t_{\frac{1}{2}}}$ |

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

**1** **(a)** A truck is accelerated from rest by a constant driving force. It experiences a drag force which is proportional to its speed. Eventually, the truck travels at a constant velocity.

Explain why the truck reaches a constant velocity.

.....

.....

.....

.....

.....

..... [2]

Due to the acceleration by the constant driving force, **truck's speed increases, hence the drag force** which opposes the driving force **increases in magnitude**. **B1**

**Eventually the drag force become equal in magnitude to the constant driving force.** Hence net force becomes zero, acceleration equals zero, hence constant velocity. **B1**

**(b)** On Fig. 1.1 sketch a graph to show how the acceleration of the truck varies with time from the time when it was at rest to the time when it reaches the constant velocity.

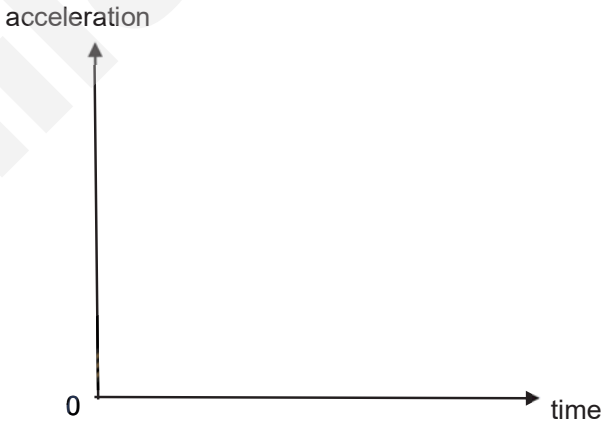


**Fig. 1.1** [1]

**Solution:**

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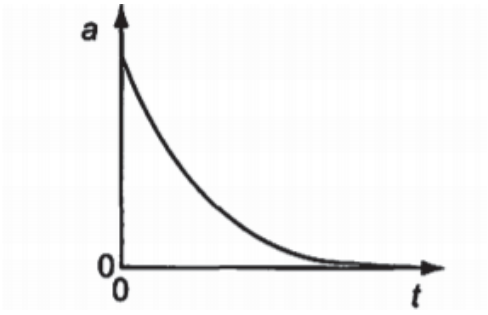
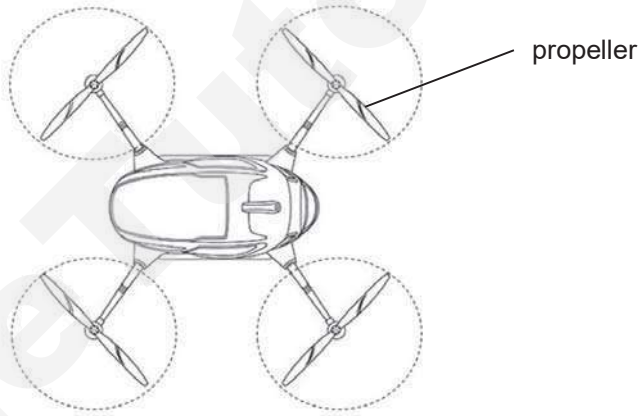



B1

– acceleration decreases and reaches zero
– acceleration decreasing at a decreasing rate from start to the end

**(c)** Fig. 1.2 shows a drone that is able to hover by rotating the four horizontal propellers attached to its body. The propellers push the air downwards and impart the air with a certain speed. The mass of the drone is 0.50 kg and each of the propellers has a radius of 15.0 cm.




Top view of a drone

**Fig. 1.2**

**(i)** Calculate the upward force by the air on the drone.

upward force = ..... N [1]

**For equilibrium,**
**Upward force = Downward force = mg = 0.50 x 9.81 = 4.905 = 4.9 N** **A1**

**(ii)** State, with a reason, the magnitude of the downward force exerted by all of the drone's propellers on the air.

.....

.....

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.....

.....

.....

..... [2]

**According Newton's 3rd Law, the downward force of the propellers on the air must be of the same magnitude as the upward force of the air on the propellers.** **M1**

**Total downward force = 4.9 N** **A1**

**(iii)** The density of air is 1.3 kg $m^{-3}$.

Determine using Newton's second law of motion the speed imparted to the air by the propellers.

speed = ..... m $s^{-1}$ [4]

L2 **Assume propellers push air downward with a speed v.**

**Total cross sectional area of the air (for 4 propellers)**
**= 4 x $\pi r^2$ = 4 x $\pi$ $(0.15)^2$ = 0.2827 $m^2$**
***[Alternatively, divide the total downwards force of 4.905 N by 4]***

**Mass of air being pushed per unit time**
**= A $\rho$ *v*** **M1**
**= 0.2827 x 1.3 x v**
**= 0.3676 v**

**Momentum gained by air per unit time**
**= 0.3676 v x $\Delta v$** **M1**
**= 0.3676 v x (*v* – *0*)**
**= 0.3676 $v^2$**

**Rate of change of momentum of air = 0.3676 $v^2$**

**By Newton's 2nd Law,**
**Total downwards force on air by 4 propellers** **M1**
**= Rate of change of momentum of air**
**4.905 = 0.3676 $v^2$** **A1**
**$v$ = 3.654 = 3.7 m $s^{-1}$**

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**2** **(a)** State the *first law of thermodynamics*.

.....

.....

.....

..... [2]

The **increase in internal energy** of a **closed system** is **equal to the sum of** **B2**
**heat supplied to the system** and the **work done on the system**.

***B1 – Correct quantities referred to***
***B1 – Directions clearly and correctly stated. Use of "sum of" or equivalent.***

**(b)** A fixed mass of monatomic ideal gas undergoes a cycle of changes A → B → C → A as shown in Fig. 2.1.

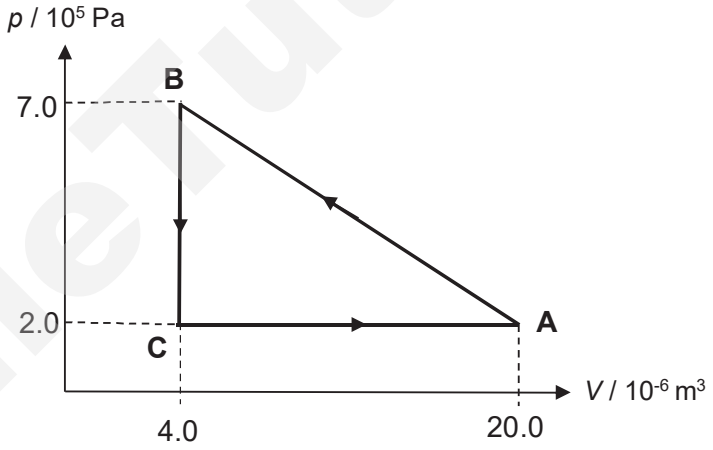


**Fig. 2.1**

**(i)** Explain why the change in internal energy of the ideal gas during a complete cycle A → B → C → A is zero.

.....

.....

.....

.....

.....

.....

.....

..... [2]

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L2 In a complete cycle, the (*p, V*) state of the gas returns to the original state. Therefore, using the equation of state of an ideal gas, the temperature of the gas also returns to the original temperature. **B1**

As the internal energy of an ideal gas is proportional to the thermodynamic temperature of the gas, there is no net change in the internal energy in a complete cycle. **B1**

**(ii)** Calculate the work done on the gas during the process from A to B.

work done on gas = ..... J [2]

L1 work done on gas

= area under the graph

$= \frac{1}{2}[(7.0+2.0)\times10^{5}]\left[(20.0-4.0)\times10^{-6}\right]$ **C1**

=7.2 J **A1**

**(iii)** Calculate the change in internal energy of the gas when it undergoes the process from A to B.

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

L2

*For a monoatomic ideal gas,*

$\Delta U = 3/2\ nR\Delta T = 3/2\ \Delta(pV)$ **M1**

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change in internal energy **A1**

$= \frac{3}{2}[(7.0\times10^{5})(4.0\times10^{-6})-(2.0\times10^{5})(20.0\times10^{-6})]$

$=-1.8$ J

**(iv)** Calculate the heat supplied to the ideal gas during the process from A to B.

heat supplied = ..... J [2]

**L1** Using 1st law of thermodynamics,
$\Delta U = Q + W$
$Q = -1.8 - (7.2)$ **C1**
$= -9.0$ J ***(No Negative, No marks)*** **A1**

**(v)** In a car engine, the expanding combustion gases push the piston which causes the car to move.

Suggest, with a reason, whether the cycle of changes A → B → C → A could be the cycle in the piston engine of a car.

.....

.....

.....

..... [1]

**L3** **Not possible, because for a car to move, there must be a positive net work done by the gas per cycle** in the piston engine. (i.e. net work done on gas is negative.) **B1**
Whereas the net work done by the gas in the cycle A→ B → C → A is negative.

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**3** **(a)** Two light identical springs are joined in series and a 120 g bar magnet is hung from the lower end as shown in Fig. 3.1. The effective spring constant of the combined springs is 11 N $m^{-1}$.

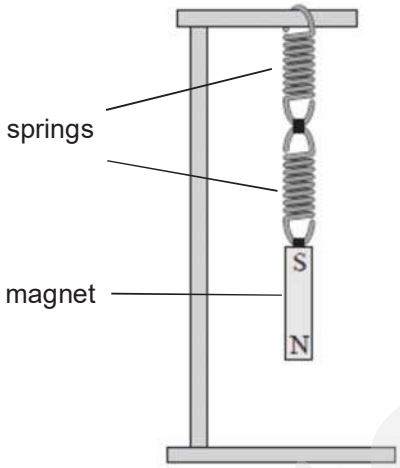


**Fig. 3.1**

The bar magnet is displaced a small distance vertically downward from its equilibrium position and released. It then oscillates in simple harmonic motion.

**(i)** By considering the forces on the magnet at its equilibrium position, and also at a small displacement *x* downward from its equilibrium position, show that the oscillation is a simple harmonic motion where the acceleration *a* is given by the equation

$$a = -92\,x$$

[4]

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Let downwards be positive.

Let e be the extension of the spring when the magnet is at its equilibrium position.

At the equilibrium position, **M1**
ke = mg ---------- (1)

At a displacement x downward from its equilibrium position, **M1**
mg – k(x + e) = ma
mg – kx – ke = ma -------- (2)

Sub (1) into (2):
- kx = ma **M1**
a = - (k/m) x
a = - [11/(120 x $10^{-3}$)] x **M1**
a = - 91.667 x
a = - 92 x (shown) **A0**

**(ii)** Hence calculate the frequency at which the magnet oscillates.

frequency = ..... Hz [2]

a = - 92 x
Comparing with the SHM equation, a = -$\omega^2$x,
$\omega^2$ = 92 **M1**
$\omega = \sqrt{92}$
$2\pi f = \sqrt{92}$
f = 1.5266 = 1.5 Hz **A1**

**(b)** Two systems in part **(a)** are now suspended with the North pole of their magnets located inside a coil of wire. The two coils are connected together with conducting leads as shown in Fig. 3.2.

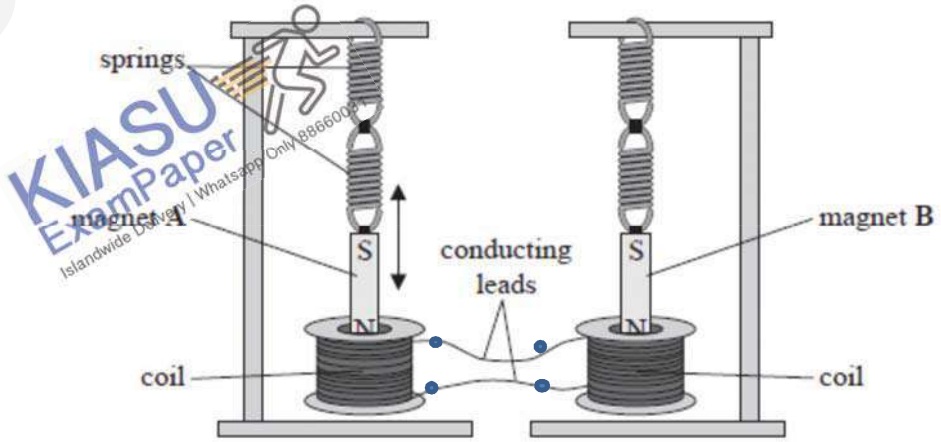


**Fig. 3.2**

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Magnet A is displaced so that it oscillates vertically. The North pole of magnet A moves into and out of the coil of wire with simple harmonic motion. As this motion continues, magnet B starts to oscillate. The amplitude of oscillation of magnet B increases over time.

Explain why magnet B starts to oscillate with an increasing amplitude.

[5]

**As magnet A moves in and out of the coil, its coil experiences a change of magnetic flux density and hence a change in magnetic flux linkage.** **B1**

**By Faraday's law, this change in magnetic flux linkage induces an electromotive force in the coil which then causes a current in both coils** (since the coils are connected to each other). **B1**

**The alternating current in the second coil creates a periodic force on magnet B** and driving it into a forced oscillation. **B1**

**Since both spring-magnet systems have the same natural frequency of oscillation,** **B1**

**resonance occurs** and thus there is a maximum transfer of energy from magnet A **to magnet B and magnet** B oscillates with increasing amplitude. **B1**

**4** **(a)** Define *electromotive force* of a cell, and explain its difference from the *terminal potential difference* across the terminals of the cell.

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.....

.....

.....

.....

..... [2]

**The electromotive force of a cell is the energy converted from other forms of energy into electrical energy per unit charge driven round a complete circuit.** **B1**

**Terminal potential difference across the battery however is the e.m.f of the cell less the loss volts across the internal resistance of the cell.** **B1**

**(b)** The variation with current $I$ of terminal potential difference $V$ across a battery with e.m.f. $E$ and internal resistance $r$ is shown in Fig. 4.1.

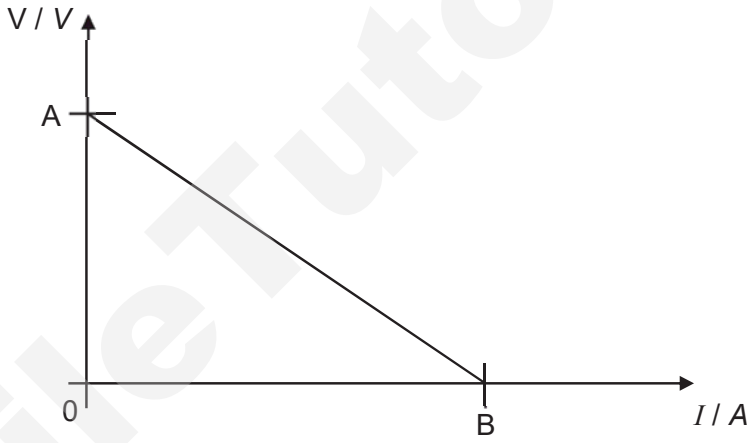


**Fig. 4.1**

In Fig. 4.1, state and explain the significance of the values of

**(i)** the vertical intercept, A;

.....

.....

..... [2]

**The vertical intercept is the value of the e.m.f. of the battery.** **M1**

**This is the potential difference across the battery when there is no current flowing through it hence zero potential difference across the internal resistance.** **A1**

**(ii)** the horizontal intercept, B.

.....

.....

.....

.....

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[2]

**The horizontal intercept is the value of the maximum current that will flow through the battery when there is no (external) resistance applied across it. (i.e. short circuit current)** **M1 A1**

**(c)** In an attempt to obtain the graph of Fig. 4.1 for the battery, a student sets up a circuit as shown in Fig. 4.2.

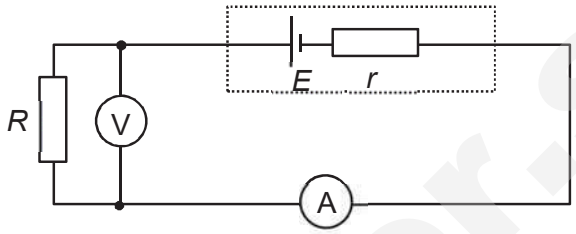


**Fig. 4.2**

State and explain why the circuit shown in Fig. 4.2 is inappropriate for obtaining data for the full range of values in Fig. 4.1.

[4]

**The resistor R used is a fixed resistor.** **B1**

**This would not allow the current to vary in Fig. 4.1, but the graph in Fig. 4.1 shows that there is a varying current in the circuit.** Thus it is not possible to have the variation of potential difference plotted while current is varying. **B1**

In addition, the **voltmeter will not be able to measure the e.m.f. of the battery as well as the current at lower values / voltage at higher values even when the fixed resistor has been replaced by a rheostat/variable resistor .** **B1**

**This is because** the rheostat cannot be adjusted to infinite resistance and thus **there would always be some current flowing through the circuit.** **B1**

**(d)** In the space below draw a circuit diagram, using the appropriate components, from which the full range of values in Fig. 4.1 may be obtained.

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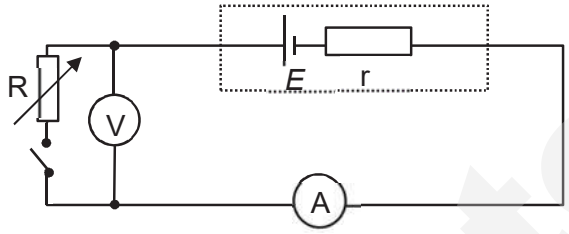
[2]

**Solution:**




- **Replace the fixed resistor with a rheostat.** **B1**
- **Add in a switch in series with the rheostat.** **B1**

**5** Fig. 5.1 shows a point source S emitting continuous waves at a distance *h* from a plane reflector R. As a result, regions of high intensity such as C, C' and C" are produced.

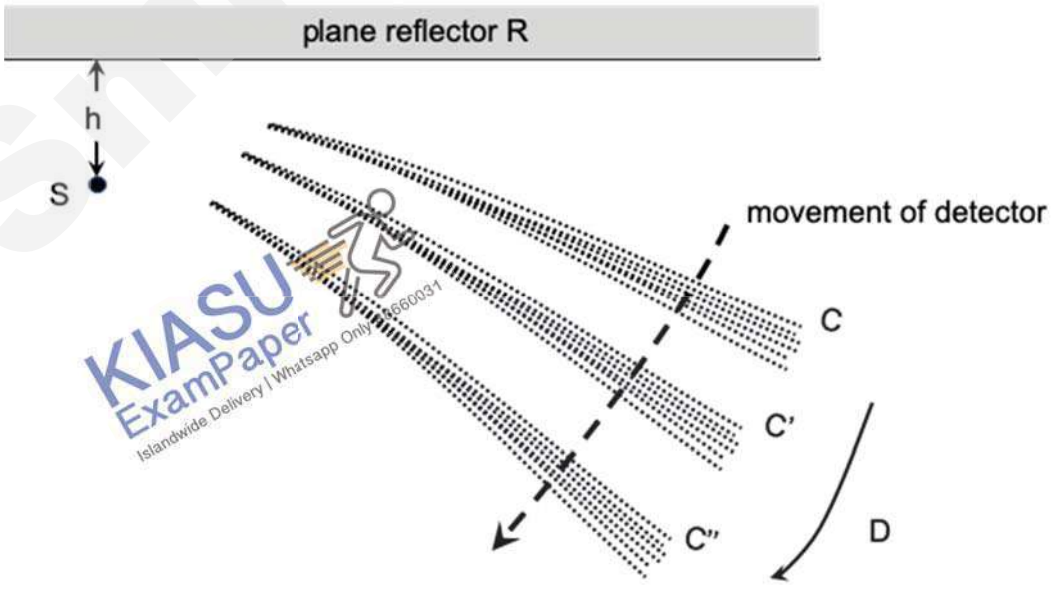



**Fig. 5.1**

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**(a)** Explain why regions of high intensity such as C, C' and C'' are produced.

[3]

When the waves are emitted from S, there are some waves that are **reflected off the reflector screen and directed towards the regions below R**.

**B1**

These reflected waves will then **meet the wave coming directly from S, that are directed towards the same regions**.

**B1**

When the reflected signal and the direct signal **meet in phase, constructive interference occurs**, and the resultant intensities will be increased, giving rise to C, C' and C''.

**B1**

**(b)** A detector is moved in the direction indicated by the dotted arrow in Fig. 5.1. Explain how the detected intensity of the waves would vary.

[3]

As the detector moves along the indicated path, it registers **alternating regions of high intensity and low intensity**.

**B1**

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However, as it moves from C to C", the **regions of high intensity are relatively lower in magnitude compared to the previous high intensity region** (e.g. C has a higher intensity compared to C' and likewise, C' has a higher intensity compared to C'). **B1**

The low intensity regions will also not remain at the same low intensity – meaning to say, **the contrast between the high and low intensity region would be poorer as we move from C to C'**. **B1**

**(c)** When the frequency of S is decreased slowly, the regions C, C' and C" move in the direction D as shown in Fig. 5.1. Explain this phenomenon.

[2]

When the frequency of the signal decreases, the **wavelength of the waves will increase**. **B1**

This will then **cause an increase in the path difference between the two waves meeting at the constructive interference fringes/intensity maxima**. **B1**
As such, previously the regions of high intensities will shift to the new positions where the waves will meet constructively again.

**6** **(a)** A simple a.c. generator which consists of a rectangular coil with 40 turns is rotating at 50 revolutions per second in a uniform magnetic field of flux density 50 mT. The coil is 50 cm long and 35 cm wide, as shown in Fig. 6.1.

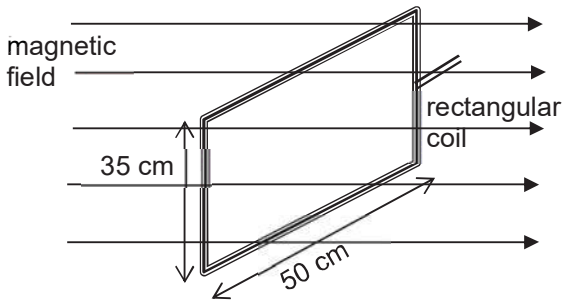


**Fig. 6.1**

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**(i)** Define *magnetic flux*.

---

---

---

[1]

The magnetic flux through a **plane surface** is defined as the **product of the magnetic flux density normal to the surface and the area of the surface.** **B1**

**(ii)** Calculate the maximum e.m.f. induced in the coil.

maximum e.m.f. = _____ V [2]

E = $NBA\omega$
= (40)(50 x $10^{-3}$)(50 x $10^{-2}$)(35 x $10^{-2}$)(2π)(50) **C1**
= 109.96 = 110 V (2 s.f.) **A1**

**(b)** The output from the generator in part **(a)** is connected to the input of a transformer. The transformer has 40 turns on its primary coil and 10 turns on its secondary coil. The transformer may be considered to be ideal. The output from the transformer is connected to a resistor of resistance 100 Ω and a diode, as shown in Fig. 6.2.

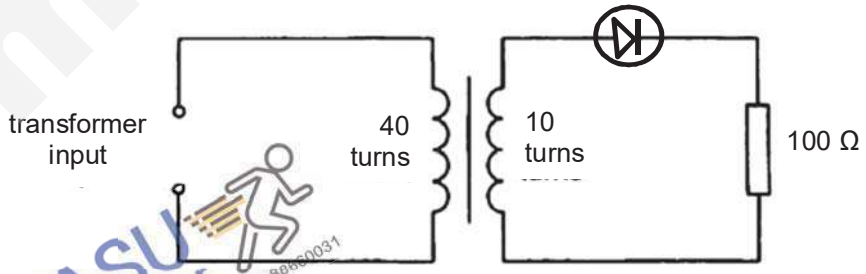


**Fig. 6.2**

Calculate the root-mean-square voltage across the resistor.

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root-mean-square voltage = ..... V [3]

Let $V_0$ be the peak voltage across the resistor.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$ **M1**

$$\frac{V_0}{110} = \frac{10}{40}$$

$V_0$ = 27.5 V (2 s.f.)

Since the voltage across the resistor is half-wave rectified,
Mean of $v_0^2$ for a half-wave rectified voltage
= area under the graph/period
= $(v_0^2 \times T)/(4 \times T)$
= $v_0^2/4$

Hence the root-mean-square, $V_{rms} = V_0/2$ **M1**
= 14 V (2 s.f.) **A1**

**(c)** In an attempt to draw the circuit diagram that represents the system in part **(b)**, a student drew Fig. 6.3 instead.

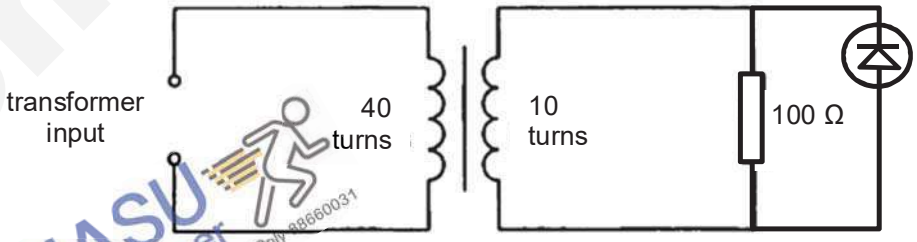


**Fig. 6.3**

Suggest, with a reason, what will happen if the circuit is set up according to Fig. 6.3.

.....

.....

.....

.....

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[2]

When the e.m.f. set up in the secondary circuit is such that the **diode is in forward bias, all / most current will by-pass the resistor and flow only via the diode back to the secondary coil**. **B1**

This means that the circuit will be short-circuited and the system could be damaged by **overheating**. **B1**

**7** When a very strong earthquake of magnitude 9.0 hit Japan on 11 March 2011, the accompanying tsunami caused the devastation of the Fukushima Dai-ichi Nuclear Power Plant (Fk-1). A large amount of radioactive material leaked out of Fk-1 as a result, mainly through cracks made by the quake on some reactors, explosions, intentional vents to relieve pressure, and leakage of cooling water that was contaminated with the melted fuel rod debris.

Fk-1 was capable of generating up to 4.7 gigawatts of power through neutron-induced fissions of Uranium-235 ($^{235}$U) nuclei. Fission resulting from neutron absorption is called *induced* fission. Some nuclides can also undergo *spontaneous* fission, but that is quite rare. Nuclear fission is a decay process in which an unstable nucleus splits into two fragments of comparable mass, although nearly equal mass is unlikely. Over 100 different nuclides, representing more than 20 different elements, have been found among the fission products. Fig. 7.1 shows the distribution of mass numbers for fission fragments from the fission of $^{235}$U. Fission yield refers to the percentage of a nuclide of a fission fragment produced per fission. Two or three free neutrons usually appear along with the fission fragments.

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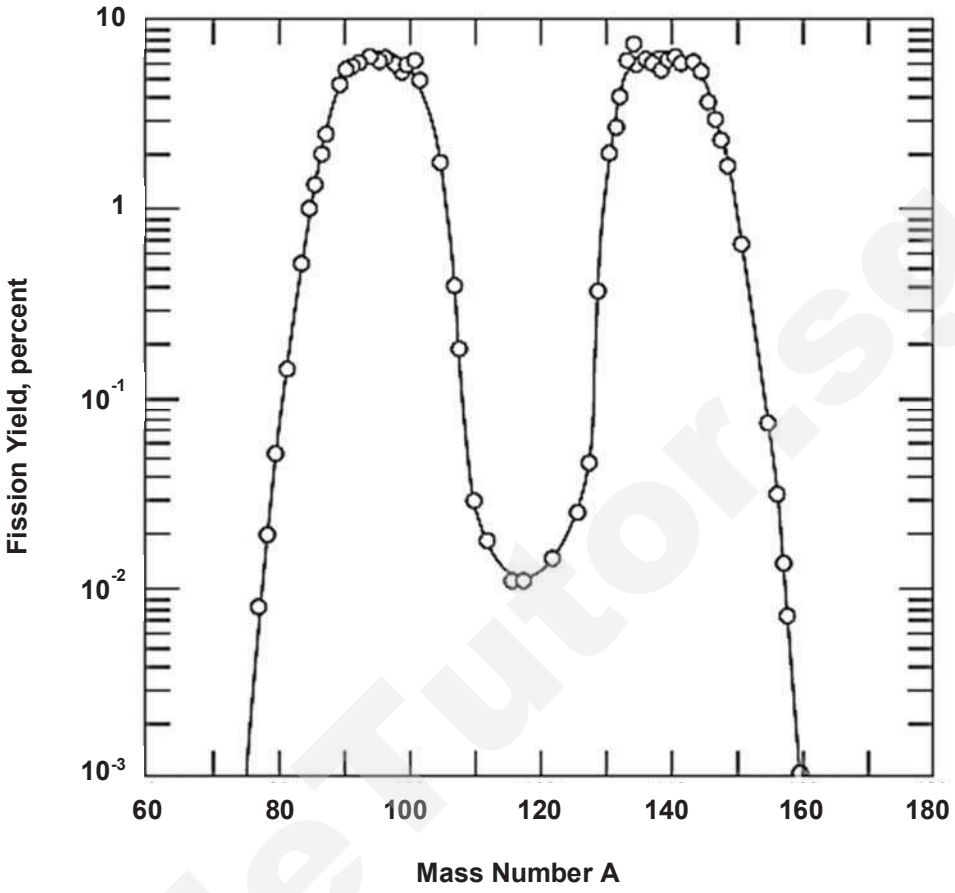


Source: https://www.quora.com/Why-is-promethium-produced-from-uranium-235

**Fig. 7.1**

The induced fission of $^{235}U$ may be represented by a nuclear equation of the form

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{a}_{b}P + {}^{c}_{d}Q + (2 \text{ or } 3){}^{1}_{0}n + \text{energy}$$

where P represents the lower mass number fission fragment, and Q represents the higher mass number fission fragment.

One day after the earthquake, elevated levels of Iodine-131, Cesium-134 and Cesium-137, which are common fission fragments of Uranium-235, were detected near the nuclear plant site. Fig. 7.2 shows some general information of the three fission fragments.

| Isotope | Symbol | Half-life |
|---|---|---|
| Iodine-131 | $^{131}_{53}I$ | 8.0197 days |
| Cesium-134 | $^{134}_{55}Cs$ | 2.065 years |
| Cesium-137 | $^{137}_{55}Cs$ | 30.17 years |

**Fig. 7.2**

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**(a)** Explain the difference between *induced* and *spontaneous* fission.

.....

.....

..... [1]

**Unlike spontaneous fission, induced fission requires initial neutron absorption to occur.** **B1**

*Candidates need to answer this question by reading the passage in context.*

**(b)** Suggest why the *percentage fission yield* in Fig. 7.1 is shown on a logarithmic scale.

.....

.....

..... [1]

Percentage fission yield varies over a wide range of many orders of magnitude. **B1**
OR
Logarithmic scale compresses the scale to accommodate the very wide range of percentage fission yield values.
OR
To enable plots on the graph to be well spaced while representing the very wide range of percentage fission yield values.

**(c)** Deduce the two most common ranges of mass numbers of the fission fragments (P and Q) of $^{235}U$.

most common range of mass numbers of P: ..... [1]

most common range of mass numbers of Q: ..... [1]

From Fig. 7.1,
Most common range of mass numbers of P: **90 to 100 (or 88 to 102)** **A1**
Most common range of mass numbers of Q: **135 to 145 (or 130 to 150)** **A1**

Note that Question has already defined P as the fragment with *lower* mass. So answers for P and Q cannot swop.
Marking points:
- Correct reading of the ranges of values.
- Answers for P and Q not swopped.

**(d)** **(i)** Uranium-235 undergoes nuclear fission to produce Rubidium-97 and Cesium-137. Write down the nuclear equation to represent this reaction. Use the chemical symbol Rb to represent Rubidium.

[2]

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$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{97}_{37}Rb + {}^{137}_{55}Cs + 2\,{}^{1}_{0}n + energy$$

- Correct value of proton number of Rb (= 37). **A1**
- Deduced that 2 neutrons are emitted. **A1**
- Deduct 1 mark for other mistakes e.g. used "=" instead of "→"; did not include ${}^{1}_{0}n$ on the LHS of the equation; wrong notations e.g. $n\,{}^{1}_{0}$ or ${}^{2}_{0}n$ instead of $2\,{}^{1}_{0}n$

Note: General equation is given in the question, hence no mark purely for writing the equation.

**(ii)** With reference to Fig. 7.1, state the percentage fission yield of

1. Cesium-137;
2. Rubidium-97.

Indicate clearly on Fig. 7.1, the points that you read off.

percentage yield of Cesium-137= ..... %

percentage yield of Rubidium-97 = ..... % [1]

6% for both. (Accept also 6.5%.) **A1**

Mark for correct method (clear indication of points read on Fig. 7.1).

Accept also if answers given a 6.5% for one, and 6% for the other.

**(iii)** Comment on the similarity of your answers in **(d)(ii)**.

.....

.....

.....

.....

..... [1]

Percentage yields of both should be similar since **they are produced from the same (unique) fission process**. So the probabilities of both of them forming are equal/same. **B1**

**(iv)** State the mass number of the other fission fragment produced if one of the fragments has a mass number of 81 in the nuclear fission of Uranium-235.

mass number = ..... [1]

**153 or 152** **A1**

**Method 1:**

Using $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{81}_{b}P + {}^{c}_{d}Q + (2 or 3)\,{}^{1}_{0}n + energy$

By conservation of mass number,

235 + 1 = 81 + c + (2 or 3)

c = 153 or 152

**Method 2:**

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Using Fig. 7.1,

1) Equal percentage fission yield for both. So draw a horizontal line across the "M" shaped curve in Fig. 7.1.
2) By conservation of mass number, and accounting for the neutrons present before and after the fission, it is necessary that either the two inner parts of the "M" shaped curve in Fig. 7.1 is read off, or the two outer parts.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{81}_{b}P + ^{c}_{d}Q + (2or3)\,^{1}_{0}n + energy$$

236 – 81 = 155
155 – 2 = 153 (if 2 neutrons)
155 – 3 = 152 (if 3 neutrons)

**(e)** Deduce which isotope in Fig. 7.2 will be about 47% as radioactive after 33 years.

isotope is ..... [2]

**L2** **Method 1:**
47% ≈ 50%, hence **M1**
33 years is close to the half-life of the isotope.
From Fig. 7.2, the isotope with a half-life close to 33 years is **Cesium-137**. **A1**

**Method 2:**
$A = A_o e^{-\lambda t}$ where $\lambda = \ln 2 / t_{1/2}$

"47% as radioactive" → $A / A_o = 0.47$

$0.47 = e^{-\lambda(33 years)}$
$\lambda = 0.022879$ years$^{-1}$
$\ln 2 / t_{1/2} = 0.022879$ years$^{-1}$
$t_{1/2}$ = ~30 years
**Answer: Cesium-137**

**(f)** The release of Iodine-131, Cesium-134 and Cesium-137 into the air, ground and seawater were monitored closely by the Japanese authority because they readily decay by emitting beta-particles and gamma-rays. For example, Cesium-137 decays into Barium-137 (Ba) through beta-emission.

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95% of Cesium-137 decays to a metastable excited nuclear energy state (Barium -137m) and is responsible for all emission of gamma-rays, while the other 5% directly decays to the ground state (Barium-137) of the nucleus. Fig. 7.4 illustrates the decay scheme of Cesium-137.

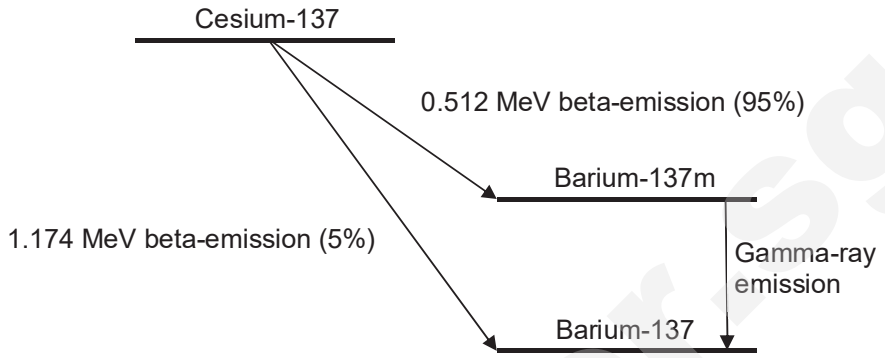


**Fig. 7.4**

Determine the photon energy of the gamma-rays emitted during Cesium-137 decay.

Energy of gamma-ray photon = 1.174 – 0.512 = **0.662 MeV** **A1**

energy = ..... MeV [1]

**(g)** Gamma spectroscopy is a technique used by scientists to identify specific radioactive products from the many possible products that can be produced from the nuclear fission of Uranium-235. Fig. 7.5 shows the gamma spectra measured at Kunimi, Fukushima Prefecture on both 19 March 2011 and 25 April 2011. Photon peaks generated by Tellurium-132, Iodine-131, -132, and Cesium-134, -136 and -137 were observed in the spectra given in Fig. 7.5. The photon peaks corresponding to Iodine-131 and Cesium-134 are indicated in Fig. 7.5.

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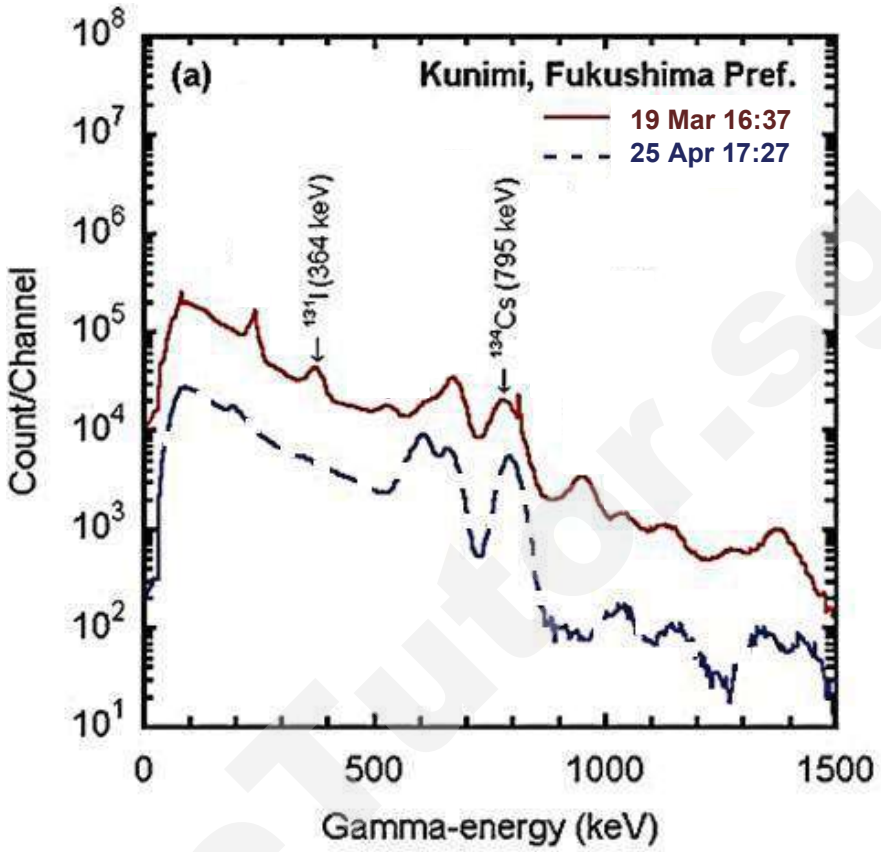


Source: https://www.nature.com/articles/srep00087 (modified)

**Fig. 7.5**

**(i)** Using your answer from **(f)**, indicate on Fig. 7.5 the position of Cesium-137 in the gamma spectra. [1]

**Solution:** **A1**

**0.662 MeV = 662 keV**

**Accept indication on either one of the solid or dotted line graphs.**

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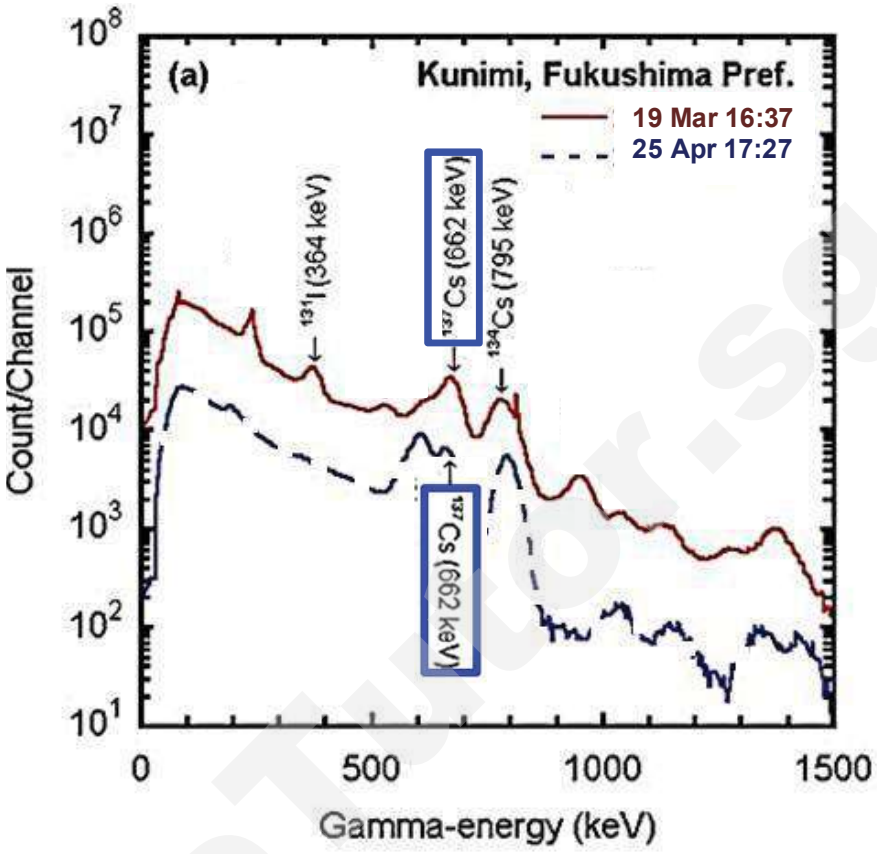


**(ii)** Suggest why no photon peak of Iodine-131 was observed on 25 April 2011.

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--- [1]

As seen from Fig. 7.2 , Iodine-131 has a short half-life of about 8 days, hence **a month after 19 March, on 25 April, about four half-lives had passed, hence most of the iodine would have already decayed**. **B1**

OR

Half life of Iodine-131 is only about 8 days, so by 25 April, yield of Iodine-131 is only 4.42% of that on 19 March which is significantly low.

[ About 36 days passed → $\frac{t}{t_{\frac{1}{2}}} = \frac{36}{8} = 4.5\ half\ lives\ passed$ →

$\frac{A}{A_o} = \left(\frac{1}{2}\right)^{4.5} = 0.0442$ → A = 4.42% ]

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**(h)** The sievert (Sv) is the SI unit of effective radiation dose. It is a measure of the biological effects of radiation. One sievert carries with it a 4% chance of developing a fatal cancer in an adult, and a 0.8% chance of hereditary defects in his or her future offspring. Doses greater than one sievert received over a short time period are likely to cause radiation poisoning, possibly leading to death within weeks.

Fig. 7.6 shows the dose rate of gamma-rays recorded by a monitoring car at Fukushima Daiichi Nuclear Power Station during the incident.

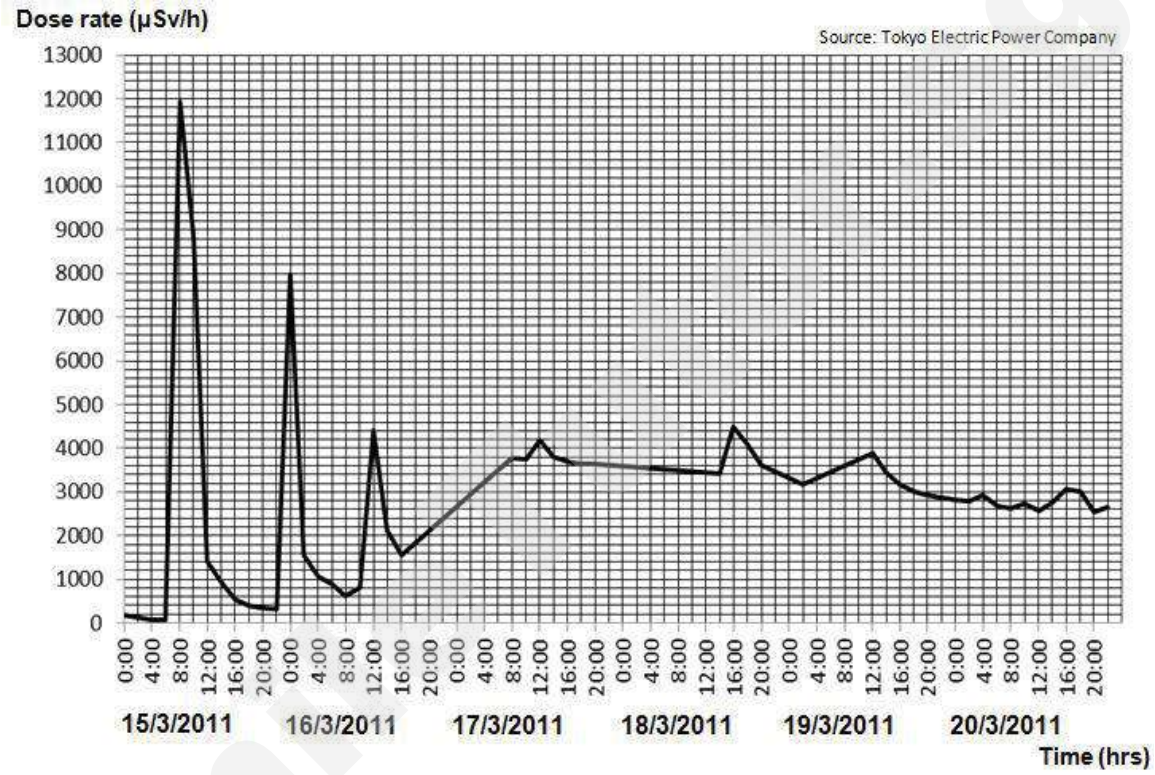


**Fig. 7.6**

On 15 March 2011, the Japanese Health and Labour Ministry increased the maximum permissible dose for Japanese nuclear workers from 100 mSv per year to 250 mSv per year for emergency situations.

If a worker was at the nuclear site from 16:00 hrs on 16/3/2011, estimate the time that he must be evacuated from the site before his life is in danger. Assume that the worker does not leave the site.

*Show evidence that **area under graph equals to the total dose**. **Find area equal to 250 mSv.*** **M1**
*Time should correspond to **19/3/2011 16:00 hrs**.* **A1**
***Allow a range from 19/3/2011 14:00 hrs to 19/3/2011 20:00 hrs**.*

***Accept also if students gave the total duration elapsed.***
***e.g. 3 days = 72 hrs***

time : _____ hrs
date: _____ [2]

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**(i)** Compare the three types of radioactive decay: alpha-decay, beta-decay and gamma-decay. Explain which of the three poses the greatest health risk if the source is:

**1.** outside the body;

.....

.....

.....

.....

..... [2]

**Gamma-decay. Because gamma-ray is the most penetrating** **B1**
**hence penetrate most deeply into the body and reach living tissues.** **B1**
**Alpha-particle cannot penetrate the skin. Beta-particle can penetrate the skin but cannot penetrate as deeply.**

**2.** ingested and enters the body.

.....

.....

.....

..... [2]

**Alpha-decay. Because alpha-particle is the most ionizing** **B1**
**hence produces the most number of free radicals per unit distance traveled inside the body / causes more extensive mutation of cells or DNA / highest cancer risk.** **B1**

**-- END OF PAPER 2 --**

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# Catholic Junior College

## JC2 Preliminary Examinations

## Higher 2

| | |
|---|---|
| CANDIDATE NAME | MARK SCHEME |
| CLASS | 2T |

# PHYSICS

**9749/03**

Paper 3: Longer Structured Questions

**29 Aug 2019**

**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 in the space provided. [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.

**Section A:** Answer **all** questions.

**Section B:** Answer **one** question only. **Circle** the question number attempted in Section B.

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

| FOR EXAMINER'S USE | | DIFFICULTY | | |
|---|---|---|---|---|
| | | L1 | L2 | L3 |
| SECTION A | | | | |
| Q1 | / 4 | | | |
| Q2 | / 9 | | | |
| Q3 | / 9 | | | |
| Q4 | / 14 | | | |
| Q5 | / 6 | | | |
| Q6 | / 11 | | | |
| Q7 | / 7 | | | |
| SECTION B | | | | |
| Q8 | / 20 | | | |
| Q9 | / 20 | | | |
| PAPER 3 | / 80 | | | |
| PAPER 2 | / 80 | | | |
| PAPER 1 | / 30 | | | |
| TOTAL FOR THEORY | / 190 | | | |

This document consists of **28** printed pages and **zero** blank page.

**[Turn over**

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**PHYSICS 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$^{-1}$ |
| | | | $\approx (1/(36\pi)) \times 10^{-9}$ 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 | $k$ | = | $1.38 \times 10^{-23}$ mol$^{-1}$ |
| gravitational constant | $G$ | = | $6.67 \times 10^{-11}$ 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 | $\phi$ | = | $-\frac{Gm}{r}$ |
| Temperature | $T/K$ | = | $T/^{\circ}C + 273.15$ |
| pressure of an ideal gas | $p$ | = | $\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E$ | = | $\frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x$ | = | $x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v$ | = | $v_0 \cos \omega t$ |
| | | = | $\pm \omega \sqrt{x_0^{\,2} - x^2}$ |
| electric current | $I$ | = | $Anvq$ |
| resistors in series | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R$ | = | $1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V$ | = | $\frac{Q}{4\pi\varepsilon_o r}$ |
| alternating current / voltage | $x$ | = | $x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B$ | = | $\frac{\mu_o I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B$ | = | $\frac{\mu_o N I}{2r}$ |
| magnetic flux density due to a long solenoid | $B$ | = | $\mu_o n I$ |
| radioactive decay | $x$ | = | $x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda$ | = | $\frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

| | | | |
|---|---|---|---|
| **1** | **(a)** | State *Newton's second law of motion*. | |
| | | | |
| | | | |
| | | | |
| | | | [2] |
| | | The **rate of** change of momentum of a body is (directly) **proportional** to the **net** force acting on it, and,<br><br>the direction of momentum **change** is in the direction of the **net** force. | |
| | **(b)** | Use Newton's second law of motion to deduce the principle of conservation of linear momentum. | |
| | | ……<br>……<br>……<br>……<br>…… | [2] |
| | | From Newton's 2nd law of motion, if a system experiences **no net** (external) **force**, (the rate of change of momentum of the system must also be zero).<br><br>Thus there is no change in **total** momentum of the system / the **total** momentum of a system remains constant / is conserved. | |

| | |
|---|---|
| **2** | A student constructs a potentiometer as shown in Fig. 2.1. The driver battery has negligible internal resistance and an e.m.f. of $E_1$ = 2.0 V. Wire PQ has a total length of 50.0 cm and resistivity $\rho$. Wire PQ also has a total resistance of 10.0 Ω. Unfortunately, there is a defect in wire PQ (shaded in Fig. 2.1) where that part of the wire has a cross-sectional area, $S$, that is half of the rest of the wire. This defective portion has a length that is denoted by $x$. |

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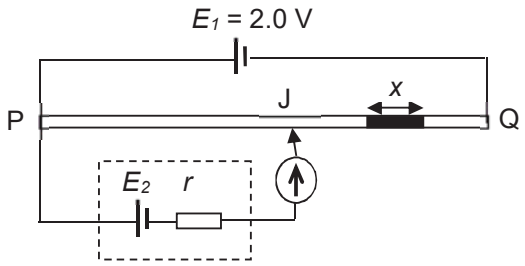


**Fig. 2.1**

The student carried out an experiment and determined that the e.m.f. $E_2$ was 1.01 V. The balance length PJ which did not include the defective portion, was 25.5 cm.

**(a)** When the potentiometer is balanced, determine the current $I_{PQ}$ in the wire PQ.

current, $I_{PQ}$ = ..... A [1]

$$I = \frac{V}{R} = \frac{2.0}{10.0} = 0.20 \text{ A}$$

**(b)** **(i)** Using your answer from **(a)**, obtain an expression for

**1.** $V_{PJ}$, the potential difference between points P and J, in terms of $S$ and $\rho$;

[1]

$$V_{PJ} = I_{PQ} R_{PJ}$$
$$= (0.20) \frac{\rho(0.255)}{2S}$$
$$= 0.0255 \frac{\rho}{S}$$

***Accept if candidate did not convert 25.5 cm to 0.255 m.***

**2.** $V_{PQ}$, the potential difference between points P and Q, in terms of $\rho$, $S$ and $x$.

[1]

$$V_{PQ} = I_{PQ} R_{PQ}$$
$$= (0.20) \left[ \frac{\rho(0.500 - x)}{2S} + \frac{\rho x}{S} \right]$$

***Accept if candidate did not convert 50.0 cm to 0.500 m.***

**3.** Hence determine the defective length, $x$.

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$x$ = ..... cm [2]

**From part 1:** $V_{PJ} = 0.0255\frac{\rho}{S}$ ---------- (1)

**From part 2:** $V_{PQ} = (0.20)\left[\frac{\rho(0.50 - x)}{2S} + \frac{\rho x}{S}\right]$ ----------(2)

$$\frac{(1)}{(2)} : \quad \frac{V_{PJ}}{V_{PQ}} = \frac{0.0255\frac{\rho}{S}}{(0.20)\left[\frac{\rho(0.50 - x)}{2S} + \frac{\rho x}{S}\right]}$$

$$\frac{1.01}{2.0} = 0.5\left[\frac{1}{(0.50 - x) + 2x}\right]$$

$$0.50495 = 0.50 + x$$

$$x = 4.95 \times 10^{-3}\ \text{m} = 0.495\ \text{cm}$$

**(c)** In a further experiment, the student swaps the connections to the wire PQ and repeats the measurement, as shown in Fig. 2.2.

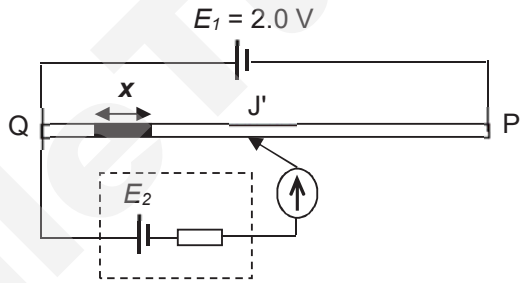


**Fig. 2.2**

State and explain if the new balance length QJ' would be shorter, longer or unchanged from the set-up in Fig. 2.1.

.....

.....

.....

.....

.....

..... [4]

**For balance length, <u>the potential difference across QJ' must still be equal to $E_2$</u>.**

**<u>Since the same current flow through PQ, the resistance of length QJ' of the potentiometer wire must be the same/equal as before</u>.**

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**Since the defective portion has a smaller cross-sectional area, it would have a higher resistance compared to the non-defective portion of similar length.**

**the balance length QJ' is shorter.**

**3** A binary star system shown in Fig.3.1 consists of two stars orbiting around their common centre of mass, P. One such binary star system is known as Sirius where the mass of Sirius A is twice the mass of Sirius B. The mass of Sirius B is $1.99 \times 10^{30}$ kg.

Sirius A is at a distance of $\frac{1}{3}D$ from P. Sirius B is at a distance of $\frac{2}{3}D$ from P.

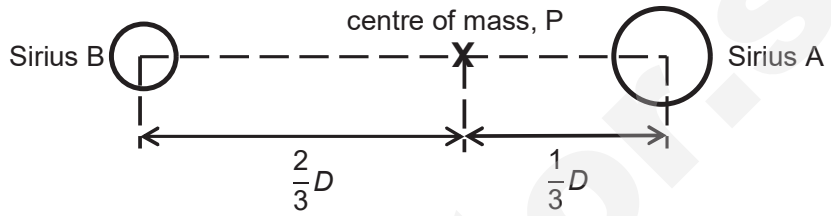


**Fig. 3.1**

**(a)** State *Newton's law of gravitation*.

.....

.....

.....

..... [2]

The mutual gravitational force of attraction between two point masses is

(directly) proportional to the product of their masses and inversely proportional to the square of their distance apart.

**(b)** The orbital period of this binary star system is 50 years. Determine the distance $D$ between the binary stars, assuming that the stars move in circular orbits.

distance $D$ = ..... m [4]

The centripetal force is provided by the gravitational force.

Consider Sirius B:

$F_g = F_c$

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$\frac{GM(2M)}{D^2} = M\omega^2\left(\frac{2D}{3}\right)$

$\frac{GM(2M)}{D^2} = M\left(\frac{2\pi}{T}\right)^2\left(\frac{2D}{3}\right)$

$D^3 = 3GMT^2/4\pi^2$

$= 3 \times 6.67\times10^{-11}\times 1.99 \times 10^{30}\times (365\times50\times24\times60\times60)^2 / 4\pi^2$

$D = 2.93 \times 10^{12}$ m

***Solution may also be obtained considering Sirius A.***

**(c)** Determine the speed of a probe, originally at rest at infinity, when it reaches the centre of mass of the star system.

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

**L2** By principle of conservation of energy,

Gain in kinetic energy = Loss in gravitational potential energy

$KE_f - KE_i = GPE_i - GPE_f$

$$\frac{1}{2}mv^2 - 0 = 0 - \left[G\left(\frac{M_A m}{R_A}\right) + G\left(\frac{M_B m}{R_B}\right)\right]$$

$$v = \sqrt{\frac{4\times6.67\times10^{-11}\times1.99\times10^{30}}{\frac{1}{3}(2.93\times10^{12})} + \frac{6.67\times10^{-11}\times1.99\times10^{30}}{\frac{2}{3}(2.93\times10^{12})}}$$

$$= \sqrt{\frac{3(6.67\times10^{-11}\times1.99\times10^{30})}{(2.93\times10^{12})}\times\left(4+\frac{1}{2}\right)}$$

$= 26100$ m s$^{-1}$

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**4** **(a)** Fig. 4.1 shows two identical small positive charged spheres A and B, each having a mass of $5.0 \times 10^{-4}$ kg in equilibrium. Sphere A is fixed in position by an insulated rod while sphere B is free to move and attached to the ceiling by a string with length 0.20 m.

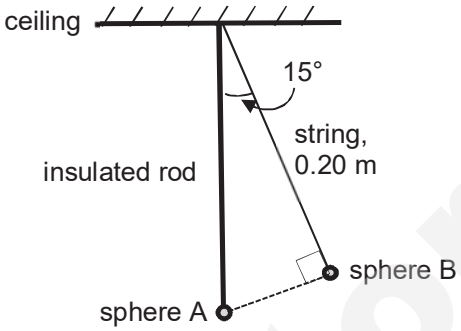


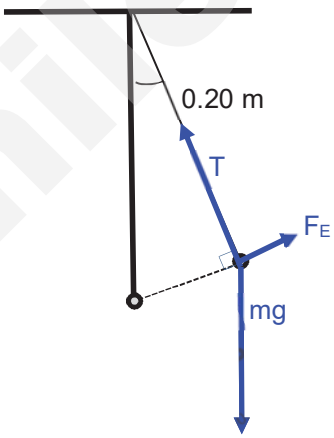

**Fig. 4.1**

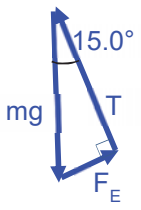
The string suspends at an angle of 15° to the vertical insulating rod and it also makes a right angle with the straight line connecting the two spheres.

Calculate

**(i)** the repulsive force acting on sphere B due to sphere A;

Draw FBD of sphere B:




Rearranging the vectors, we form a vector triangle

$$\sin 15° = \frac{F_E}{mg}$$

$F_E = 5 \times 10^{-4} \times 9.81 \times \sin 15°$
$= 1.27 \times 10^{-3}$ N
$= 1.3 \times 10^{-3}$ N (2 s.f.)

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repulsive force = …… N [3]

**(ii)** the magnitude of the charge on each sphere.

By Coulomb's law: $F_E = q_1q_2/4\pi\varepsilon_o r^2 = q^2/\{4\pi\varepsilon_o[(0.20 \tan (15°)]^2\}$

$q = (0.20 \tan (15°))\sqrt{(4\pi(8.85 \times 10^{-12})(1.27 \times 10^{-3})}$
$= 2.01 \times 10^{-8}$ C
$= 2.0 \times 10^{-8}$ C (2 s.f.)

charge = ……C [2]

**(b)** Sphere B connected with the same string as part **(a)** is now projected into the page at a speed of 0.50 m $s^{-1}$ such that it orbits horizontally around the same vertical insulating rod as shown in Fig. 4.2.

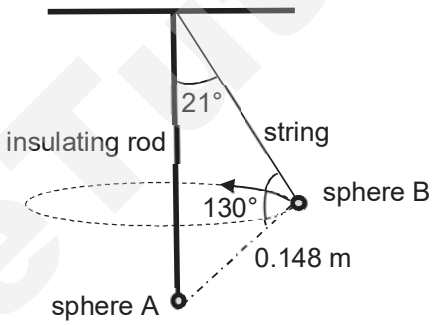


**Fig. 4.2**

The string makes an angle of 21° with the insulating rod. The distance between sphere A and sphere B is now found to be 0.148 m and the angle between the string and this line connecting sphere A and B is now 130°.

**(i)** Show that the resultant horizontal force on sphere B is $1.7 \times 10^{-3}$ N.

The resultant horizontal force is the centripetal force,

$F_c = mv^2/r$
$= 5.0 \times 10^{-4} \times (0.50)^2/ (0.20 \sin 21°)$
$= 1.74 \times 10^{-3}$ N
$= 1.7 \times 10^{-3}$ N

[2]

**(ii)** Calculate the tension in the string.

The resultant horizontal force by the horizontal component of tension and the horizontal component of the electrostatic force provides the centripetal force.

The new electrostatic force

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$= \frac{1}{4\pi\varepsilon_0}\frac{qq}{r^2}$

$= \frac{1}{4\pi(8.85\times10^{-12})}\frac{(2.01\times10^{-8})^2}{0.148^2}$

$= 1.642 \times 10^{-4}$ N

Hence,

$T \sin 21° - F_E \cos 61° = F_c$

$T \sin 21° - 1.642 \times 10^{-4} \cos 61° = 1.74 \times 10^{-3}$

$T = 5.1 \times 10^{-3}$ N (2 s.f.)

tension = ..... N [3]

**(c)** A uniform magnetic field perpendicular to the motion of sphere B is now introduced to the system in part **(b)** as shown in Fig. 4.3.

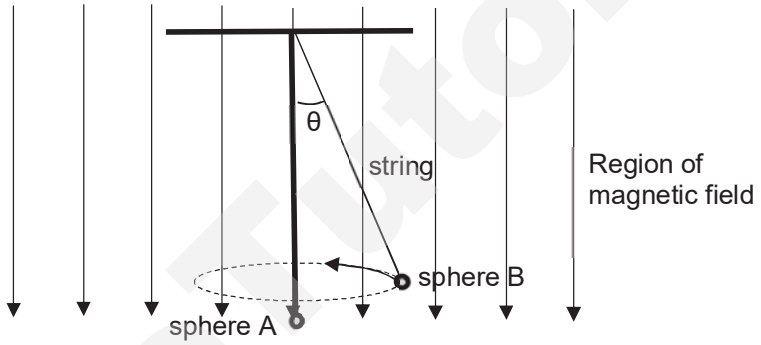


**Fig. 4.3**

Discuss how this might affect the subsequent motion of sphere B.

With the introduction of the magnetic field, there will be magnetic force directed horizontally towards the vertical insulating rod on sphere B.

The magnitude of the centripetal force will therefore increase.

Hence the speed of motion increase, and/or, the radius of circular motion will decrease.

[3]

**(d)** In the presence of air, sphere B and A will slowly discharge as they ionize the air particles around them.

Describe the path of sphere B when this happens.

It will spiral inwards / towards sphere A (and eventually come to a stop).

[1]

**5** **(a)** State two differences between a progressive wave and a stationary wave.

**difference 1** .....

.....

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.....

**difference 2** .....

.....

.....

[2]

**Any two of the following (1 mark each):**

- The amplitude in a stationary wave varies from zero to a maximum (2A) at the antinode, whereas the amplitude is the same for all points in a progressive wave.
- Between any 2 adjacent displacement nodes, all points in a stationary wave are always at the same phase of oscillation; points in adjacent nodal loops are always oscillating in antiphase. However, for a progressive wave, all points within one wavelength are in different phases of oscillation.
- Waveform of a stationary wave does not advance, whereas the waveform of a progressive wave advances (with the velocity of the wave).
- No energy is transferred along a stationary wave, whereas energy is transferred from point to point in the direction of travel of the progressive wave.

**(b)** Two coherent radiowave sources $S_1$ and $S_2$ that are in phase face each other, separated by a distance of 1.25 m, as shown in Fig. 5.1. Point P is located along line AB, *x* metres away from A.

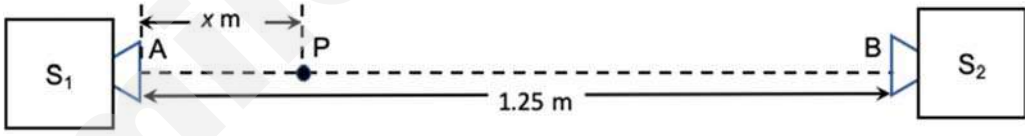


**Fig. 5.1**

**(i)** Show that the positions of minimum intensity along the line AB can be described by the following equation:

$$2L = (2n+1)\lambda$$

where
*L* is the path difference between the waves from $S_1$ and $S_2$,
*n* is any integer and
$\lambda$ is the wavelength of the radiowaves.

[1]

Since the 2 sources are in phase, for locations where minimum intensity is located, the path difference between the 2 waves must be an odd number integer of half wavelength.

$L = (2n+1)\frac{\lambda}{2}$

$2L = (2n+1)\lambda$

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| | | | | |
|---|---|---|---|---|
| | | | | |
| | | **(ii)** | Determine the number of points along AB where minima would be expected when radiowave signals of wavelength 0.429 m are produced. | |
| | | | number of points = …….. | [3] |
| | | | Method 1<br>**1.25 / 0.429 = 2.9 wavelengths**<br>**= 5.8 half-wavelengths**<br>**→ 6 nodal points**<br><br>Method 2<br>2L =(2n+1)λ<br>**2(1.25 - 2x) =(2n+1)λ**<br>2.5 - 4x =(2n+1)λ<br>2.5 - 4x =(2n+1)(0.429)<br>$x=\frac{(2n+1)(0.429)-2.5}{-4}$<br><br>Since $0 \leq x \leq 1.25$<br><br>$0 \leq \frac{(2n+1)(0.429)-2.5}{-4} \leq 1.25$<br>$-5 \leq (2n+1)(0.429)-2.5 \leq 0$<br>$-2.5 \leq (2n+1)(0.429) \leq 2.5$<br>$-3.41 \leq n \leq 2.41$<br><br>Therefore, n = -3, -2, -1, 0, 1 and 2.<br>**There are 6 positions.**<br><br>Method 3<br>2L =(2n+1)λ<br>**2(1.25 - 2x) =(2n+1)λ**<br>2.5 - 4x =(2n+1)λ<br>2.5 - 4x =(2n+1)(0.429)<br>$x=\frac{(2n+1)(0.429)-2.5}{-4}$<br><br>Substitute n = 0, 1, 2, -1, -2, -3…. until x cannot be more then 1.25 m, or less than 0 m. **There will only be 6 possibilities**.<br><br>***Mark scheme for Methods 2 & 3:***<br>***1 mark: correct derivation of expression for x***<br>***1 mark: correct calculations of x for the substitutions***<br>***1 mark: final answer (n has 6 possibilities)*** | |

| | | |
|---|---|---|
| **6** | **(a)** | A metal plate has work function of 4.5 eV. When ultraviolet radiation of wavelength 120 nm is incident on the plate, a photoelectric current is detected. |

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**(i)** Calculate the maximum speed of the photoelectrons as a result of this illumination.

maximum speed = ..... m $s^{-1}$ [2]

Using the Einstein photoelectric equation,

$$hf = \phi + KE_{max}$$

$$hf = \phi + \frac{1}{2} m_e v_{max}^2$$

$$v_{max} = \sqrt{\frac{2\left(h\frac{c}{\lambda} - \phi\right)}{m_e}}$$

$$= \sqrt{\frac{2\left(6.63\times10^{-34} \times \frac{3.0\times10^{8}}{120\times10^{-9}} - 4.5\times1.6\times10^{-19}\right)}{9.11\times10^{-31}}}$$

$$= 1.43\times10^{6} \text{ m s}^{-1}$$

**(ii)** The uncertainty in the speed of the photoelectrons in **(a)(i)** is 0.50%. Assuming that the photoelectrons are moving in the horizontal direction,

**1.** determine the uncertainty in the horizontal momentum of the photoelectrons;

uncertainty = ..... N s [3]

Momentum of the electron:

$$p_x = m_e v_x$$

$$= 9.11 \times10^{-31} \times 1.43\times10^{6}$$

$$= 1.30 \times10^{-24} \text{ kg m s}^{-1}$$

$\frac{\Delta p_x}{p_x} = \frac{\Delta v_x}{v_x} = \frac{0.50}{100}$ since mass of electron is constant

$$\frac{\Delta p_x}{p_x} = \frac{0.50}{100}$$

$$\Delta p_x = \frac{0.50}{100} \times 1.30 \times10^{-24}$$

$$= 0.70 \times10^{-26} \text{ kg m s}^{-1}$$ *(must be 2 s.f. Do NOT accept 1 s.f.)*

**2.** determine the minimum uncertainty in the position of the electron.

uncertainty = ..... m [2]

Applying Heisenberg's uncertainty principle,

$$\Delta p_x \Delta x \gtrsim h$$

$$\Delta x \gtrsim \frac{h}{\Delta p_x}$$

$$\Delta x \gtrsim \frac{6.63\times10^{-34}}{0.70 \times10^{-26}}$$

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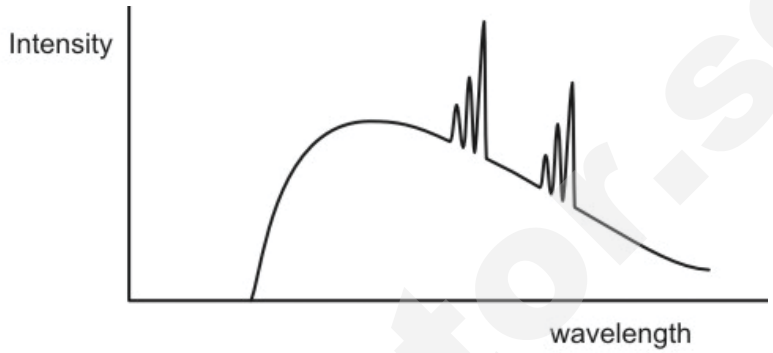
| | | | | | |
|---|---|---|---|---|---|
| | | | | $= 9.5\times10^{-8}$ m<br><br>*Also accept if candidate uses the exact form of Heisenberg's uncertainty principle* $\Delta p_x \Delta x \geq \frac{h}{4\pi}$ | |
| | **(b)** | Fig. 6.1 shows an x-ray spectrum.<br><br>  <br><br><br>**Fig. 6.1**<br><br>Describe how the continuous spectrum is produced. | | | |
| | | ……<br><br>……<br><br>……<br><br>……<br><br>……<br><br>…….. | | | [4] |
| | | **A high speed electron** interacts with the nucleus of a target metal.<br>It experiences a net force **due to** the electric force exerted by the target nucleus, and thus **accelerates/decelerates**. This **produces an x-ray photon of energy equal to the kinetic energy lost by the incident electron** via Bremsstrahlung process.<br><br>**If an electron has excess kinetic energy after the deceleration**, it will continue to interact with another nucleus in the metal, and undergo another Bremsstrahlung process / further deceleration, emitting another photon of a different wavelength.<br><br>**This process continues** until the incident electrons completely loses its kinetic energy. **This series of Bremsstrahlung processes / series of decelerations produce photons of a (continuous) range of wavelengths.** | | |

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| | | | | |
|---|---|---|---|---|
| **7** | **(a)** | State experimental evidence to suggest that the process of radioactive decay is | | |
| | | **(i)** | random; | |
| | | | ……<br>…… | [1] |
| | | | **The points on a count rate against time graph scatter about the (exponential) line of best fit.**<br>**OR**<br>**Measured count rate fluctuates** from instant to instant in time. | |
| | | **(ii)** | spontaneous. | |
| | | | ……<br>…… | [1] |
| | | | **The rate of decrease of the measured count rate is unaffected by external stimuli and changes in physical conditions.**<br>**OR**<br>**Repeated experiments under different physical conditions result in no change in the rate of decrease of the measured count rate.**<br><br>***Answers must refer to an observable measurement e.g. "measured count rate".*** | |
| | | | | |
| | **(b)** | A student measured the count rate from a sample of pure iodine-131 at various times. The results are shown in Fig. 7.1. Iodine-131 decays by beta emission to form xenon-131 which is stable. | | |

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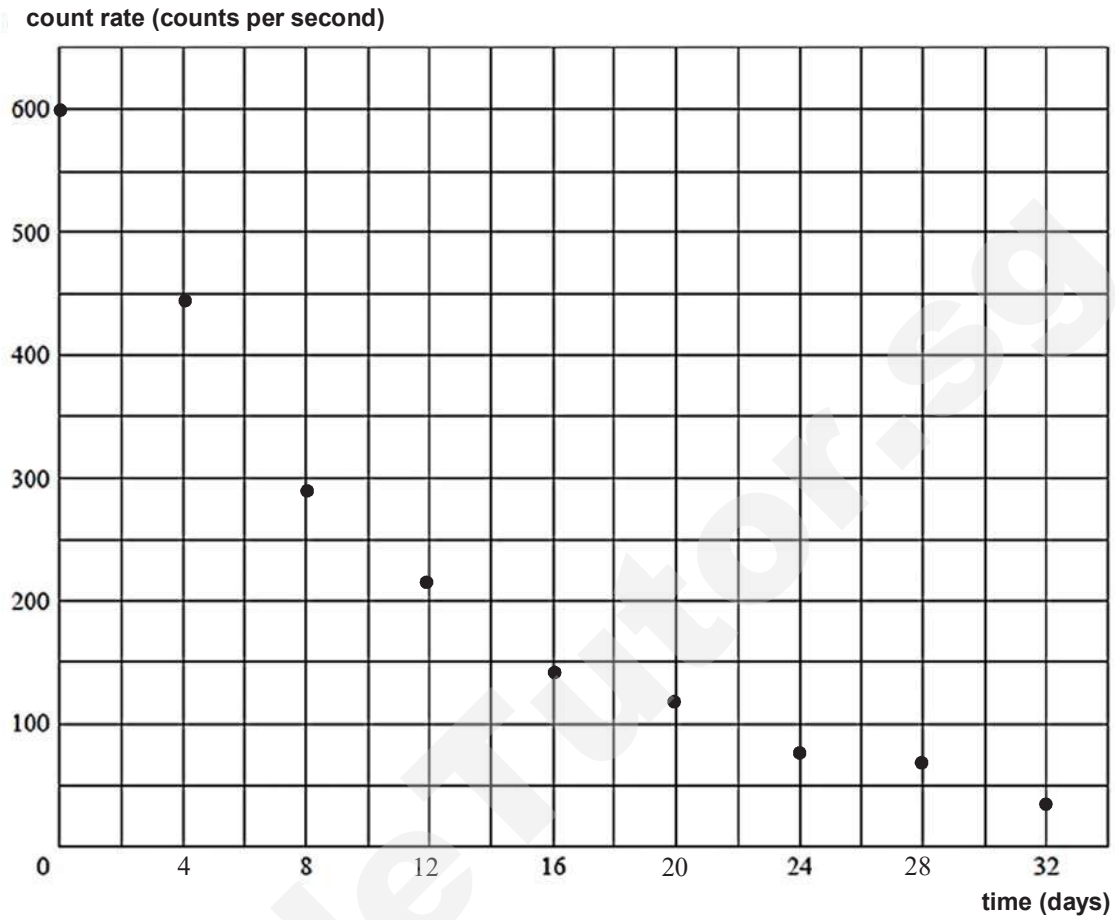


**Fig. 7.1**

| | | | |
|---|---|---|---|
| | | Use Fig. 7.1 to determine a value for the half-life, in days, of iodine-131. | |

**Solution:**

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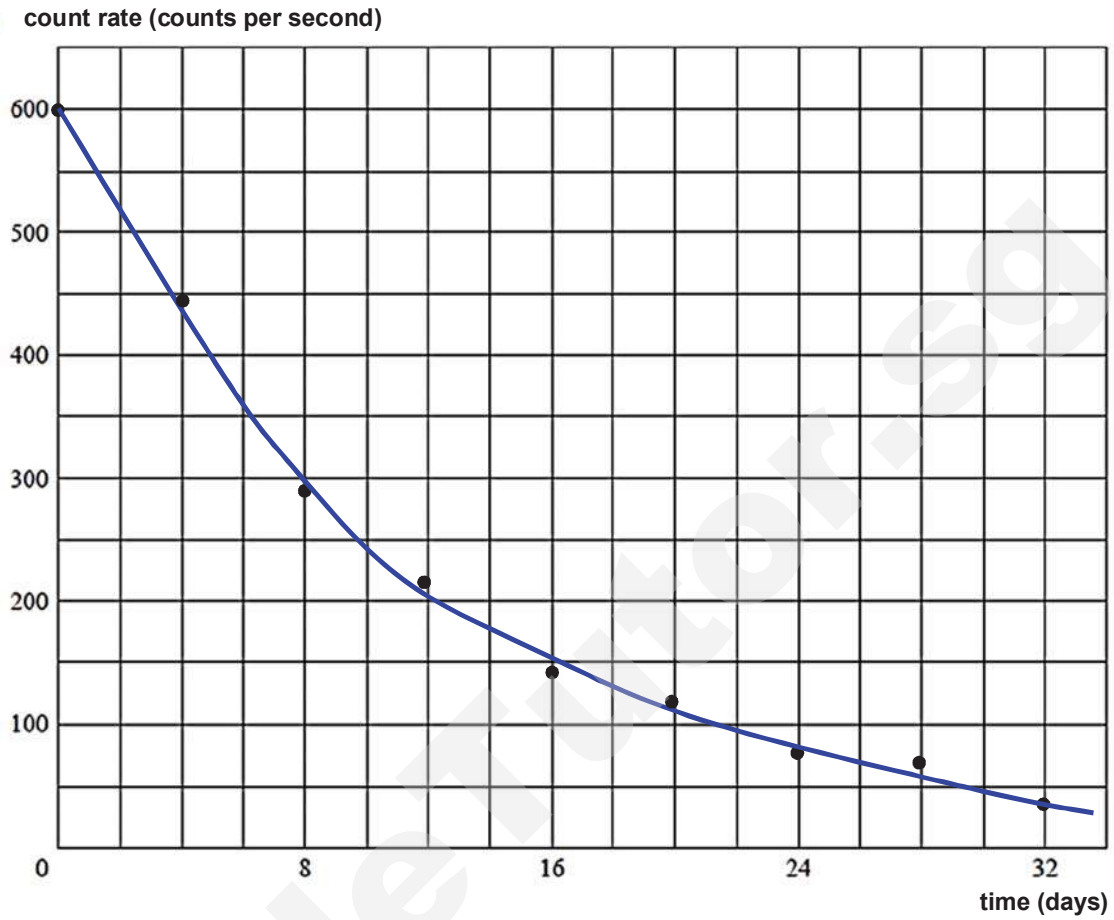


- **Draw a curve of best-fit on Fig. 7.1.**

- **Use coordinates from best-fit curve to determine the average time taken for count rate to decrease to half the original value.**

**e.g.**
**Read of time taken for count rate to decrease from 600 $s^{-1}$ to 300 $s^{-1}$ → $t_{1/2,\,1}$**
**Read of time taken for count rate to decrease from 300 $s^{-1}$ to 150 $s^{-1}$ → $t_{1/2,\,2}$**
**Calculate the average of $t_{1/2,\,1}$ and $t_{1/2,\,2}$.**
***[Working for determining the half-life from the average of at least 2 half-lives must be shown. ]***

- **Answer: Accept (8 days ± 1 day). [Actual half-life is about 8.06 days.]**

**Alternative working:**
**Accept use of $C = C_o\, e^{-\lambda t}$ and $C = C_o\, (\,½\,)^{t\,/\,t_{½}}$ provided coordinates are read off the best-fit curve and not the raw data points.**
**Also, two values of half-life should be computed from at least two different coordinates that are far apart on the best-fit curve, and average calculated.**

half-life = …….. days [3]

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| | | | |
|---|---|---|---|
| | **(c)** | Explain why the determination of the half-life of iodine-131 by the method in **(b)** requires that the product of the decay is stable. | |
| | | ……<br>…… | [1] |
| | | If the product is unstable, it will decay into another product and emit radiation in the process, and so **the measured count rate would be higher than the actual count rate due to iodine-131 only.**<br>**OR**<br>**the measured count rate would not be due to the decay of iodine-131 only.** | |
| | **(d)** | Suggest why the percentage systematic error will not be significant if the student neglected the background radiation. | |
| | | ……<br>…… | [1] |
| | | **From the graph, the count rate is almost zero eventually; indicating that the background radiation is insignificant (or much smaller) compared to the count rates in this experiment (in the order of hundreds per second).**<br>**OR**<br>**Background radiation is typically less than 1 count per second (or around 0.5 counts per second or 30 counts per minute), which is much smaller compared to the count rates in this experiment (in the order of hundreds per second).** | |

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## Section B

Answer **one** question from this Section in the spaces provided.

**8** In a roller coaster ride, a train of mass 1200 kg and carrying a load of 400 kg is pulled up a smooth slope at a constant speed of 1.5 m $s^{-1}$ by an electric motor to a height of 80.0 m as shown in Fig. 8.1. The train with its load is then released from rest at point A and moved to point B along the curved track.

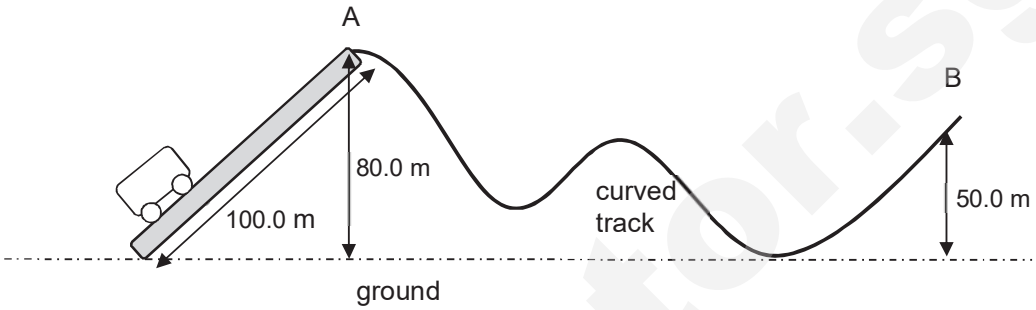


**Fig. 8.1**

**(a) (i)** Calculate the minimum force required to pull the train with its load up the slope at the given speed.

minimum force = ..... N [2]

Assuming no friction,
The upslope pull needs to balance the downslope component of weight.

Minimum Force required = m g sin θ
= (1200 + 400) x 9.81 x 80.0 / 100.0
= 12556.8 N = 12600 N (3 s.f.)

**(ii)** The efficiency of the motor is 80%. Calculate the electrical power that is supplied to the motor to pull the train with its load up the slope to point A.

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| | | | |
|---|---|---|---|
| | | electrical power = …… kW | [3] |
| | | Output Power = F v<br>= 12556.8 x 1.5<br>= 18835 W<br><br>Actual power required by motor<br>= Output Power / efficiency<br>= 18835 / 0.80<br>= 23544 W = 24 kW (2 s.f.) | |
| | | **(iii)** Between A and B, the train experiences an average resistive force of 3.0 kN. If the train arrives at B with a speed of 8.0 m $s^{-1}$, determine the distance travelled by the train between A and B. | |
| | | | |
| | | distance travelled = …… m | [3] |
| | | By conservation of energy, from A to B,<br>Loss in GPE = Gain in KE + Work done against resistive force<br>$mg(h_A - h_B) = (½ mv_B^2 - 0) + 3000 \times d$<br>$(1200 + 400)(9.81)(80.0 - 50.0) = ½ (1200 + 400)(8.0^2) + 3000d$<br>d = 139.89 = 140 m (2 s.f.) | |
| | | **(iv)** Suggest why the resistive force on the train is unlikely to remain constant. (Ignore the resistive force due to air resistance.) | |
| | | …… | |
| | | …… | |
| | | …… | [1] |
| | | A component of resistive force is the frictional force between the wheels and the platform.<br><br>**Normal contact force exerted by the track on the wheels differs in magnitude at different points of the ride, which causes the frictional force exerted by the track on the wheels to vary as well.** | |
| | **(b)** | In another segment of the ride, the train loop the loop in a circular track as shown in Fig.8.2. The radius of the circular motion is 25 m.<br><br>Point D is at the bottom of the circular motion.<br>Point E is at the right of the circular motion.<br>Point F is at the top of the circular motion.<br>Point G is at the left of the circular motion. | |

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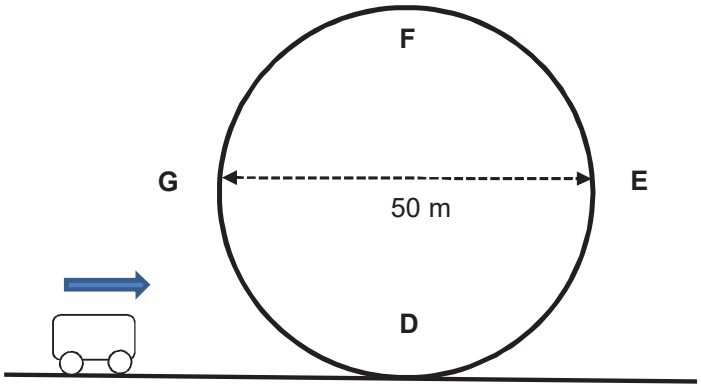


Fig. 8.2

**(i)** On Fig. 8.3 below, draw the free body diagram of the train at point D and point F.




Fig. 8.3

[2]

Weight directed downwards for both top and bottom.
Normal contact Force (at bottom, D) directed upwards.
Normal contact Force (at Top, F) directed pointing downwards.

1 mark – Labelled and named all forces in the correct directions.
1 mark – Normal contact force at D **greater than** Weight, and Weight constant in magnitude at D and at F.

**(ii)** Determine the minimum speed of the train at point D so that it can loop the loop.

At the top of the circular motion,
Normal contact force and train's weight provide for the centripetal force required:
$N + mg = F_c$
$N = F_c - mg$
Normal contact force at top needs to be > 0 for the train to stay on track.
$F_c - mg > 0$

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$\frac{mv_F^2}{r} - mg > 0$

$\frac{v_F^2}{r} - g > 0$

$v_F^2 > rg$

$v_F > \sqrt{25 \times 9.81}$

$v_F > 15.660 \text{ m s}^{-1}$

Total KE at bottom = min KE at top + GPE gained

$\frac{mv_D^2}{2} = \frac{mv_F^2}{2} + mgh$

$\frac{v_D^2}{2} = \frac{v_F^2}{2} + gh$

$v_D^2 = v_F^2 + 2gh$

$v_D^2 = (15.660)^2 + 2(9.81)(50)$

$v_D = 35.018 = 35 \text{ m s}^{-1}$

Minimum speed = ..... m $s^{-1}$ [4]

**(c)** It is suggested to keep the speed of the train constant.

**(i)** On Fig. 8.4, sketch the graph to show how the normal contact force experienced by the train varies as it moves from Point D to G and back to D.

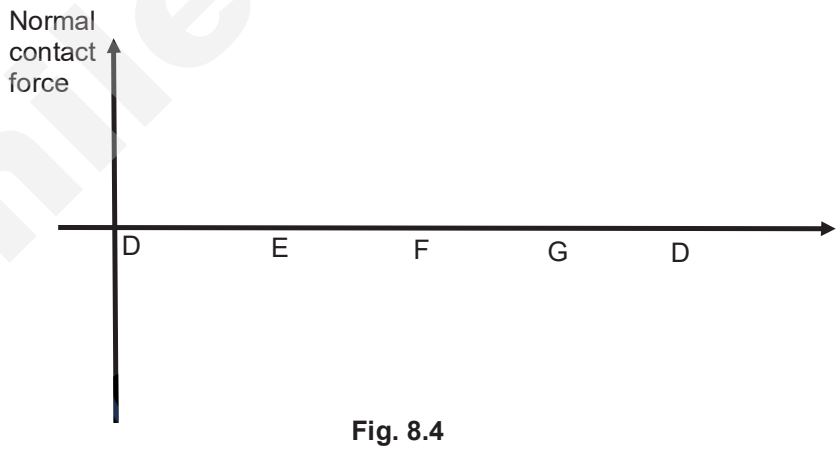


**Fig. 8.4**

[3]

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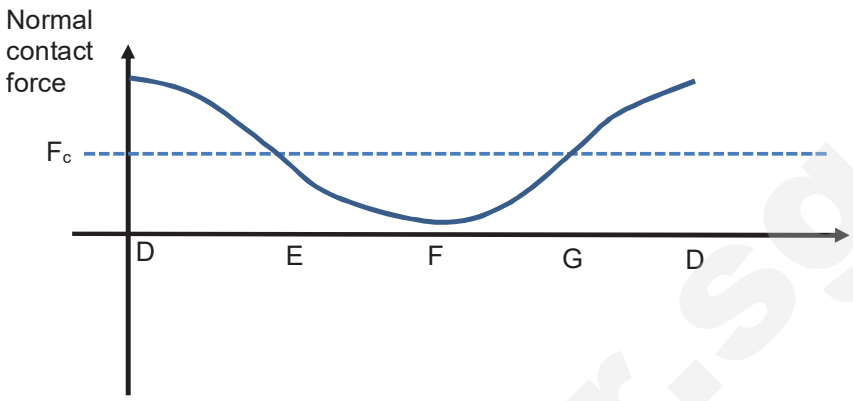
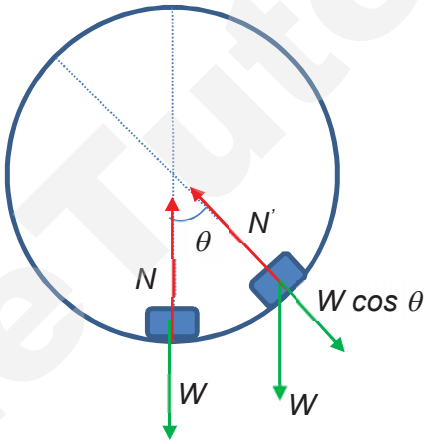
**Solution**




General Formula:

$N = Fc + mg\cos\theta$

Point D : $\theta$ = 0°

$N = Fc + mg$

Point E : $\theta$ = 90°

$N = Fc$

Point F : $\theta$ = 180°

$N = Fc - mg$

Point G : $\theta$ = 270°

$N = Fc$

Where $F_C$ is constant throughout since m, v, r remain constant.

All positive values. [Deduct 1 mark if there are negative values]
Point D and F correct [B1] : accept N ≥ 0 at F.
Point E and G correct (shows indication that N is equal at these 2 points) [B1]
Sinusoidal shape. [B1]

**(ii)** Discuss why it is difficult to maintain the train at constant speed during the loop the loop.

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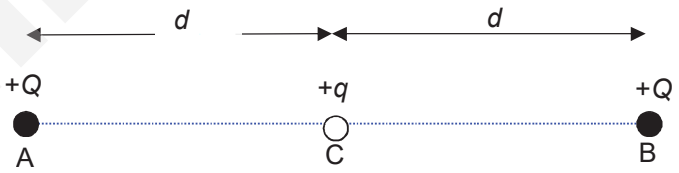
| | | | | |
|---|---|---|---|---|
| | | | | |
| | | | ……. | |
| | | | | |
| | | | ……. | |
| | | | | |
| | | | ……. | [2] |
| | | L3 | On the upward part of the journey, the train requires an engine to do positive work / supply energy to it at varying rates because kinetic energy (KE) remains unchanged while gravitational potential energy (GPE) needs to increase at varying rates.<br><br>On the downwards part of the journey, the train requires a braking system to do negative work / dissipate energy from it at varying rates to prevent increase in KE, since GPE converts to KE at varying rates. | |

| | | | | |
|---|---|---|---|---|
| **9** | **(a)** | Define *electric potential*. | | |
| | | ……<br>……. | | [2] |
| | | The electric potential at a point in an electric field is defined as **the work done per unit positive charge by an external agent in moving a point charge from infinity to that point, (without any change in kinetic energy).** | | |
| | **(b)** | Two identical point charges, of +*Q* each, are located at a distance 2*d* apart as shown in Fig 9.1.<br>  <br><br>**Fig. 9.1**<br>A third charge of mass *m*, and charge +*q* is placed at C, midpoint between the two charges. | | |
| | | **(i)** | Obtain an expression for the electric potential at point C due to the two point charges at A and B. | |
| | | | | |
| | | | electric potential at point C = ……V | [2] |
| | | | **$V = V_A + V_B$**<br>**$V = Q / (4\pi\varepsilon_o d) + Q / (4\pi\varepsilon_o d)$**<br>**$= 2Q / (4\pi\varepsilon_o d)$**<br>**$= Q / (2\pi\varepsilon_o d)$** | |

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**(ii)** Sketch in Fig. 9.2 to show how the electric potential varies with the position along AB for the following cases:

1. due to the point charge at A
2. due to the point charge at B
3. due to both point charges at A and B.

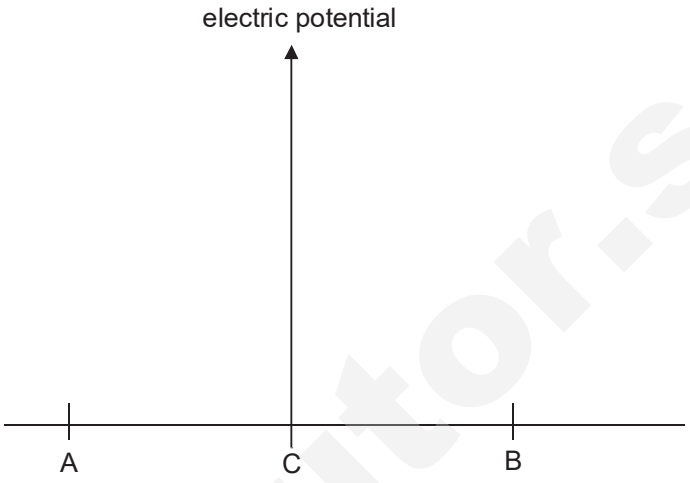
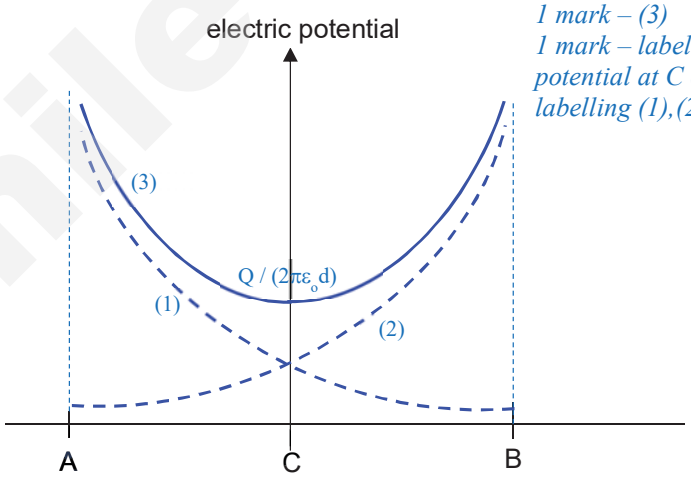



**Fig. 9.2** [3]

Solution:




*1 mark – (1) and (2)*
*1 mark – (3)*
*1 mark – labelling of potential at C & labelling (1),(2),(3)*

**(iii)** The charge $+q$ is then being displaced horizontally and released. It is observed that charge $+q$ exhibits simple harmonic motion with an amplitude of $x_o$, where $x_o$ is significantly smaller than $d$.

**1.** On Fig. 9.3, draw a well-labelled free body diagram to show the electrostatic forces acting on the third charge $+q$ at the instant when it is being displaced at a distance of $x$ to the left of C.

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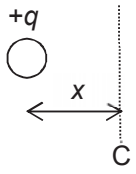
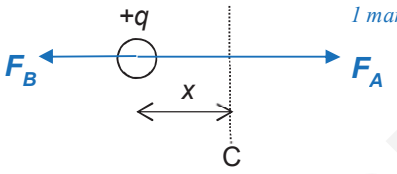



**Fig. 9.3** [2]

Solution:

*1 mark for label and directions*
*1 mark for length of arrows*




**2.** Derive an expression for the magnitude of the resultant electrostatic force experienced by the charge due to the point charges at A and B.

resultant electrostatic force = ……N [1]

Using $F = Q_1Q_2/(4\pi\varepsilon_o r^2)$

$F_R = F_A - F_B$

$= Qq/(4\pi\varepsilon_o(d-x)^2) - Qq/(4\pi\varepsilon_o(d+x)^2)$

$= \mathbf{qQ/(4\pi\varepsilon_o)\,[1/(d-x)^2 - 1/(d+x)^2]}$

**3.** The angular frequency of the oscillations can be expressed as follows.

$$\omega = \sqrt{\frac{qQ}{\pi\varepsilon_o md^3}}$$

Determine the period of oscillation using the data provided below:

*m*: $6.8 \times 10^{-25}$ kg
*q*: $3.2 \times 10^{-19}$ C
*Q*: $1.28 \times 10^{-18}$ C
*d*: 8.6 cm

period = …… s [1]

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Using $T = \frac{2\pi}{\omega}$

$=2\pi \times \sqrt{\frac{\pi\varepsilon_o m d^3}{qQ}}$

$= 2\pi \times \sqrt{\frac{\pi 8.85\text{x}10^{-12} \times 6.8\text{x}10^{-25} \times 0.086^3}{3.2\times10^{-19} \times 1.28\times10^{-18}}}$

$= 1.08$ s

**4.** On Fig. 9.4, sketch three graphs to show how the *total energy*, *potential energy* and k*inetic energy* of the charge +*q* vary as it oscillates between – $x_o$ and $x_o$, Label each graph.

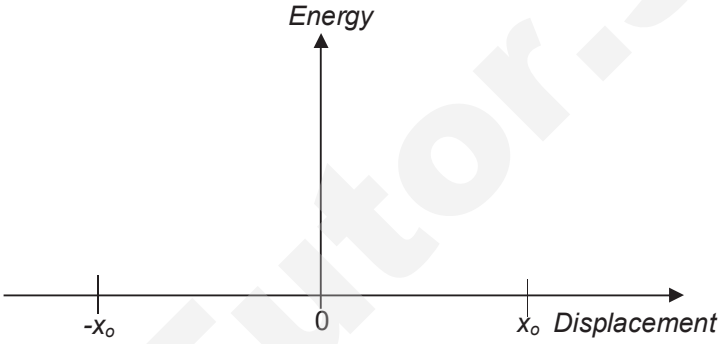
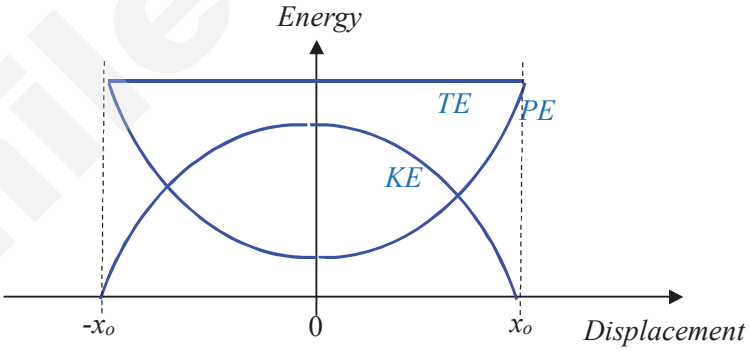



**Fig. 9.4**

[3]

Solution:




*1 mark for each graph*

**(c)** An electron was accelerated from rest with potential difference of 1.0 x $10^4$ V, before entering at right angle into a uniform electric field region provided by a pair of charged parallel plates, separated at a distance of 3.0 cm as shown in Fig. 9.5.

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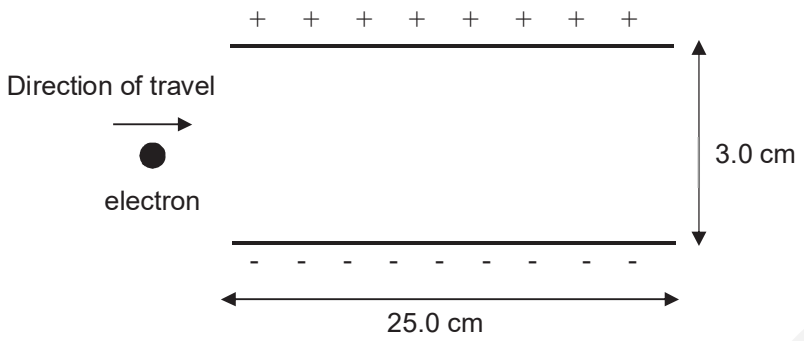



**Fig. 9.5**

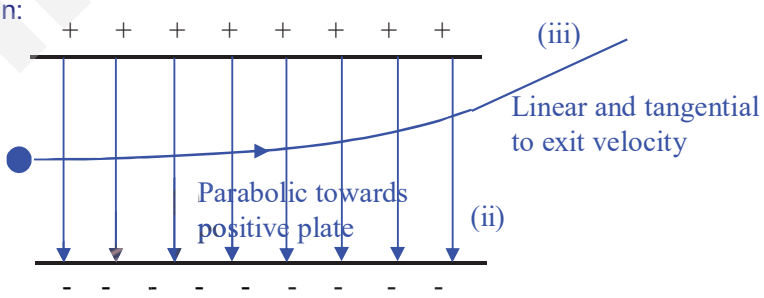
**(i)** Determine the speed of the electron when it entered the uniform electric field region.

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

**During acceleration of the electron,**
**Gain in KE = Loss in EPE**
**$\frac{1}{2} mv^2 - 0 = q \Delta V$**
**$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 1.60 \times 10^{-19} \times 1.0 \times 10^4$**
**$v = 5.9 \times 10^7$ m $s^{-1}$**

**(ii)** On Fig. 9.5, draw the electric field lines between the pair of charged parallel plates. [1]

Solution:




**(iii)** The electron entered the uniform electric field region at the midpoint between the two charged parallel plates.

**1.** On Fig. 9.5, sketch the trajectory of the electron within and beyond the parallel plates. [1]

**2.** Show that the electron did not hit any of the parallel plates when it emerged from the uniform electric field region. The electric field strength between the parallel plates is $5.7 \times 10^3$ N $C^{-1}$.

[2]

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| | | | | | |
|---|---|---|---|---|---|
| | | | | **Horizontally:** $s_x = u_x t$<br>$0.25 = 5.9 \times 10^7 \times t$<br>$t = 4.2 \times 10^{-9}$ s<br><br>**Vertically:** $s_y = u_y t + \frac{1}{2} a_y t^2$<br>$= \frac{1}{2} \times (qE/m) \times t^2$<br>$= \frac{1}{2} \times (1.6\times10^{-19} \times 5.7\times10^3 / (9.11\times10^{-31})) \times (4.2\times10^{-9})^2$<br>$= 0.0088$ m $< (\frac{1}{2} \times 0.030)$ m | |

**-- END OF PAPER 3 --**

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NAME: _____ CLASS: _____

# CATHOLIC JUNIOR COLLEGE
## JC2 Preliminary Examinations
## Higher 2

# PHYSICS
9749/04

Paper 4: Practical

**MARK SCHEME**

20 August 2019
2 hours and 30 minutes

**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. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use an HB or 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **ALL** questions.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| 1 | / 14 |
| 2 | / 9 |
| 3 | / 20 |
| 4 | / 12 |
| Total | / 55 |

This document consists of **24** printed pages and **zero** blank page.

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**1.** In this experiment, you will investigate the variation of current $I$ with potential difference $V$ of an electrical component Y.

**(a)** Set up the circuit as shown in Fig. 1.1, with the rheostat connected as a potential divider and taking care component Y is connected the right way around.

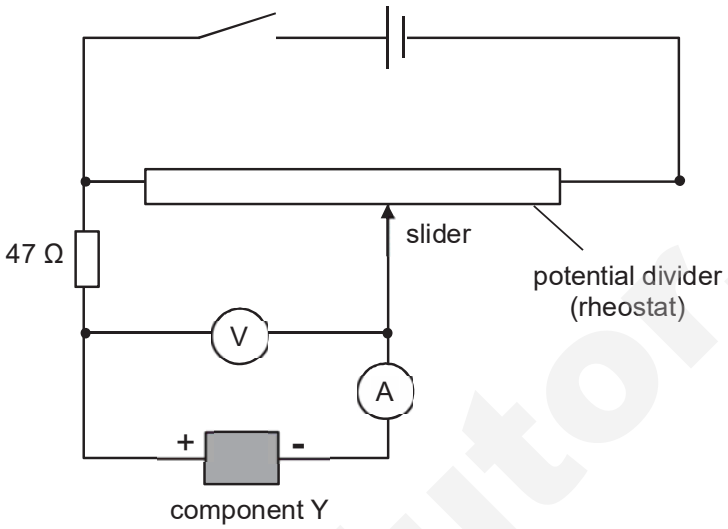


**Fig. 1.1**

**(b)** Place the slider of the rheostat at its mid-point.

**(c)** Close the switch. Record the potential difference across component Y and the current flowing through it.

Accept only 2 d.p. for $V$ ( Set to 20 V range)
Accept only 1 d.p. for mA or 4 d.p for A (set to 200 mA range)
Units required
Repeated readings not required.

potential difference = ……2.78 V……..……..[1]

current = ……5.2 mA……..……..[1]

**(d)** Adjust the slider to vary the potential difference $V$, from 0 V to the maximum value, across component Y so as to obtain further readings of the current $I$ through component Y. The current will remain zero for low values of $V$.

Record sufficient readings of $V$ and $I$ so that a curve could be plotted.

8 or more readings – 1 mark

Include (0,0), and also at least 2 readings showing $I$ = 0 for small values of $V$. – 1 mark

Readings should spread out approximately evenly to the maximum range of the rheostat – 1 mark

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Correct headings with units -- 1 mark
Consistent and correct d.p for raw data – 1 mark (ecf for d.p )

Repeated readings of *I* not required.

| V/V | *I* /mA |
|---|---|
| 0.00 | 0.0 |
| 1.00 | 0.0 |
| 2.00 | 0.0 |
| 2.50 | 0.4 |
| 2.60 | 1.2 |
| 2.80 | 5.2 |
| 2.90 | 8.9 |
| 3.00 | 13.2 |
| 3.20 | 24.8 |
| 3.40 | 39.2 |
| 3.50 | 46.4 |

[5]

**(e)** On the graph grid on **page 5**, draw a curve to show how *I* varies with *V*. [3]

Label axes & scale – 1 mark
All points plotted correctly – 1 mark
Curve line of best fit - 1 mark

**(f) (i)** From the curve drawn on **page 5**, describe how the resistance of component Y varies. [2]

For *V* less than 2.4 V, the resistance of Y is infinite (or very large). - 1 mark

For *V* > 2.4 V, the resistance decreases (significantly). - 1 mark
Cannot accept 'decreases a little or constantly'

**(ii)** Suggest a practical purpose of using component Y in an electrical circuit. [1]

Component Y can be used to allow a current to pass through a circuit only when the potential difference/voltage exceeds a minimum potential difference/voltage.

**(g)** Suggest a reason for connecting the 47 Ω resistor in series to component Y. [1]

The purpose of the 47 Ω is to prevent damage to the Component Y by limiting current flowing through it.
OR
The purpose of the 47 Ω is to adjust *V* to a limiting range to prevent damage of component Y.

**[Total: 14 marks]**

**[Turn Over**

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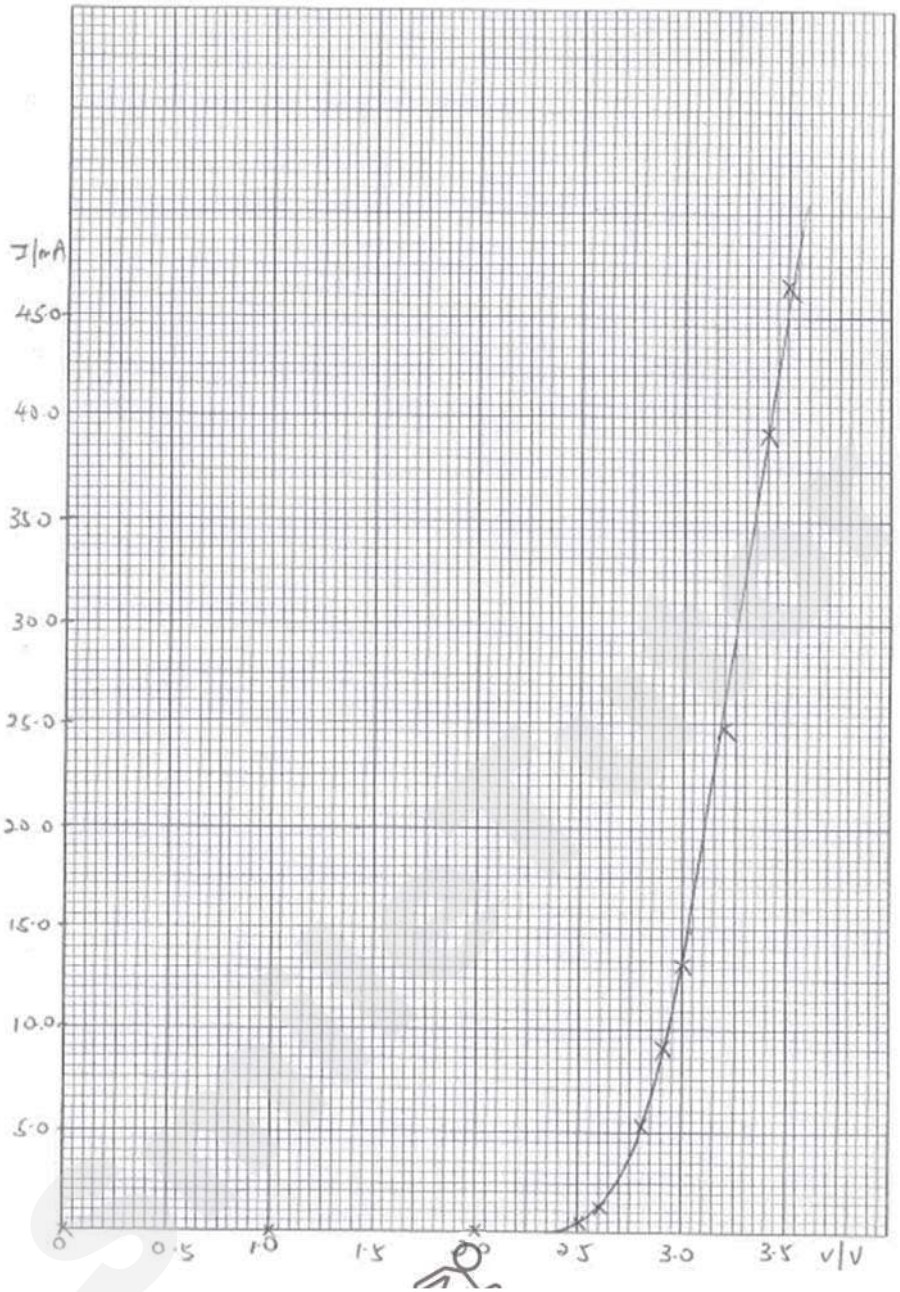


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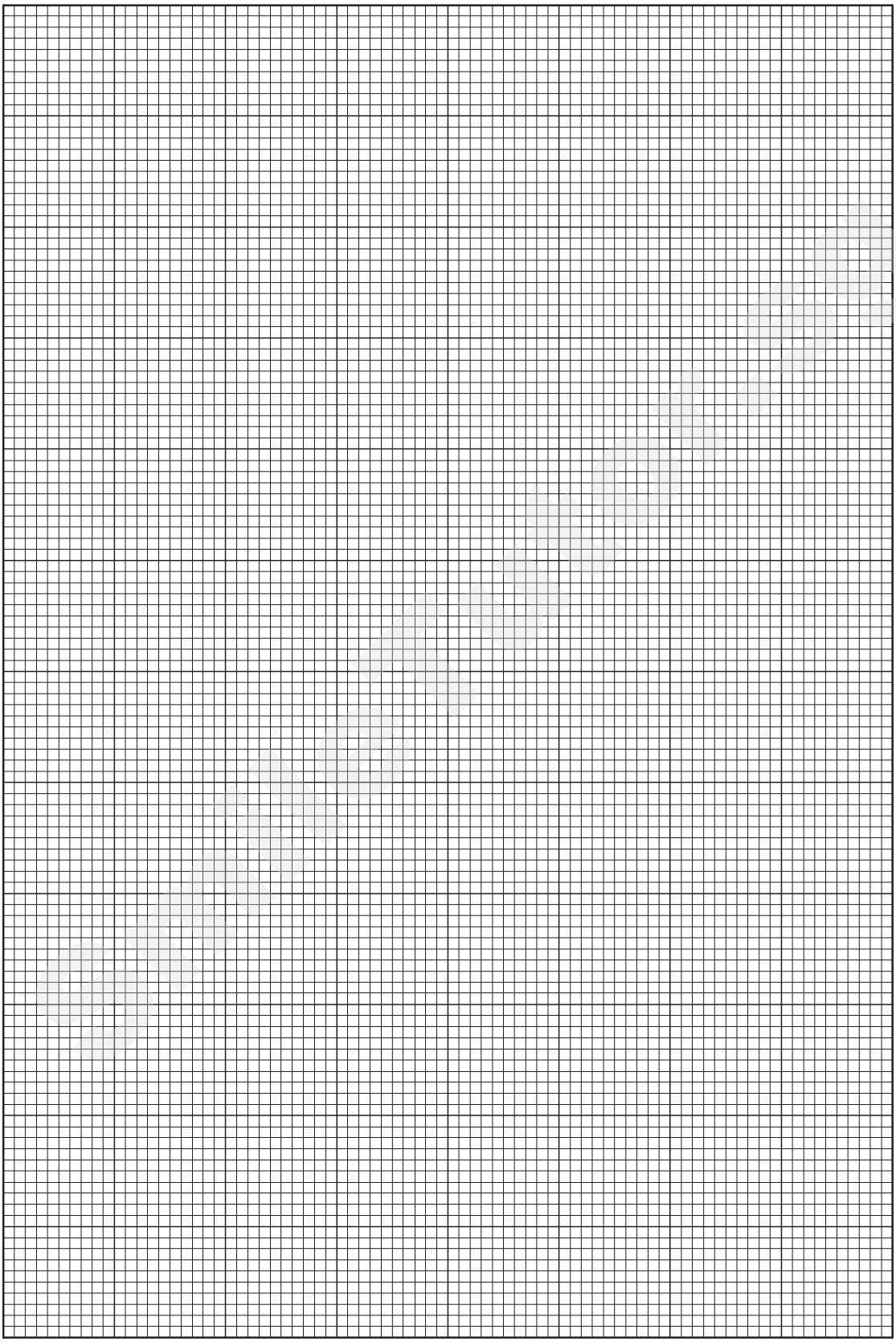



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**2.** In this experiment, you will investigate the extension of a spring.

**(a)** You have been provided with a spring.
Measure and record the length $x_0$ of the unstretched spring, as shown in Fig. 2.1.

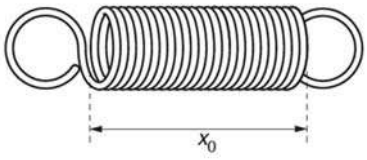


**Fig. 2.1**

$x_{01}$ = 2.1 cm, $x_{02}$ = 2.1 cm
$x_{0ave}$ = 2.1 cm

$x_0$ = ……2.1 cm……..……

**(b)** Set up the apparatus as shown in Fig. 2.2.

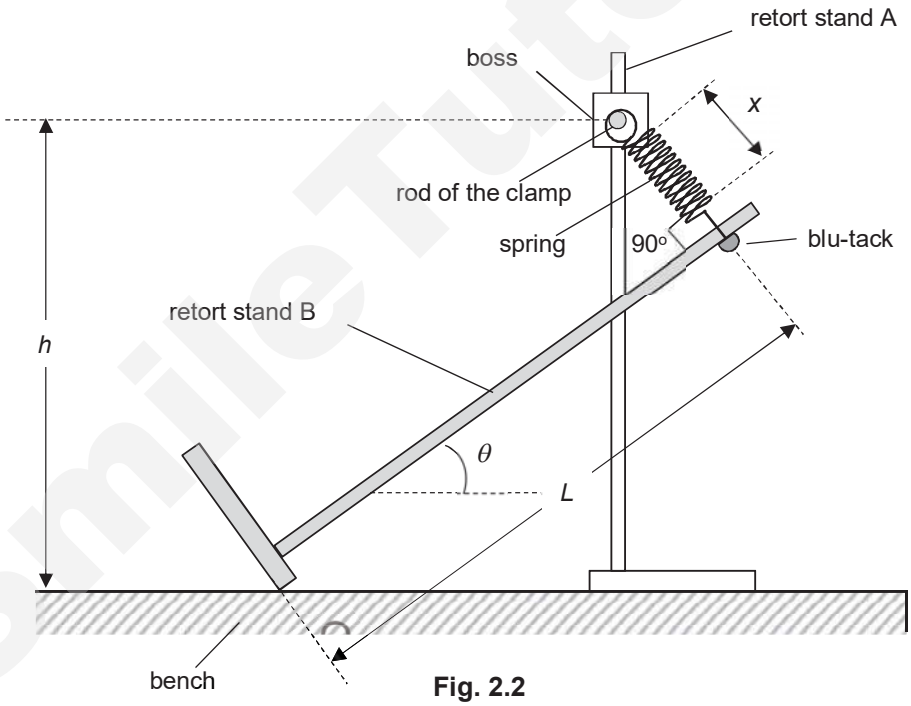


**Fig. 2.2**

The height *h* of the rod of the clamp above the bench should be approximately 38 cm.

One loop of the spring should be around the rod of the clamp.

The other loop of the spring should be around the rod of retort stand B close to the top of the rod and secured using blu-Tack.

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**(c)** Slide the base of retort stand B until the angle between the rod of retort stand B and the stretched spring is 90°.

The length of the coiled section of the spring is $x$.
The angle between the rod of retort stand B and the horizontal is $\theta$.
The length between the base of the retort stand B and the spring is $L$.

Measure and record $x$, $\theta$ and $L$.

Repeated readings of $x$, $\theta$ and $L$.
Correct d.p and units of $x$, $\theta$ and $L$.

Deduct 1 mark if there is no repeated readings any one of $x$, $\theta$ or $L$.
Deduct 1 mark if there is wrong d.p. in any one of $x$, $\theta$ or $L$.
Deduct 1 mark if there is wrong units or no units quoted in any one of $x$, $\theta$ or $L$.

$x_1 = 9.2$ cm
$x_2 = 9.3$ cm

$\theta_1 = 22^o$
$\theta_2 = 21^o$

$L_1 = 62.5$ cm
$L_2 = 62.5$ cm

$$x_{ave} = \frac{9.3 + 9.2}{2} = 9.3\,\text{cm} \qquad \theta_{ave} = \frac{22 + 21}{2} = 22^0 \qquad L_{ave} = \frac{62.5 + 62.5}{2} = 62.5\,\text{cm}$$

$x$ = ……9.3 cm……..

$\theta$ = ……22°……..

$L$ = ……62.5 cm……..
[2]

**(d)** Calculate $e$ where

$$e = x - x_0$$

e = 9.3 – 2.1 = 7.2 cm

Correct calculation, units and d.p.

$e$ = ……7.2 cm……..[1]

**(e)** Estimate the absolute uncertainty of $\theta$.

Accept value between 2° and 4° because of the thickness of the rod of retort stand B.
Students need NOT state the reason for their estimated value.

absolute uncertainty = ……Accept 2° to 4° ……..[1]

**[Turn Over**

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**(f)** Reduce the height *h* of the rod of the clamp to approximately 32 cm. Keeping *L* constant, slide the base of retort stand B until the angle between the rod of retort stand B and the stretched spring is again 90°.

Measure and record *x* and $\theta$. Calculate *e*.

Repeated readings of *x* and $\theta$
Correct d.p and units of *x* and $\theta$

$x_1$ = 10.7 cm
$x_2$ = 10.7 cm
$x_{ave} = \frac{10.7 + 10.7}{2} = 10.7\,\text{cm}$

$\theta_1$ = 13°
$\theta_2$ = 14°
$\theta_{ave} = \frac{13 + 14}{2} = 14^0$

e = 10.7 – 2.1 = 8.6 cm

*x* = ……10.7 cm……..……..

$\theta$ = ……14°……..……..

*e* = ……8.6 cm……..……

**(g)** Theory suggests that the quantities *e* and *θ* are related by the equation

$$e + \frac{mp}{L}\tan\theta\cos\theta = \frac{mq}{L}\cos\theta$$

where *p* and *q* are constants and *m* is the mass of retort stand B.

**(i)** Using the values in **(c)**, **(d)**, **(f)** and *m* = 1800 g, calculate *p* and *q*.

When $\theta$ = 22° , e = 7.2 cm, L = 62.5 cm,

$$7.2 + \frac{1800p}{62.5}\tan 22^0 \cos 22^0 = \frac{1800q}{62.5}\cos 22^0$$

$$\frac{7.2}{\cos 22^0} + \frac{1800p}{62.5}\tan 22^0 = \frac{1800q}{62.5} \quad -----(1)$$

When $\theta$ = 14° , e = 8.6 cm, L = 62.5 cm,

$$8.6 + \frac{1800p}{62.5}\tan 14^0 \cos 14^0 = \frac{1800q}{62.5}\cos 14^0$$

$$\frac{8.6}{\cos 14^0} + \frac{1800p}{62.5}\tan 14^0 = \frac{1800q}{62.5} \quad -----(2)$$

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Equating (1) = (2)

$$\frac{7.2}{\cos 22^0} + \frac{1800p}{62.5}\tan 22^0 = \frac{8.6}{\cos 14^0} + \frac{1800p}{62.5}\tan 14^0$$

$$\frac{1800p}{62.5}(\tan 22^0 - \tan 14^0) = \frac{8.6}{\cos 14^0} - \frac{7.2}{\cos 22^0}$$

$$\frac{1800p}{62.5}(0.1547) = 1.0978$$

$$p = \frac{1.0978 \times 62.5}{1800 \times 0.1547} = 0.2464 \text{ cm}^2\text{ g}^{-1} = 0.246 \text{ cm}^2\text{ g}^{-1} \text{ or } 0.0246 \text{ m}^2\text{ kg}^{-1}$$

From Eqn (1),

$$(\frac{62.5}{1800})\frac{7.2}{\cos 22^0} + p\tan 22^0 = q$$

$$(\frac{62.5}{1800})\frac{7.2}{\cos 22^0} + (0.2464)\tan 22^0 = q$$

$$q = 0.36919 \text{ cm}^2\text{ g}^{-1} = 0.369 \text{ cm}^2\text{ g}^{-1} \text{ or } 0.0369 \text{ m}^2\text{ kg}^{-1}$$

Units of $p$ and $q$:

$$[\frac{mp}{L}\tan\theta\cos\theta] = [\frac{mq}{L}\cos\theta] = [e]$$

$$[\frac{mp}{L}] = [e] \quad \& \quad [\frac{mq}{L}] = [e] \Rightarrow [p] = [q] = \frac{[e][L]}{[m]} = \frac{\text{cm.cm}}{\text{g}} = \text{cm}^2\text{ g}^{-1}$$

Correct substitution to form 2 equations (1) & (2) – 1 mark
Correct calculation of $p$ and $q$ with correct units – 1 mark
If length, L, was not the same as found in the substituted value in both equations then the first mark cannot be awarded.
Overall if steps taken to determine constants and units of $p$ and $q$ were correct with all variables correctly substituted then 1 mark awarded for method marks.
If the final answers had units that were not written correctly then the 2nd mark is not awarded.

$p$ = ……0.246 cm$^2$ g$^{-1}$……..

$q$ = ……0.369 cm$^2$ g$^{-1}$……..

[2]

**[Turn Over**

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**(ii)** It is also found that

$$p = \frac{gy}{k}$$

where $g$ = 9.81 m s$^{-2}$, $y$ = 4.2 cm and $k$ is the spring constant of the spring.

Calculate $k$.

$$p = \frac{gy}{k} \Rightarrow k = \frac{gy}{p} = \frac{(9.81)(4.2\times10^{-2})}{(0.2464\times10^{-1})} = 16.722 = 16.7 \text{ Nm}^{-1}$$

Correct calculation of k and conversion into N m$^{-1}$. – 1 mark

$k$ = ……16.7……..……N m$^{-1}$
[1]

**(iii)** If you were to repeat this experiment with other values of $\theta$, describe the graph that you would plot to determine $k$.

1 mark -
Linearised the equation into :

$$\frac{e}{\cos\theta} = -\frac{mp}{L}\tan\theta + \frac{mq}{L}$$

Plot $\frac{e}{\cos\theta}$ against tan $\theta$ to obtain a straight line graph.

1 mark -
Calculate the gradient of the straight line graph to determine $p$. From the value of $p$, determine k.

[2]

**[Total: 9 marks]**

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**3.** In this experiment, you will investigate the variation of the fundamental frequency $f$ of a stretched string with a fixed tension $T$.

**(a)** Fig. 3.1 shows the apparatus which has been set up for this experiment.

The mass M = 1.000 kg.

**Do not dismantle the apparatus during the experiment.**

$L$ is the length between the bridges and is initially set to approximately 25 cm.

The paper rider should be placed on the string around the mid-point between the two bridges.

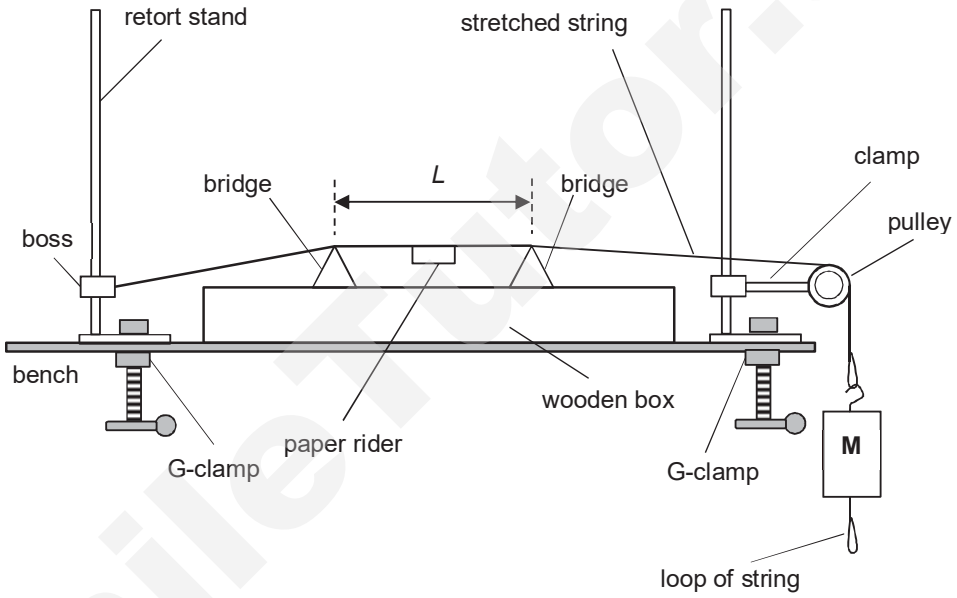


**Fig. 3.1**

**(i)** Hit the tuning fork against the rubber bung to set the tuning fork into vibration and, immediately, rest its handle gently on the wooden box as shown in Fig. 3.2.

**(ii)** While keeping the handle of the vibrating tuning fork resting on the wooden box, move the bridges gradually to increase the length $L$ until you observe the **strongest** vibration of the paper rider or the paper rider jumps off the string. You may need to hit the tuning fork more than once.

The length $L$ should not exceed 35 cm.



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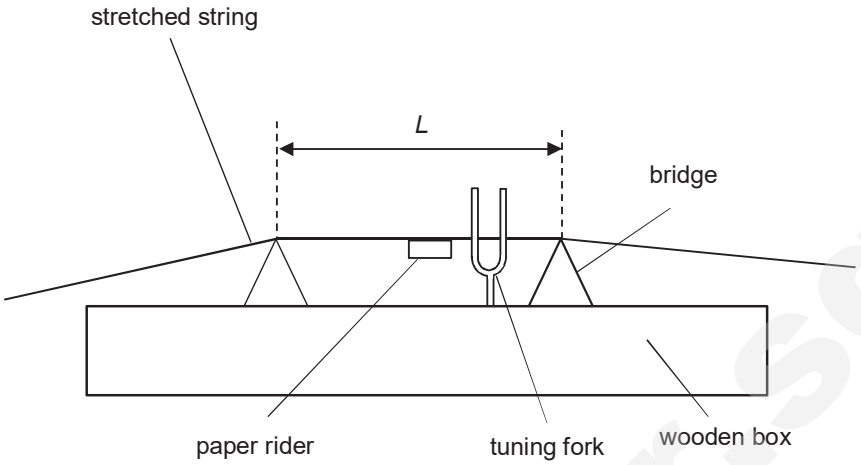


**Fig. 3.2**

**(iii)** Measure and record the length *L* and the frequency *f* of the tuning fork, when the paper rider has the strongest vibration or jumps off the string.

1 mark - Evidence of Repeated readings of *L*.
1 mark - zero d.p. for *f*, and, 1 d.p or zero d.p. for *L* (d.p. of L must be quoted to the same d.p. of ΔL in part (b) ). Units required.

$L_1$ = 30.6 cm $L_2$ = 30.8 cm

$$L_{ave} = \frac{30.6 + 30.8}{2} = 30.7 \text{ cm}$$

frequency *f* = ……288 Hz……..……..

length *L* = ……31 cm (rounded off to same precision as ΔL in part (b)……
[2]

Accepted ranges of values of L for corresponding values of f:

| f / Hz | 271 | 288 | 302 | 320 |
|---|---|---|---|---|
| L / cm | 32.8 – 33.4 | 30.6 – 31.4 | 29.8 – 30.2 | 28.3 – 28.5 |
| *Theory L / cm* | *32.9* | *30.9* | *29.5* | *27.8* |

**(b)** Estimate the percentage uncertainty in your value of *L*.

ΔL = 2 cm (Accept 0.5 cm to 2 cm) (quoted in 1 s.f. with units)

$$\frac{\Delta L}{L} \times 100\% = \frac{2}{31} \times 100 = 6.45\% = 6\% (1 \text{ s.f})$$

percentage uncertainty in *L* = ……6 % (1 s.f.)……..……[1]

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**(c)** Choose another tuning fork of a different frequency and repeat **(a)(i) and (a)(ii)** to obtain another set of readings for *L* and *f*.

Measure and record *L* and *f*.

$L_1$ = 28.5 cm  $L_2$ = 28.5 cm

$$L_{ave} = \frac{28.5 + 28.5}{2} = 28.5 \text{ cm}$$

frequency *f* = ……320 Hz……

length *L* = ……29 cm (rounded off to same precision as ΔL……

**(d)** It is suggested that

$$2Lf = k\sqrt{mg}$$

where *k* is a constant and *m* is the total mass hung on the stretched string.

**(i)** Use your values from **(a)(iii)** and **(c)** to determine two values of *k*.

Give your values of *k* to an appropriate number of significant figures.
Assume *g* = 9.81 m $s^{-2}$.

1 mark - Correct units of k – accept m $s^{-1}$ $N^{-½}$ or m Hz $N^{-½}$ or $m^{½}kg^{-½}$
1 mark - Correct computation and 3 s.f. ( since *L* ,*f* and *mg* are all 3 s.f.)

$$[k] = \frac{[L][f]}{\sqrt{[mg]}} = \frac{(m)(s^{-1})}{(kg\,m\,s^{-2})^{½}} = m^{½}kg^{-½}$$

$$k = \frac{2Lf}{\sqrt{Mg}}$$

$$k_1 = \frac{2(30.7 \times 10^{-2})(288)}{\sqrt{1.000 \times 9.81}} = 56.481 = 56.4 \text{ m}^{½}\text{ kg}^{-½}$$

$$k_2 = \frac{2(28.5 \times 10^{-2})(320)}{\sqrt{1.000 \times 9.81}} = 58.236 = 58.2 \text{ m}^{½}\text{ kg}^{-½}$$

first value of *k* = ……56.4 $m^{½}$ $kg^{-½}$……

second value of *k* = ……58.2 $m^{½}$ $kg^{-½}$……
[2]



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**(ii)** State whether the results of your experiment support the suggested relationship in **(d)**.

Justify your conclusion by referring to your values in **(b).**

Correct calculation of percentage difference of two values of k.
Appropriate comparison with values in (b).

$$\text{Percentage difference} = \frac{k_2 - k_1}{k_1} \times 100\% = \frac{(58.2 - 56.4)}{56.4} \times 100\% = 3.191\% = 3.2\%$$

Since the percentage difference of 3.2 % is less than the uncertainty of L (6 %), the results support suggested relationship

[1]

**(e)** You will now determine two more values of *k* by varying *m* for two different frequencies of tuning fork.

**(i)** Adjust the bridges such that the length *L* is **fixed** at 35.0 cm. **Do not change the length *L* in this part of the experiment**.

**(ii)** Hang the 100 g mass hanger onto the loop of string, shown in Fig. 3.3.

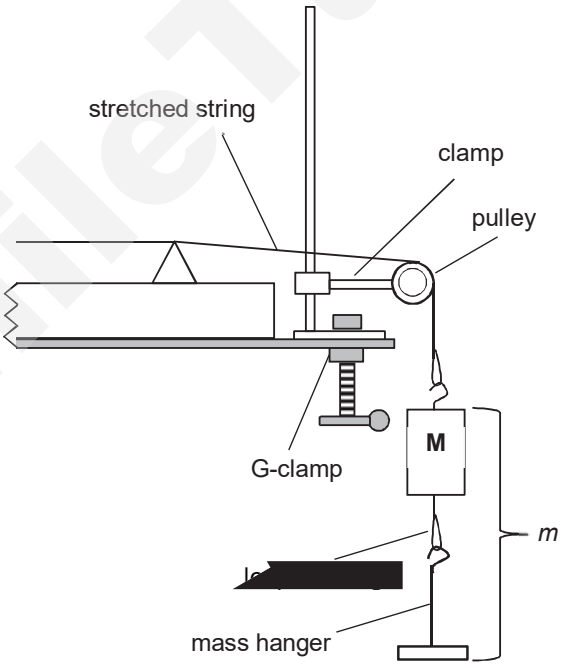


**Fig. 3.3**

**(iii)** Hit the tuning fork against the rubber bung to set the tuning fork into vibration and, immediately, rest its handle gently on the wooden box. Observe the vibration of the paper rider.

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**(iv)** If the paper rider does not show the **strongest** vibration or jump off the string, increase *m* in steps of 100 g slotted mass and repeat step **(iii)**.

**(v)** Stop increasing *m* when you observe the **strongest** vibration of the paper rider or the paper rider jumps off the string.

Measure and record *f* and *m*.

**Repeat for a second tuning fork.**

Tabulate your results of *m* and *f*, including the values of *k*.

| *f* / Hz | m / kg | k / $m^{½}$ $kg^{-½}$ |
|---|---|---|
| 271 | 1.100 | 57.7 |
| 320 | 1.400 | 60.5 |
| d.p. as stated in tuning fork (calibrated precision) | 3 d.p. in kg OR 0 d.p. in g<br><br>m is TOTAL mass, hence should be greater than 1.000 kg | Follow least s.f. of raw values; 3 s.f. in this case. |

1 mark – Correct units and d.p. for m & f. m should be 0 d.p. in g or 3 d.p. in kg; f is zero d.p. in Hz.
1 mark – 2 sets of readings (f, m) shown. Correct values of m. (Note: m should be more than 1.000 kg since M is already 1.000 kg).
1 mark – Correct computation of k. (ecf for units or similar computation errors from previous part)

Deduct 1 mark if instructions are not followed. E.g.
- results are not tabulated
- 1 set of readings only, or more than 2 sets of readings
- Values of k not part of the table
- Improper tabulation methods e.g. spit tables, showing a column of Yes/No for maximum vibration for various values of m (question specifically requires m & f to be recorded only for the scenario when maximum vibrations is seen).

[3]

**(vi)** Comment on your values of *k* in **(d)(i)** and **(e)(v).**

$$\% \text{ difference} = \frac{k_4 - k_3}{k_3} \times 100\% = \frac{(60.5 - 57.7)}{57.7} \times 100\% = 4.85\% = 4.9\%$$

As L is kept constant in (e)(v), the uncertainty of the experiment is contributed most significantly by m, due to increments of m in quantum of 100g slotted masses.
Uncertainty due to m = $\frac{1}{2}\frac{\Delta m}{m} x100\% = \frac{1}{2}\left(\frac{100}{1100}\right) x100\% = 5\%\ (1\ s.f.)$

Since the percentage difference of 4.9 % is within 5%, the results support that *k* is constant (when L is constant and m & f varied).

**[Turn Over**

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$$\text{Average of } k_3 \text{ \& } k_4 = \frac{57.7 + 60.5}{2} = 59.1 \text{ m}^{½} \text{ kg}^{-½}$$

$$\text{Average of } k_1 \text{ \& } k_2 = \frac{58.2 + 56.4}{2} = 57.3 \text{ m}^{½} \text{ kg}^{-½}$$

$$\% \text{ difference} = \frac{(59.1 - 57.3)}{57.3} \times 100\% = 3.14\%$$

Since the percentage difference in the magnitudes of *k* between (d)(i) and (e)(v) is less than the combined uncertainty of m and L (6% + 5% = 11%), the results support that *k* is constant regardless of which variable is changed (L, m or f).

1 mark – correctly calculate the percentage difference of k values in (e)(v) & conclusion about k (constant / not constant) when L is kept constant by comparison with uncertainty in the experiment *.
1 mark – calculate percentage difference in magnitudes of k between (d)(i) and (e)(v).
1 mark – conclusion about k (constant / not constant) overall regardless of which variable is changed (L, m or f) by comparison with uncertainty in the experiment *.
*Note: Accept comparisons with any of the following uncertainties:

- Percentage uncertainty of L in (b)
- Percentage uncertainty due to m [ = $\frac{1}{2}\frac{\Delta m}{m} x100\%$ ]. Factor ½ is necessary due to the formula.
- Combined percentage uncertainty due to L and m [ =$\left(\frac{\Delta L}{L} + \frac{1}{2}\frac{\Delta m}{m}\right) x100\%$ ]

[3]

**(f) (i)** State two significant sources of error in this experiment.

1 .....

.....

.....

2 .....

.....

.....[2]

- If the tuning fork is struck too hard against the rubber bung, there is an initial 'clang' tone that has a frequency different from the one printed on the tuning fork.
- The tension in the string is not equal to mg due to the friction between the bridge and the string. The measured *L* may not be for the length when the tension is equal to mg.
- As L is adjusted, the paper rider may not always be at the mid-point to ascertain that the vibration is the strongest.
- It is not easy to judge when vibration is the strongest, affecting accuracy of L.

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- As the increments of m are only in 100g standard mass, the strongest vibration may occur in smaller increments of less than 100g. Thus, the recorded m may not be the value where the strongest vibration is observed.

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

……

……

……..[1]

- Allow the initial 'clang' tone to fade away before placing the tuning fork on the wooden board / bridge.
- Make a mark on the centre of the paper rider and use the rules to ensure the rider is at the mid-point between the bridges.
- Video-record the experiment, with a measuring tape/ruler to measure L also in the recording. Play back the video in magnified view to enhance observation of when the vibration is strongest.
- Use standard mass of 10 g, 20g and 50 g as increments for m so as to obtain a more accurate value of m where the strongest vibration can be observed.

**(g)** The oscillation of a stretched string depends on the properties of the string.

It is suggested that the fundamental frequency *f* is inversely proportional to the square root of the diameter *d* of the string.

Explain how you would investigate this relationship using the same apparatus. In addition, you have access to a set of 12 tuning forks and 6 strings of different diameters.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show inverse proportionality
- why you might not have enough results to reach a valid conclusion.

| | |
|---|---|
| Independent variable: d<br>Dependent variable: f<br><br>Use a micrometer screw gauge to measure d of each string.<br><br>Select one string to begin the experiment. Starting with the tuning fork of lowest frequency, determine which frequency of tuning fork first causes the paper rider to jump off the string. (This is important to obtain the fundamental frequency.) Record the frequency as f.<br><br>Repeat for the various diameters of strings. | 1<br><br>1 |

**[Turn Over**

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| | |
|---|---|
| Control of variables: The tension of the string, length of string between the bridges and the density/material of the string used should be kept constant throughout. | 1 |
| Plot a graph of f against $\frac{1}{\sqrt{d}}$ | 1 |
| If the suggested relationship holds, a graph of straight line (i.e. constant gradient) passing through the origin should be obtained. | 1 |
| Limitations of results:<br>Use of tuning forks does not allow for a continuous variation of frequency (i.e. small enough increments in frequency), hence it may not be possible to determine f for all the string diameters prepared. This may result in fewer than 6 sets of results. | |

[5]

**[Total: 20 marks]**

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**4.** A student is investigating the force between two charged metal spheres S and T, as shown in Fig. 4.1.

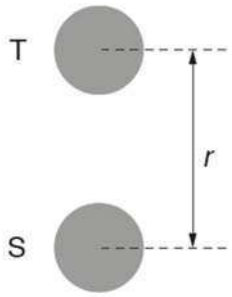


**Fig. 4.1**

Each sphere may be charged by connecting the positive lead from a power supply to the sphere and then removing the lead. The electromotive force (e.m.f.) of the power supply used to charge sphere T is $V$.

The force $F$ between the two charged spheres may be determined by attaching sphere S to an electronic balance.

For a constant charge on sphere S, it is suggested that the relationship between $F$ and $V$ is

$$F = kV^m r^n$$

where $r$ is the distance between the centres of the spheres; and $k$, $m$ and $n$ are constants.

Design an experiment to determine the values of $k$, $m$ and $n$.

You should draw a diagram to show the arrangement of your apparatus and you should pay particular attention to

**(a)** the equipment you would use

**(b)** the procedure to be followed

**(c)** the measurements to be taken

**(d)** the control of variables

**(e)** any precautions that should be taken to improve the accuracy and safety of the experiment.



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**Diagram**

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.....[12]

**[Total: 12 marks]**

**[Turn Over**

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| Question 4 | Marking Instructions | Mark | Code |
|---|---|---|---|
| Diagram | Fully labelled Diagram with mass at the top end of the rod and clamp at the bottom end of the rod<br>Award 1 mark if the following is the diagram –<br>• retort stand to suspend sphere T<br>• sphere S, on electronic balance, is vertically below T<br>• the spheres have insulated holder | 1 | A1 |
| Procedure | Procedure<br>1. Set up the apparatus as shown in the diagram.<br><br>2. Measuring *r:* Using fiducial markers to reference the top of each sphere, measure the distance between the two markers with a metre rule. This is equal to the distance *r*.<br>[OR, any other methods to measure r accurately e.g. Use of calipers/micrometer to measure diameter of spheres to determine *r*.]<br><br>3. Measuring *V*: Measure and record *V* across the power supply with a voltmeter [OR, Read and record *V* from high voltage power supply/EHT power supply.]<br><br>4. Measuring *F*:<br>a. Before charging the sphere S and T, measure, using the electronic balance, the total mass of the sphere S with its holder. Record as $m_1$.<br>b. Charge both spheres S and T by connecting the positive lead from the EHT power supply to each sphere and then removing the lead.<br>c. After charging the sphere S and T, measure the total mass of the Sphere S with its holder. Record as $m_2$.<br>d. Calculate $F = (m_2 - m_1)$ x *(acceleration due to gravity)*<br><br>Varying I.V.<br><br>Part 1: Vary *r* and keep *V* constant<br>5. Set the power supply to fixed voltage $V = V_0$, and ensure that the same voltage is used throughout Part 1 of the experiment. Record $V_o$ as in step 3.<br>6. Vary *r* by adjusting the clamp holding sphere *T*.<br>7. For each value of *r*, repeat steps 2 and 4 to obtain further readings of *r* and *F*.<br>8. $F = kV^m r^n$<br>Take log on both sides:<br>$\lg F = n\lg r + (\lg k + m\lg V)$<br>9. Plot a straight line graph of lg *F* against lg *r*. Calculate the gradient and the value is equal to *n*, where the vertical-intercept is $(\lg k + m\lg V)$.<br><br>Part 2: Vary *V* and keep *r* constant<br>10. Adjust the clamp so that sphere T is at a fixed distance $r = r_o$. from sphere S. Ensure that this distance does not change throughout Part 2 of the experiment. Record $r_o$ as in step 2.<br>11. Vary *V* by adjusting the power supply.<br>12. For each value of *V*, repeat steps 3 and 4 to obtain further readings of *V* and *F*.<br>13. With the equation in step 8,<br>$\lg F = m\lg V + (\lg k + n\lg r)$ | 1<br><br>1<br><br>1<br><br>1 (steps 5&6)<br><br>1<br><br>1 (steps 10&11) | B1<br><br>B2<br><br>B3<br><br>B4<br><br>B5<br><br>B6 |

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| | | | |
|---|---|---|---|
| | 14. Plot a straight line graph of lg *F* against lg *V*. Calculate the gradient and the value is equal to *m*, where the vertical-intercept is $(\lg k + n \lg r)$.<br>15. To determine *k*, determine the vertical-intercept of the graph of Part 2 and equate to $(\lg k + n \lg r)$, using the value of *n* obtained in Part 1 (step 9), and using the constant value of $r = r_o$ in Part 2 (step 10). | 1<br><br>1 | B7<br><br>B8 |
| Additional Details | Additional details: (Any 2 of the followings)<br>1. Insulated holder (e.g. Wood, rubber, Styrofoam) for top and bottom spheres – to prevent spheres from discharging when if they were in contact with the metal clamps or top-pan of the electronic balance, and a 'holder' design prevents roll off. (Reliability)<br>2. Put all the above in place first before charging the spheres to prevent discharging. (Reliability)<br>3. Ensure the spheres are charged to the same V as that set on the EHT power supply before every reading is taken. This can be ensured by connecting an ammeter along the lead connecting the positive terminal of the EHT power supply and the end touching the sphere, check the current is reduced to zero before removing the lead from the sphere. (Reliability)<br>4. Use an EHT power supply so that the spheres can be charged high enough to produce a larger and measureable force using the electronic balance. (Reliability)<br>5. Conduct experiment in a room with air-conditioning or de-humidifier to reduce the rate of discharge. (Reliability)<br>6. Conduct in the same room conditions throughout e.g. humidity. (Controlled variable)<br>7. Ensure the 2 spheres are vertically aligned. E.g. position 2 plumblines behind the setup as fiducial markers, used to ensure the 2 leftmost and rightmost points on the 2 spheres are vertically aligned. (Controlled variable) | 2 | C1<br><br>C2<br><br>C3<br><br><br><br><br><br>C4<br><br>C5<br><br>C6<br><br>C7 |
| Safety | Safety (Any one of the following)<br>1. Use insulating gloves to hold charge spheres or leads of power supply to avoid electrocution.<br>2. Ensure that there are no bare connections and avoid touching metal parts to avoid electrocution. | 1 | D1<br><br>D2 |
| | **Total Marks** | | **12** |



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DUNMAN HIGH SCHOOL
Preliminary Examinations
Year 6
Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

# PHYSICS

**9749/01**

Paper 1 Multiple Choice

**September 2019**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and index number on the Answer Sheet in the spaces provided unless this has been done for you.

DO **NOT** WRITE IN ANY BARCODES.

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

**Read the instructions on the Answer Sheet very carefully.**

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

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

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

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**Data**

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

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**Formulae**

| | | | |
|---|---|---|---|
| uniformly accelerated motion | $s$ | = | $ut + \frac{1}{2}at^2$ |
| | $v^2$ | = | $u^2 + 2as$ |
| work done on/by a gas | $W$ | = | $p\Delta V$ |
| hydrostatic pressure | $p$ | = | $\rho gh$ |
| gravitational potential | $\phi$ | = | $-\frac{Gm}{r}$ |
| temperature | $T$/K | = | $T$/°C + 273.15 |
| pressure of an ideal gas | $p$ | = | $\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E$ | = | $\frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x$ | = | $x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v$ | = | $v_0 \cos \omega t$ |
| | | = | $\pm \omega \sqrt{x_0^2 - x^2}$ |
| electric current | $I$ | = | $Anvq$ |
| resistors in series | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R$ | = | $1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V$ | = | $\frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current / voltage | $x$ | = | $x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B$ | = | $\frac{\mu_o I}{2\pi d}$ |
| magnetic flux denxity due to a flat circular coil | $B$ | = | $\frac{\mu_o NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B$ | = | $\mu_o nI$ |
| radioactive decay | $x$ | = | $x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda$ | = | $\frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** Which of the following definitions is correct?

**A** Density is mass per cubic metre.

**B** Potential difference is energy per unit current.

**C** Pressure is force per unit area.

**D** Speed is distance travelled per second.

**2** A body is thrown vertically upwards in a medium in which the viscous drag cannot be neglected. If the times of flight for the upward motion $t_u$ and the downward motion $t_d$ (to return to the same level) are compared, then

**A** $t_d > t_u$ , because the body moves faster on its downward flight and therefore the viscous force is greater.

**B** $t_d < t_u$ , because the effect of the viscous force is greatest at the moment of projection.

**C** $t_d = t_u$ , because effect of the viscous force is the same whether the body is moving upwards or downwards.

**D** $t_d > t_u$ , because at a given speed the net accelerating force when the body is moving downwards is smaller than the retarding force when it is moving upwards.

**3** A good driver is driving a car at 30 m $s^{-1}$ on a lane when another bad driver travelling at a constant speed of 20 m $s^{-1}$ swerves into the lane 20 m ahead. As soon as the good driver sees the car in front of him, he begins to brake.

Assume that the deceleration is constant.

Determine the smallest deceleration to avoid hitting the rear of the car.

**A** 1.5 m $s^{-2}$ **B** 2.5 m $s^{-2}$ **C** 5.0 m $s^{-2}$ **D** 12.5 m $s^{-2}$

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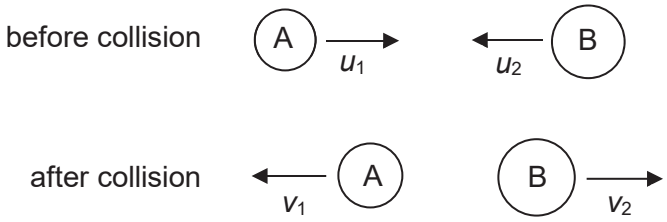
**4** Two spheres, A and B, are moving towards each other at speeds $u_1$ and $u_2$ respectively and make a head-on elastic collision. After the collision, A and B move off with speeds $v_1$ and $v_2$ respectively, as shown.

$u_1$ is more than $u_2$ and $v_2$ is more than $v_1$.




What is the correct expression that equates the relative speed of approach to the relative speed of separation?

**A** $u_1 + u_2 = v_1 + v_2$

**B** $u_1 + u_2 = v_2 - v_1$

**C** $u_1 - u_2 = v_1 + v_2$

**D** $u_1 - u_2 = v_2 - v_1$

**5** A 20 g object travelling to the right at 8.0 m $s^{-1}$ collides head-on with a 10 g object travelling to the left at 7.0 m $s^{-1}$.

Determine the loss in kinetic energy for both the 20 g and 10 g objects during the collision if the collision was perfectly inelastic.

**A** 3.0 kJ **B** 0.75 kJ **C** 3.0 J **D** 0.75 J

**6** A 50 g piece of ice is added to a cup containing 250 $cm^3$ of water.

Given that the density of water and ice is 1000 kg $m^{-3}$ and 900 kg $m^{-3}$ respectively, after all the ice has melted, the volume of water in the cup will

**A** remain unchanged.

**B** increase by 17 %.

**C** increase by 20 %.

**D** increase by 22 %.

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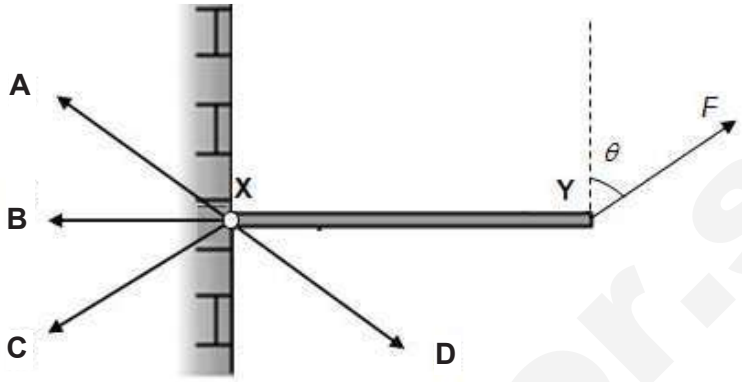
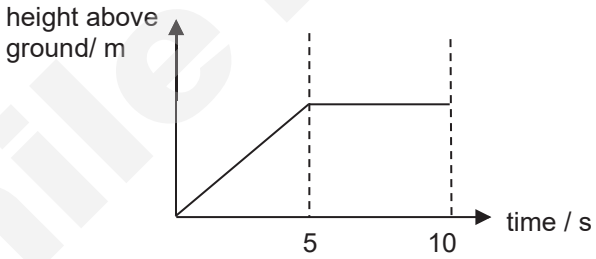
7 A uniform rod **XY** is freely hinged to the wall at **X**. It is held horizontal by a force *F* acting from **Y** at an angle $\theta$ to the vertical as shown in the diagram.

Which of the four options (**A**, **B**, **C** and **D**) best shows the direction of the force exerted by the rod on the wall?

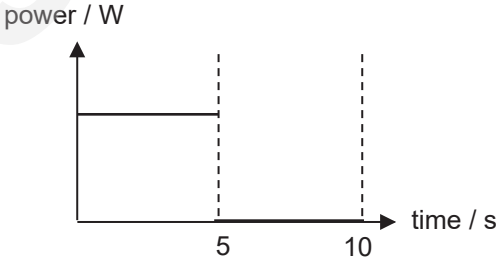



8 A crane lifts a load at constant speed vertically for the first five seconds. It then holds it at a fixed height for another five seconds. The variation of the height of the load above the ground with time is shown in the graph below.

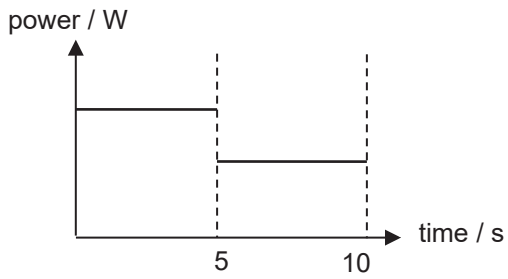



Which of the following graphs shows the variation of power supplied to the load with time?

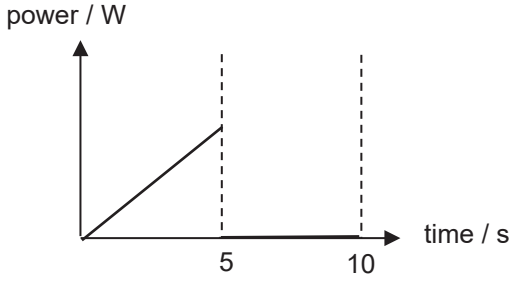
A



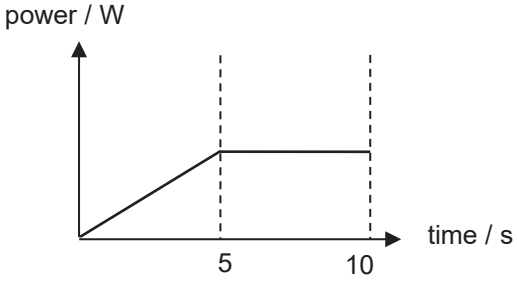

B




C




D

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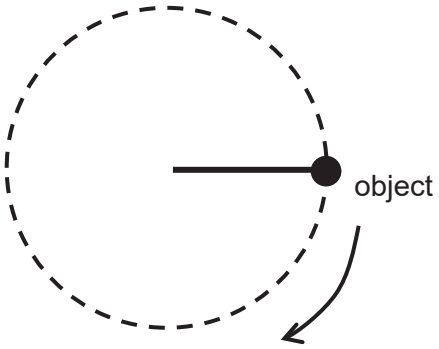
**9** An object attached to a rigid rod moves in a uniform circular motion in a vertical plane as shown.

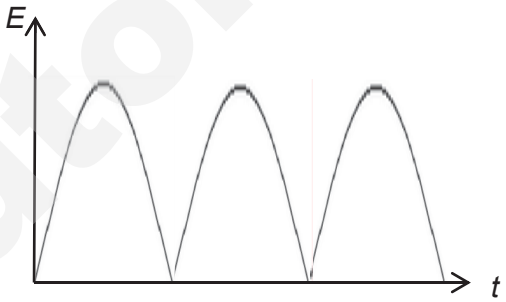



Which of the following shows the variation with time $t$ of its gravitational potential energy $E$?

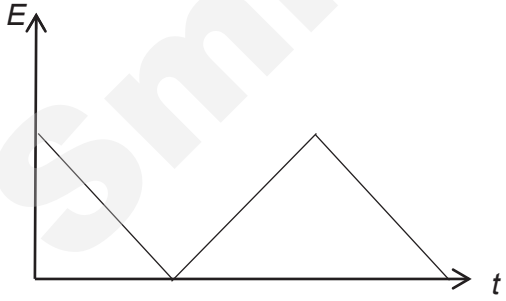
**A**



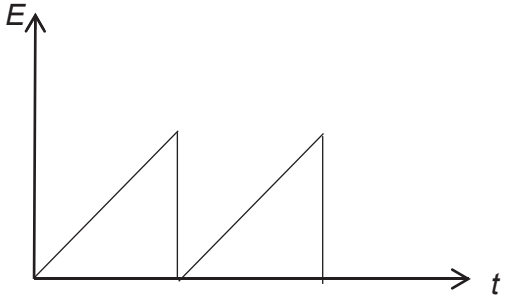

**B**




**C**




**D**




**10** The drag force acting on a car moving at a speed $v$ through still air is proportional to $v^2$.

When the car is travelling at 20 m $s^{-1}$ on a level road, the power required to overcome the drag force is 4800 W.

What power is required when the car travels at 25 m $s^{-1}$?

**A** 6000 W **B** 7500 W **C** 8000 W **D** 9400 W

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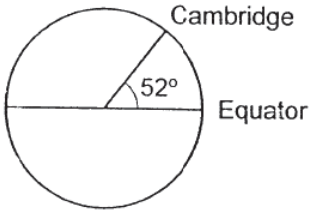
**11** Singapore is on the Equator. Cambridge is at a latitude of $52^{O}$ N, as shown in the diagram.




A student at Singapore has a centripetal acceleration $a_s$ because of the Earth's rotation about its axis. The centripetal acceleration of another student at Cambridge is $a_c$.

What are the magnitudes of the centripetal accelerations?

(radius of Earth = $6.4 \times 10^6$ m; angular velocity of Earth about axis = $7.3 \times 10^{-5}$ rad $s^{-1}$)

| | $a_s$ / m $s^{-2}$ | $a_c$ / m $s^{-2}$ |
|---|---|---|
| **A** | $3.4 \times 10^{-2}$ | $2.1 \times 10^{-2}$ |
| **B** | $3.4 \times 10^{-2}$ | $2.7 \times 10^{-2}$ |
| **C** | $3.4 \times 10^{-2}$ | $3.4 \times 10^{-2}$ |
| **D** | $4.7 \times 10^{2}$ | $4.7 \times 10^{2}$ |

**12** Which statement about geostationary orbits is **false**?

**A** A geostationary orbit must be directly above the equator.

**B** All satellites in a geostationary orbit must have the same mass.

**C** The period of a geostationary orbit must be 24 hours.

**D** There is only one possible radius for a geostationary orbit.

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**13** Four different solids **A**, **B**, **C** and **D** of equal masses at 20 °C are separately heated at the same rate. Their melting points and specific heat capacities are as shown in the table below.

Which of these solids will be the third to start to melt?

| Solid | Melting point/ °C | Specific heat capacity/ J kg$^{-1}$ K$^{-1}$ |
|---|---|---|
| **A** | 150 | 600 |
| **B** | 80 | 1200 |
| **C** | 300 | 250 |
| **D** | 100 | 800 |

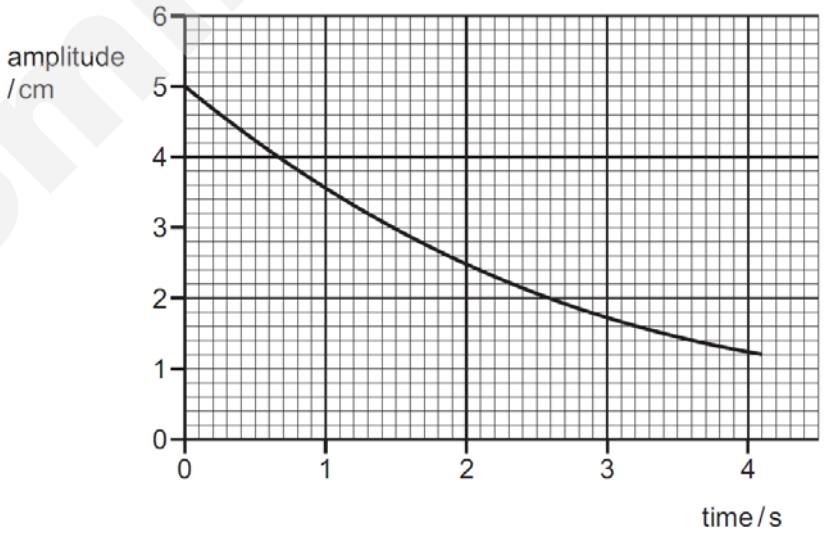
**14** Container X contains neon and container Y contains argon. The two containers are identical and the two gases are at the same temperature. The pressure in X is twice that in Y.

What is the ratio of the mean kinetic energy of a neon molecule to the mean kinetic energy of an argon molecule?

[The relative atomic masses of neon and argon are 20 and 40 respectively.]

**A** 0.5 **B** 1 **C** 2 **D** 4

**15** The graph shows how the amplitude of a simple pendulum decays with time from an initial amplitude of 5.0 cm.




What is the fraction of the initial energy that has been lost in the first 4.0 s?

**A** $\frac{1}{16}$ **B** $\frac{1}{4}$ **C** $\frac{3}{4}$ **D** $\frac{15}{16}$

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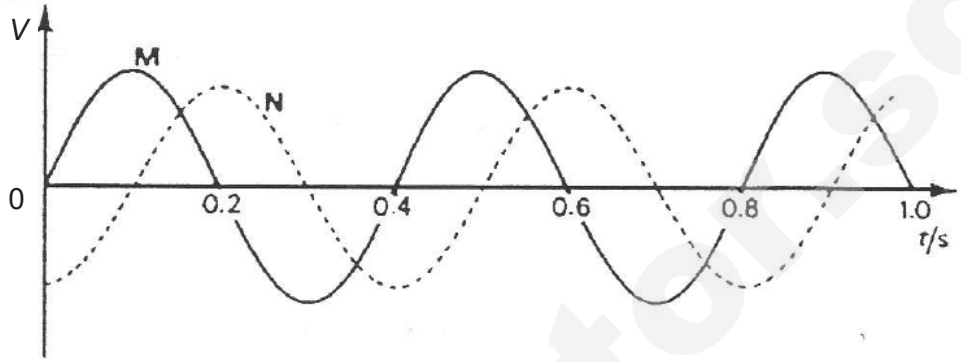
**16** A small mass executes s.h.m. about a point O with amplitude $a$ and period $T$. Its displacement from O at time $T/8$ after passing through O is

**A** $\frac{a}{8}$ **B** $\frac{a}{2\sqrt{2}}$ **C** $\frac{a}{2}$ **D** $\frac{a}{\sqrt{2}}$

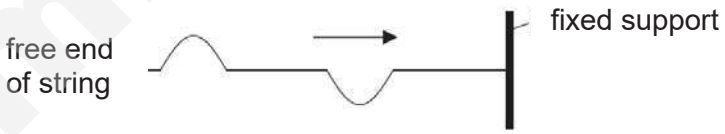
**17** Two sinusoidal voltages of the same frequency are shown in the diagram.




What is the phase lead of N over M, in rad, between the voltages?

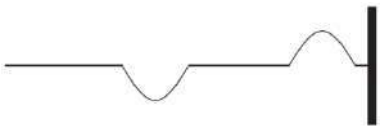
**A** $-\frac{\pi}{2}$ **B** $+\frac{\pi}{2}$ **C** $-\frac{\pi}{4}$ **D** $+\frac{\pi}{4}$

**18** A string is held horizontally with one end attached to a fixed support. Two pulses are created at the free end of the string. The pulses are moving towards the fixed support as shown in the diagram.

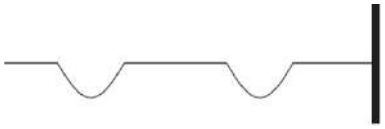



Which one of the following is a possible subsequent picture of the string?

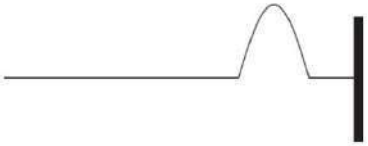
**A**



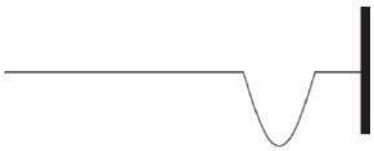
**B**



**C**



**D**



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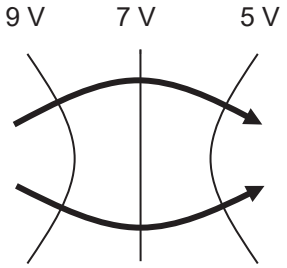
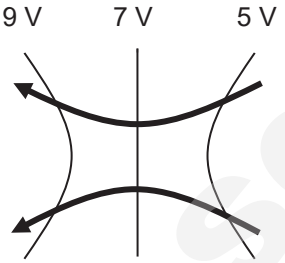
**19** In the following diagrams, the thin lines show equipotential lines and the bold arrows show the electric field lines and their directions.

Which set of equipotential lines and field lines is possible?

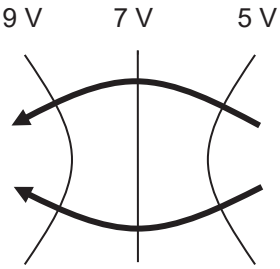
**A**



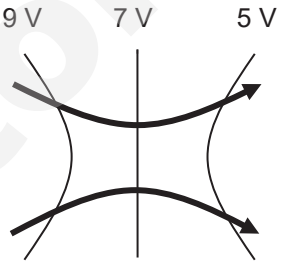

**B**



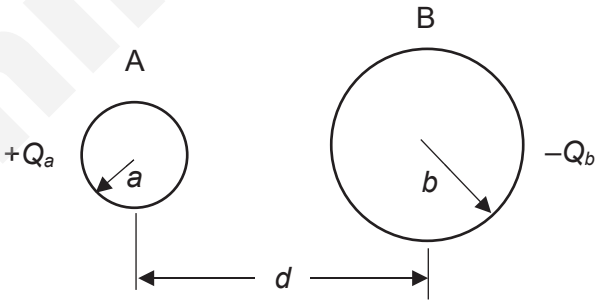

**C**




**D**




**20** A and B are two large conducting spheres, of radii *a* and *b* and carrying charges $+Q_a$ and $-Q_b$ respectively. They are placed a short distance *d* apart.




Which of the following statements about the magnitude of electrostatic forces *F*, between the spheres is true?

**A** $F = \dfrac{Q_a Q_b}{4\pi\varepsilon_o d^2}$

**B** $F = \dfrac{Q_a Q_b}{4\pi\varepsilon_o (d - a - b)^2}$

**C** $F > \dfrac{Q_a Q_b}{4\pi\varepsilon_o d^2}$

**D** $F > \dfrac{Q_a Q_b}{4\pi\varepsilon_o (d - a - b)^2}$

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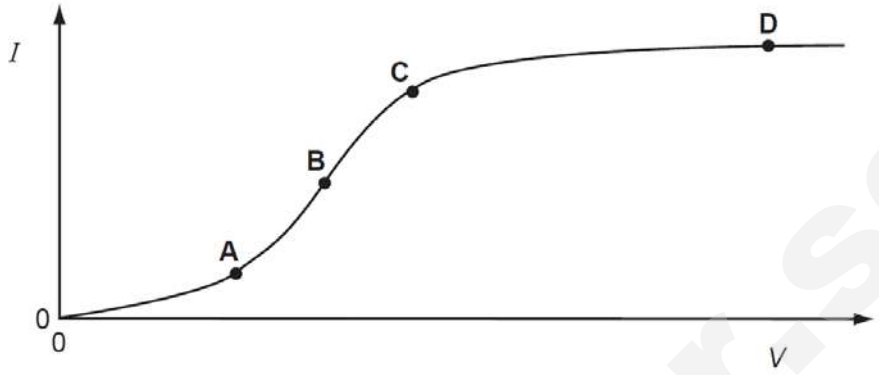
**21** The graph shows how the electric current $I$ through a conducting liquid varies with the potential difference $V$ across it.

At which point on the graph does the liquid have the smallest resistance?




**22** Which statement about electrical resistivity is correct?

**A** The resistivity of a material is numerically equal to the resistance in ohms of a cube of that material, the cube being of side length one metre and the resistance being measured between opposite faces.

**B** The resistivity of a material is numerically equal to the resistance in ohms of a one metre length of wire of that material, the area of cross-section of the wire being one square millimetre and the resistance being measured between the ends of the wire.

**C** The resistivity of a material is proportional to the cross-sectional area of the sample of the material used in the measurement.

**D** The resistivity of a material is proportional to the length of the sample of the material used in the measurement.

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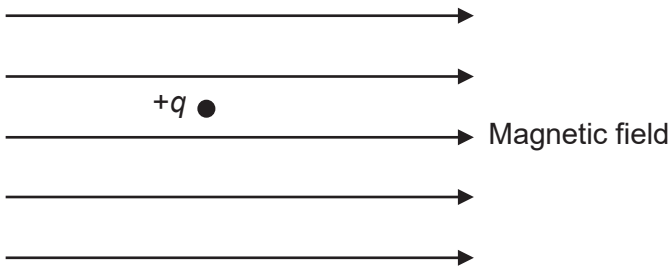
**23** A positive charge $+q$ is held at rest in a uniform magnetic field, and then released. The effect of gravity on the charge can be ignored.




How does the charge move after it is released?

**A** The charge moves to the right with constant velocity.

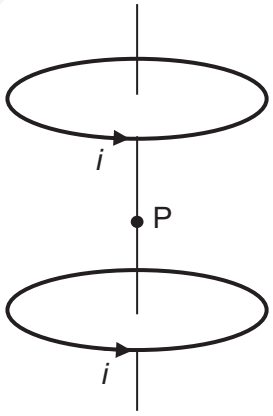
**B** The charge moves in a circle with constant speed.

**C** The charge moves in a circle with increasing speed.

**D** The charge stays at rest.

**24** Two identical loops of wire carry identical currents $i$. The loops are located with their centres vertically above each other as shown in the diagram.

Which arrow best represents the direction of the magnetic field at the point P, midway between the loops?




**A** ↓ **B** → **C** ↑ **D** zero

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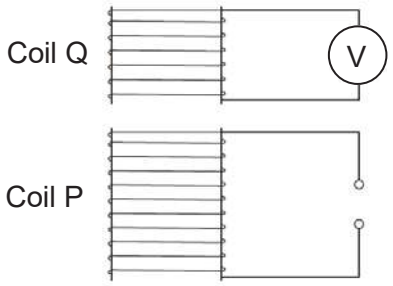
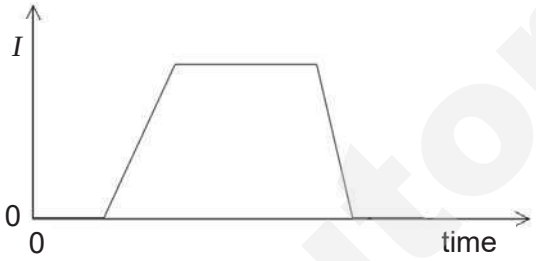
**25** Two coils P and Q are arranged as shown below.

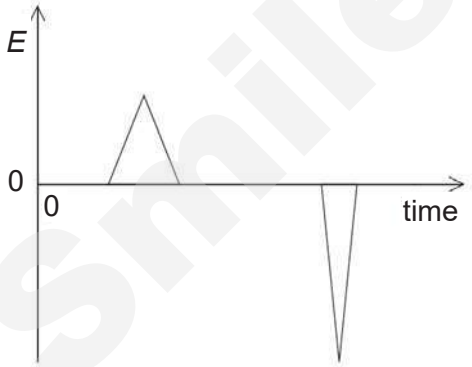



Coil Q is connected to a sensitive voltmeter. The current $I$ in coil P is varied as shown below.

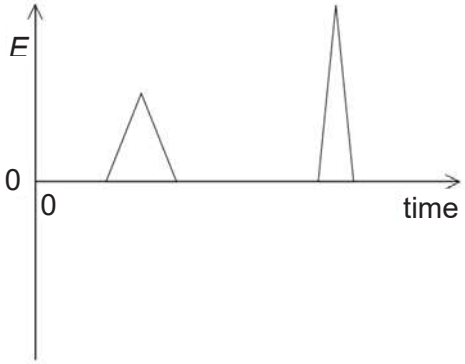



Which of the following graphs best shows the variation with time of the e.m.f. $E$ induced in the coil Q?

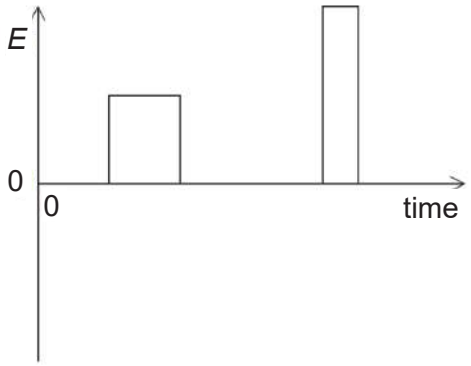
**A**



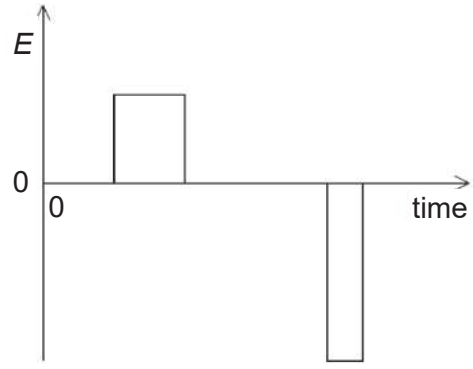

**B**




**C**




**D**

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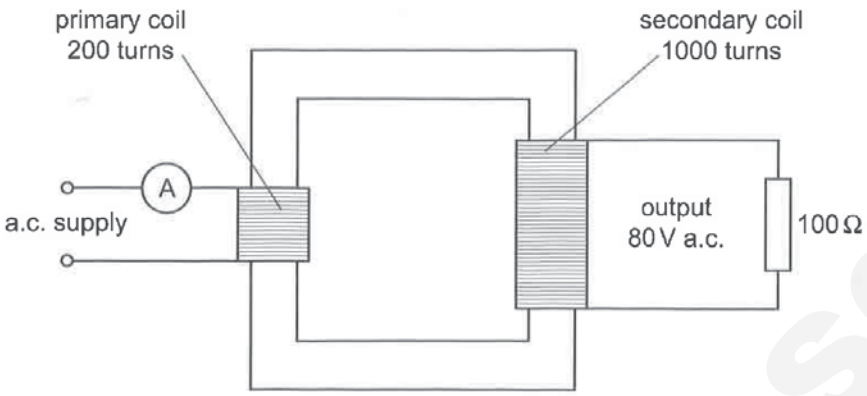
**26** An ideal transformer is connected as shown to a sinusoidal a.c. supply.




What is the reading on the ammeter?

**A** 0.16 A **B** 0.80 A **C** 2.8 A **D** 4.0 A

**27** 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

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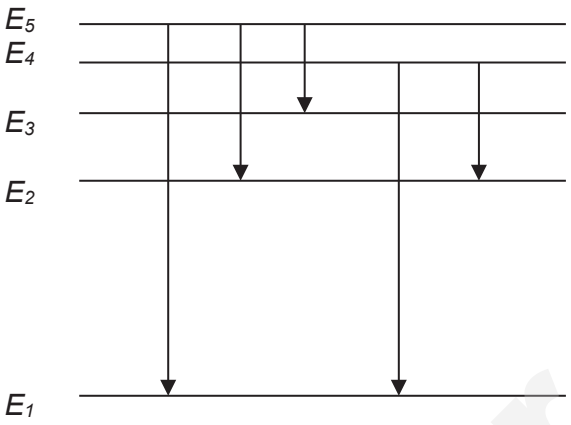
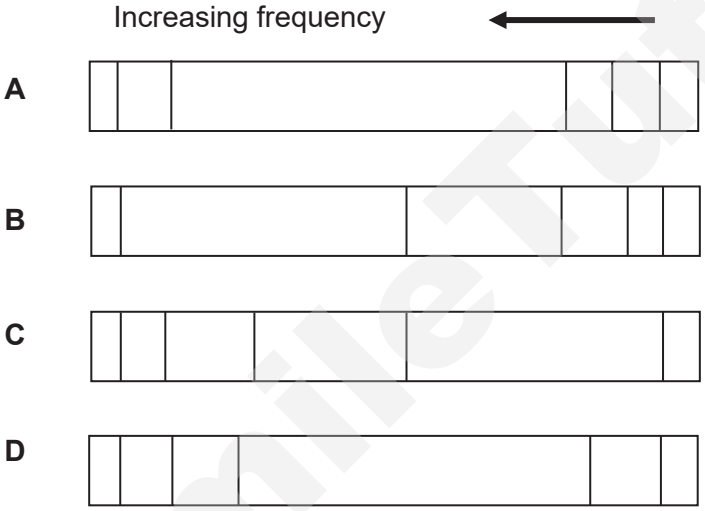
**28** The figure below shows five energy levels of an atom, $E_1$ being much lower than the other four. Five transitions between the levels are indicated, each of which produces a photon of definite energy and frequency.




Which one of the following spectra below best corresponds to the set of transitions indicated?

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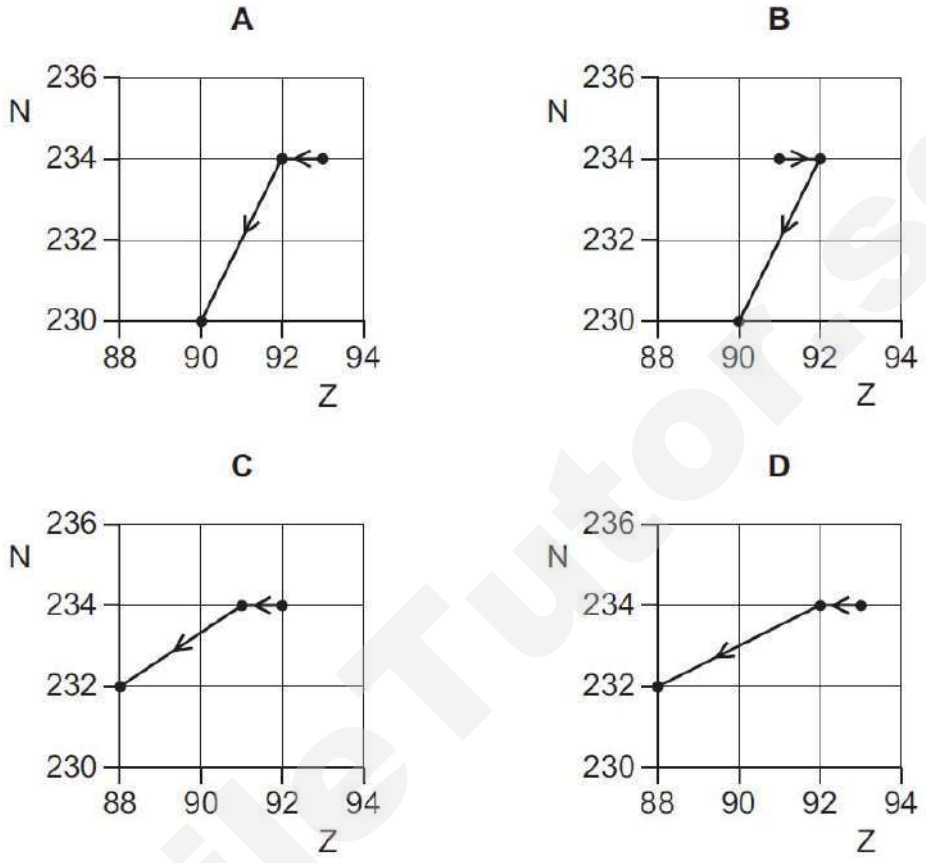
**29** A radioactive nucleus is formed by β-decay. This nucleus then decays by α-emission.

Which graph of nucleon number N plotted against proton number Z shows the β-decay followed by α-emission?




**30** Nuclei of atoms can exist in excited states.

The mass of a nucleus in its ground state is 59.9308 *u*.

When this nucleus returns from an excited state to the ground state, a gamma ray photon of energy $2.13 \times 10^{-13}$ J is emitted.

What is the mass of a nucleus in the excited state?

**A** 59.9280 *u*

**B** 59.9294 *u*

**C** 59.9322 *u*

**D** 59.9337 *u*

- END OF PAPER –

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DUNMAN HIGH SCHOOL
Preliminary Examinations
Year 6
Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

# PHYSICS

**9749/02**

Paper 2 Structured Questions

**September 2019**

**2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

Write your class, index number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

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

Answer **all** questions.

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

| For Examiner's Use | |
|---|---|
| 1 | /8 |
| 2 | /8 |
| 3 | /9 |
| 4 | /10 |
| 5 | /9 |
| 6 | /8 |
| 7 | /10 |
| 8 | /18 |
| Total | /80 |

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**Data**

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

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**Formulae**

| | | | |
|---|---|---|---|
| uniformly accelerated motion, | $s$ | = | $ut + \frac{1}{2}at^2$ |
| | $v^2$ | = | $u^2 + 2as$ |
| work done on/by a gas, | $W$ | = | $p\Delta V$ |
| hydrostatic pressure, | $p$ | = | $\rho gh$ |
| gravitational potential, | $\phi$ | = | $-Gm/r$ |
| temperature, | $T$/K | = | $T$/°C + 273.15 |
| pressure of an ideal gas, | $p$ | = | $\frac{1}{3}\frac{Nm}{V}<c^2>$ |
| mean translational kinetic energy of an ideal gas molecule, | $E$ | = | $\frac{3}{2}kT$ |
| displacement of particle in s.h.m., | $x$ | = | $x_0 \sin \omega t$ |
| velocity of particle in s.h.m., | $v$ | = | $v_0 \cos \omega t$ |
| | | = | $\pm\omega\sqrt{x_o^2 - x^2}$ |
| electric current, | $I$ | = | $Anvq$ |
| resistors in series, | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel, | $1/R$ | = | $1/R_1 + 1/R_2 + \ldots$ |
| electric potential, | $V$ | = | $\frac{Q}{4\pi\varepsilon_o r}$ |
| alternating current / voltage, | $x$ | = | $x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire, | $B$ | = | $\frac{\mu_0 I}{2\pi d}$ |
| magnetic flux denxity due to a flat circular coil, | $B$ | = | $\frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid, | $B$ | = | $\mu_0 nI$ |
| radioactive decay, | $x$ | = | $x_0 \exp(-\lambda t)$ |
| decay constant, | $\lambda$ | = | $\frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** A ball is projected with a horizontal velocity of 1.1 m $s^{-1}$ from point A at the edge of a table, as shown in Fig. 1.1.

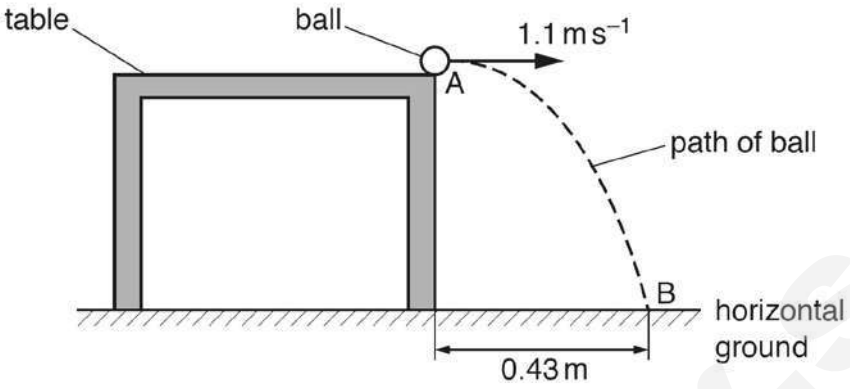


**Fig. 1.1**

The ball lands on the horizontal ground at point B which is a distance of 0.43 m from the base of the table. Air resistance is negligible.

**(a)** Calculate the time taken for the ball to fall from A to B.

time = ..... s [1]

**(b)** Calculate the magnitude of the displacement of the ball at point B from point A.

displacement = ..... m [3]

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**(c)** The ball leaves the table at time $t = 0$.

For the motion of the ball between points A and B, sketch graphs on Fig. 1.2 to show the variation with time $t$ of

**(i)** the acceleration $a$ of the ball,

**(ii)** the vertical component $s_v$ of the displacement of the ball from A.

Numerical values are not required.

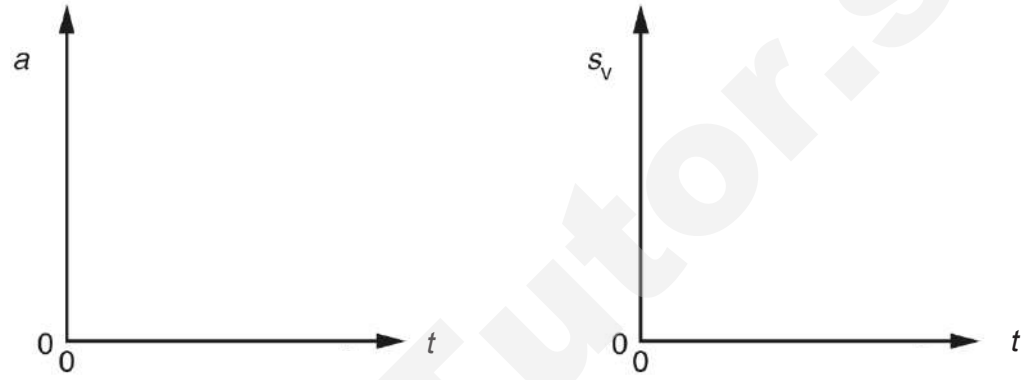


**Fig. 1.2**

[2]

**(d)** Explain why the distance travelled by the ball is different from the magnitude of the displacement of the ball.

……

……

……[1]

**(e)** Another ball of greater mass is projected from the table with the same horizontal velocity of 1.1 m $s^{-1}$. Air resistance is still negligible.

State and explain the effect, if any, of the increased mass on the time taken for the ball to fall to the ground.

……

……[1]

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**2** Domestic washing machines often incorporate washing, rinsing, spinning and drying of clothes. This question is about the spin-dry function of a washing machine.

**(a)** The inner drum of the machine into which the clothes are placed has quite large holes in it.

Explain how, when the clothes are being spin-dried, the water gets out from the clothes and through the holes.

……..……..

……..……..

……..……..

……..……..

……..……..

……..……[3]

**(b)** One of the spin speeds in one model of washing machine was listed as 1000 rpm (revolutions per minute).

Calculate the largest resultant force that could be exerted on a wet jacket of mass 0.500 kg given that the radius of the spinning drum is 12.5 cm.

largest resultant force = …….. N [3]

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**(c)** If clothes are unevenly distributed in a washing machine, it vibrates slightly as it rotates.

The drums of a washing machine are suspended from the casing by springs, at the top and bottom, as shown in Fig. 2.1.

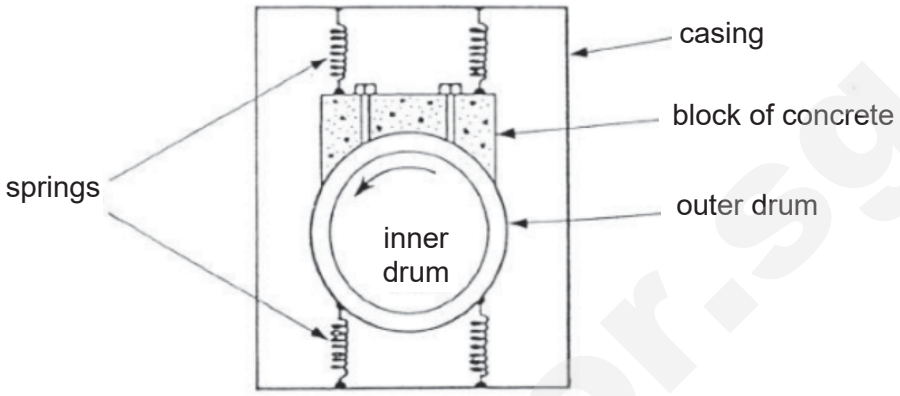


**Fig. 2.1**

Suggest and explain the purpose of these springs.

……

……

……

……

……[2]

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**3** **(a)** State the meaning of the term *internal energy* of a system.

……..……..

……..……..

……..…….[2]

**(b)** An ideal gas undergoes a cycle of changes A → B → C → A, as shown in Fig. 3.1.

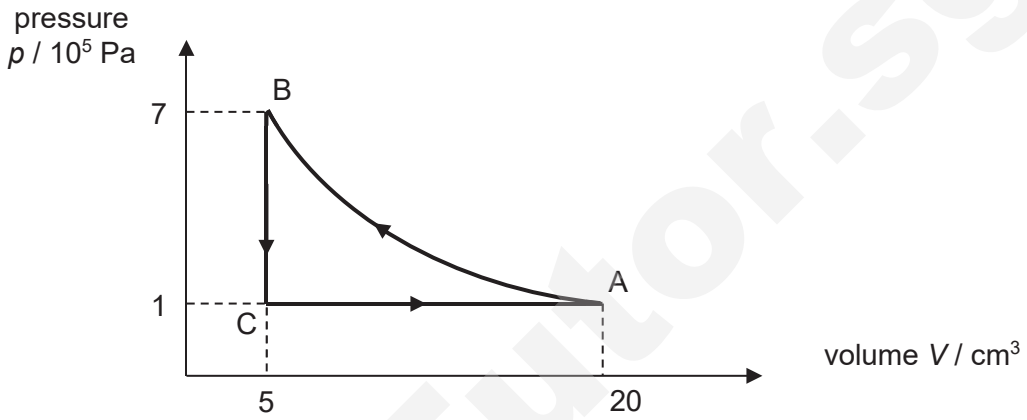


**Fig. 3.1**

**(i)** Calculate the work done by the gas during the change C → A.

work done by gas = …….. J [2]

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**(ii)** Fig 3.2 is a table of energy changes during one cycle. Complete Fig. 3.2. [3]

| section of cycle | heat supplied to gas / J | work done on gas / J | increase in internal energy of gas / J |
|---|---|---|---|
| A → B | zero | 4.2 | |
| B → C | - 8.5 | | |
| C → A | | | |

**Fig. 3.2**

**(c)** Heat is a type of energy, but temperature is not a type of energy.

State two other differences between heat and temperature.

**1.** .....

.....

**2.** .....

.....[2]

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**4** **(a)** A mass is undergoing oscillations in a vertical plane.

The variation with displacement $x$ of the acceleration $a$ of the mass is shown in Fig. 4.1.

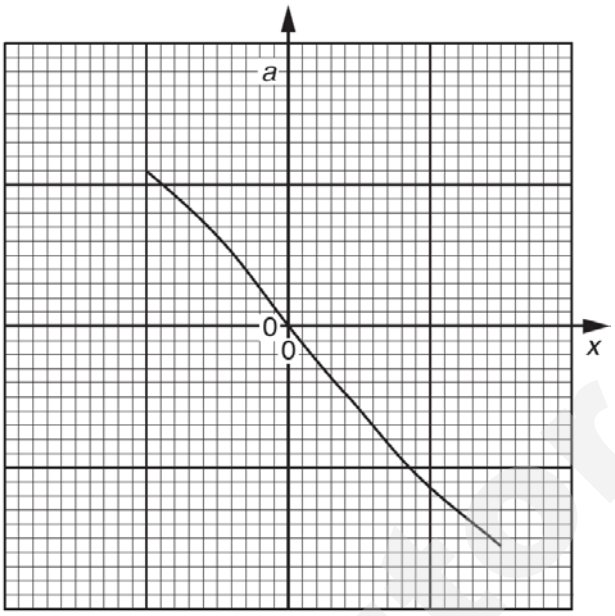


**Fig. 4.1**

Use Fig. 4.1 to state two reasons why the oscillations are not simple harmonic.

**1.** .....

.....

**2.** .....

.....[2]

**(b)** To illustrate simple harmonic motion, a student attaches a trolley to two similar stretched springs as shown in Fig. 4.2.

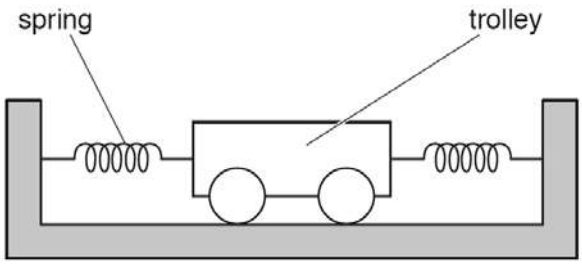


**Fig. 4.2**

The trolley has mass $m$ of 810 g.

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The trolley is displaced along the line joining the two springs and then released. The subsequent acceleration $a$ of the trolley is given by the expression

$$a = -\frac{2kx}{m}$$

where the spring constant $k$ for each of the springs is 64 N m$^{-1}$ and $x$ is the displacement of the trolley.

**(i)** Show that the frequency of oscillation of the trolley is 2.0 Hz. [2]

**(ii)** The maximum displacement of the trolley is 1.6 cm.
Calculate the maximum speed of the trolley.

maximum speed = …… m s$^{-1}$ [2]

**(iii)** As the trolley passes the position where $x$ = 0 cm, a mass is dropped vertically from a small height above the trolley and sticks to the trolley.

State and explain the change, if any, that occurs in the maximum speed and in the amplitude of the subsequent oscillations of the trolley.

speed ……

……[2]

amplitude……

……[2]

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**5** An $\alpha$-particle is emitted from a radium nucleus with a kinetic energy of 5.75 MeV.

The $\alpha$-particle travels in a vacuum directly towards a gold ($^{197}_{79}Au$) nucleus, as illustrated in Fig. 5.1.




**Fig. 5.1**

**(a)** Explain why, as the $\alpha$-particle approaches the gold nucleus, it comes to rest.

……..……..

……..……..

……[2]

**(b)** For the closest approach of the $\alpha$-particle to the gold nucleus determine

**(i)** their separation,

separation = …… m [2]

**(ii)** the magnitude of the force on the $\alpha$-particle.

force = …… N [1]

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**(c)** State two assumptions made in the determination in **(b)**.

**1.** .....

.....

**2.** .....

.....[2]

**(d)** The $\alpha$-particle travels from the initial position to the position of closest approach to the gold nucleus.

On Fig. 5.2, sketch the variation with position of

**(i)** the electric potential energy between the $\alpha$-particle and the gold nucleus, labelled as *EPE*,

**(ii)** the kinetic energy of the $\alpha$-particle, labelled as *KE*.




[2]

**Fig. 5.2**

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**6** **(a)** Explain how an electric field and a magnetic field may be used for the velocity selection of charged particles. You may draw a diagram if you wish.

……..……..

……..……..

……..……..

……..……[3]

**(b)** An ion of charge $Q$ and mass $m$ is moving with speed $v$ normal to a magnetic field of magnetic flux density $B$. The ion will move in a circular path of radius $r$.

Derive an expression for $r$ in terms of $Q$, $m$, $v$ and $B$. [2]

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**(c)** The isotopes strontium-87 ($^{87}_{38}Sr$) and strontium-86 ($^{86}_{38}Sr$) are found in samples of Moon rock. Particles of a sample of Moon rock are vaporised, releasing strontium isotopes that are sent into the velocity selector of a mass spectrometer as shown in Fig. 6.1. The positive ions of strontium isotopes then pass through a uniform magnetic field which makes them follow separate circular paths.

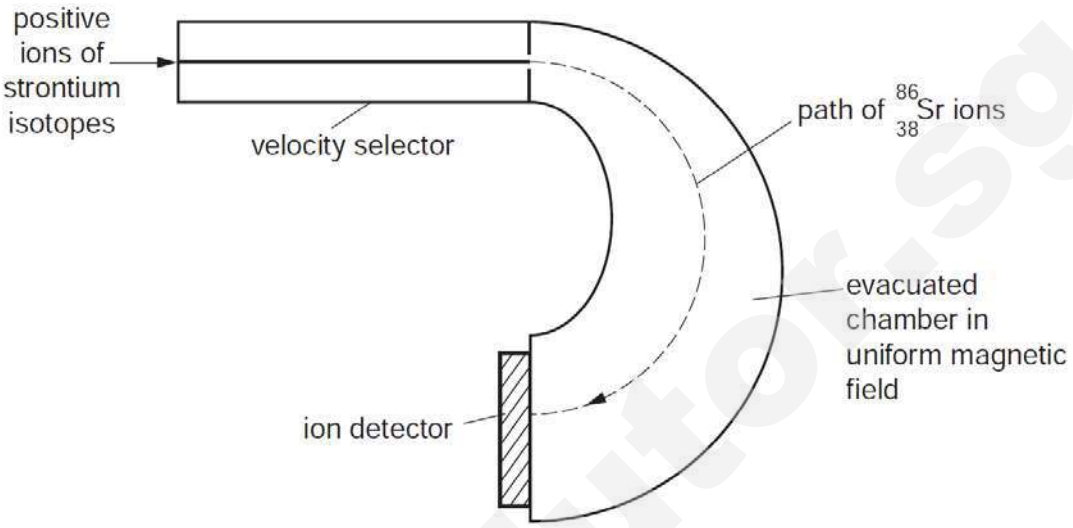


**Fig. 6.1**

**(i)** On Fig. 6.1, sketch a possible path for the strontium-87 ($^{87}_{38}Sr$) ions. [1]

**(ii)** The velocity selector allows strontium ions of speed $7.6 \times 10^5$ m $s^{-1}$ to enter the evacuated chamber in uniform magnetic field of magnetic flux density 680 mT.

Determine the change in the magnetic flux density needed to make the strontium-87 ($^{87}_{38}Sr$) ions follow the same path taken initially by the strontium-86 ions.

change in magnetic flux density = ..... T [2]

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**7** An evacuated tube contains two plane, parallel, metal electrodes, one of which is an emitter of electrons and the other a collector. When the emitter is illuminated with electromagnetic radiation of photon energy 4.7 eV at a power of 3.8 mW, photoelectrons are emitted.

The potential difference $V$ between collector and emitter is adjusted, and the photocurrent $I$ is measured.

Fig. 7.1 is a graph of the variation with the potential difference $V$ of the photocurrent $I$.

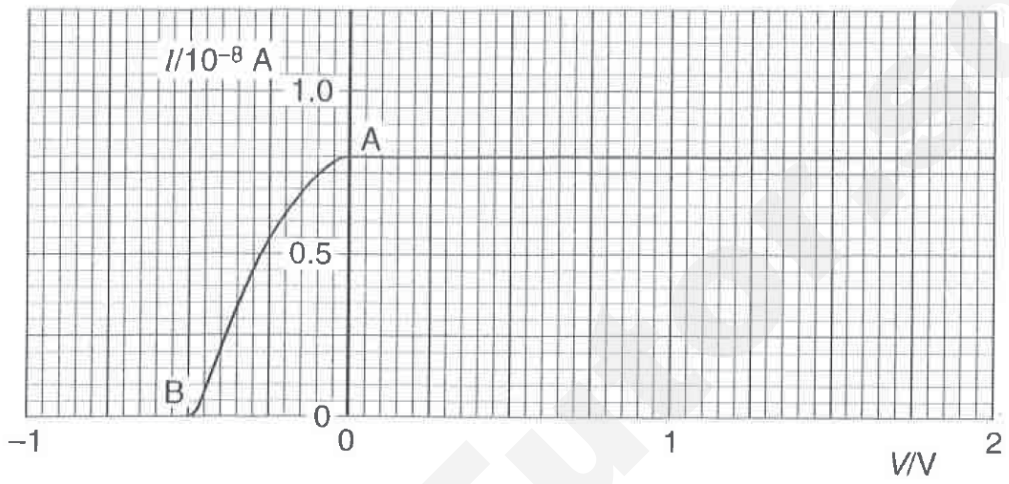


**Fig. 7.1**

**(a)** Calculate the rate at which photons are incident on the emitter.

rate = ..... $s^{-1}$ [2]

**(b)** Calculate the maximum rate at which electrons leave the emitter.

maximum rate = ..... $s^{-1}$ [1]

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**(c)** Suggest two reasons to explain for the difference between your answers to **(a)** and **(b)**.

**1.** .....

.....

**2.** .....

.....[2]

**(d)** Calculate the maximum speed at which electrons leave the emitter.

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

**(e)** The intensity of illumination is then increased and the experiment repeated. Sketch, on Fig. 7.1, the new variation with the potential difference $V$ of the photocurrent $I$. [2]

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**8** Prior to the alpha-scattering experiment conducted by Rutherford, the plum pudding model of the atom was widely assumed. In this model, the positive charge of the atom was thought to be evenly spread out through the entire volume of the atom, and its electrons vibrating about fixed positions within this sphere of charge.

In the experiment conducted by Rutherford, alpha particles are directed towards a thin gold foil as shown in Fig. 8.1. A detector is used to record the number of alpha particles scattered by the foil. The experiment is performed in a vacuum. The detector can be rotated such that it is able to capture the alpha particles at various scattering angles $\theta$. The variation with the scattering angle $\theta$ of the number of alpha particles $N$ striking the detector are shown in Fig. 8.2. The vertical axis in Fig. 8.2 is logarithmic.

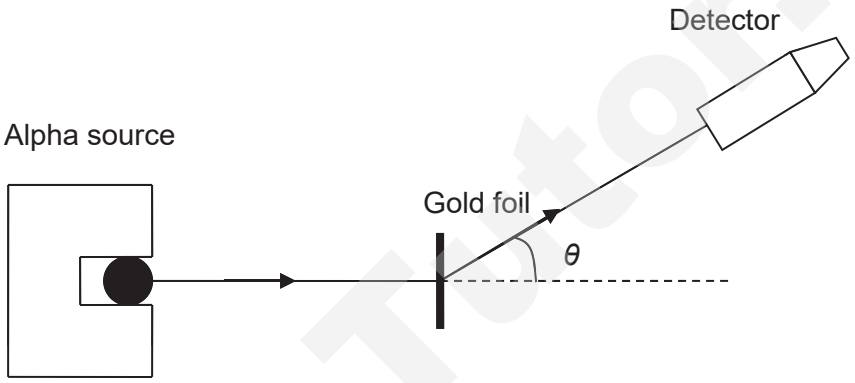


**Fig. 8.1**

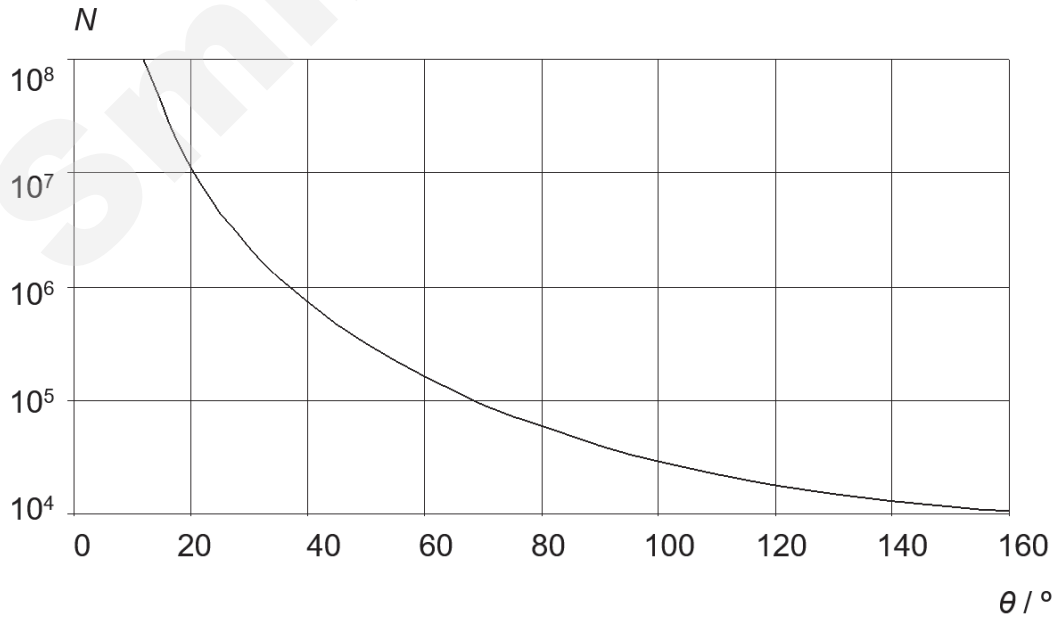


**Fig. 8.2**

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**(a)** State and explain why

**(i)** the experiment is not conducted in air, and

……

……

……[2]

**(ii)** the vertical axis is logarithmic.

……

……

……[2]

**(b)** On Fig. 8.2, sketch the results expected if the structure of the atom was indeed that of a plum pudding. [1]

**(c)** It is thought that the number of alpha particles $N$ striking the detector is directly proportional to $(\sin(\theta/2))^n$ where $n$ is an integer. The variation with $\theta$ between 60º to 80º of $N$ is shown in Fig. 8.3.

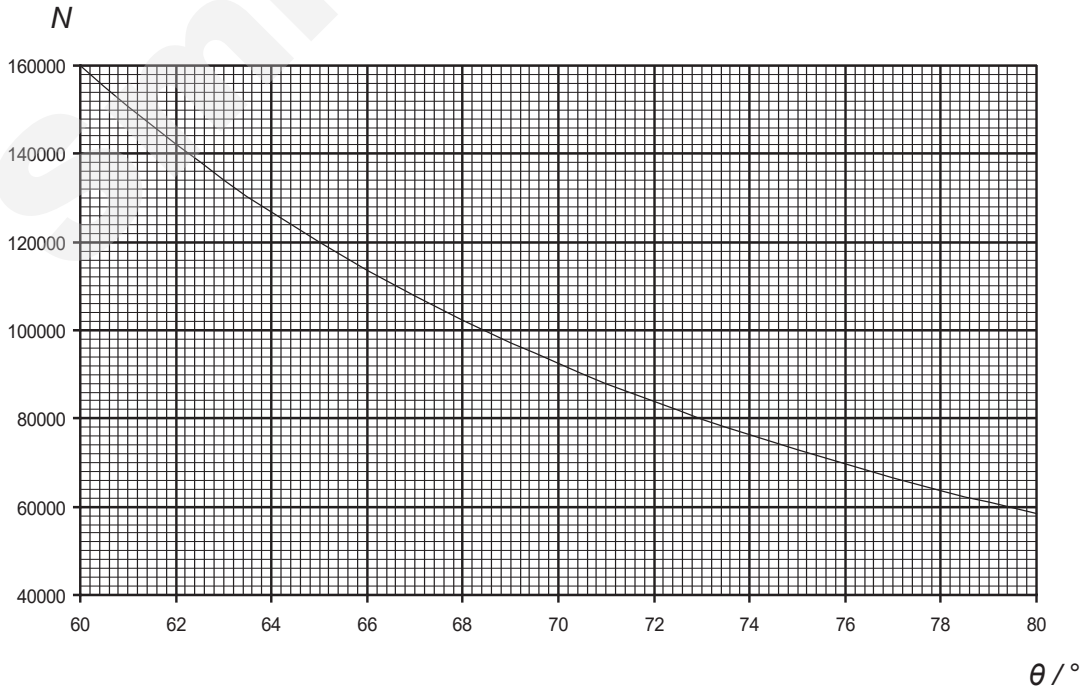


**Fig. 8.3**

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Some corresponding values of lg (sin ($\theta$/2) ) and lg $N$ are plotted on the graph of Fig. 8.4.

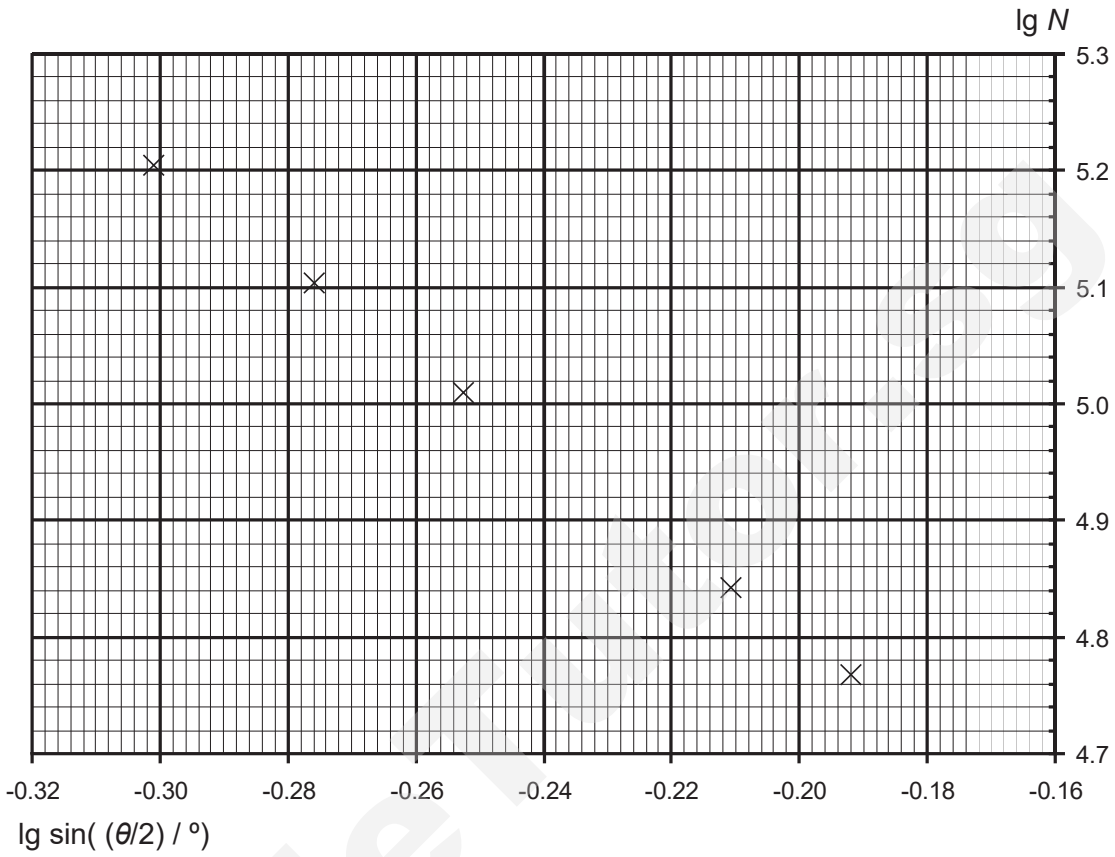


**Fig. 8.4**

**(i)** On Fig. 8.4,

**1.** plot the point corresponding to $\theta$ = 72º, and

**2.** draw the best-fit line for all plotted points. [2]

**(ii)** Determine the gradient of the line drawn in **c(i)2.**

gradient = ..... [2]

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**(iii)** Hence, deduce a value for $n$. Show your working clearly.

$n$ = ..... [2]

**(d)** The experiment is repeated using target foils made of 3 other different elements - tungsten W, iridium Ir and platinum Pt. The results for the angles between 65º to 74º are shown in Fig. 8.5 together with that of gold Au.

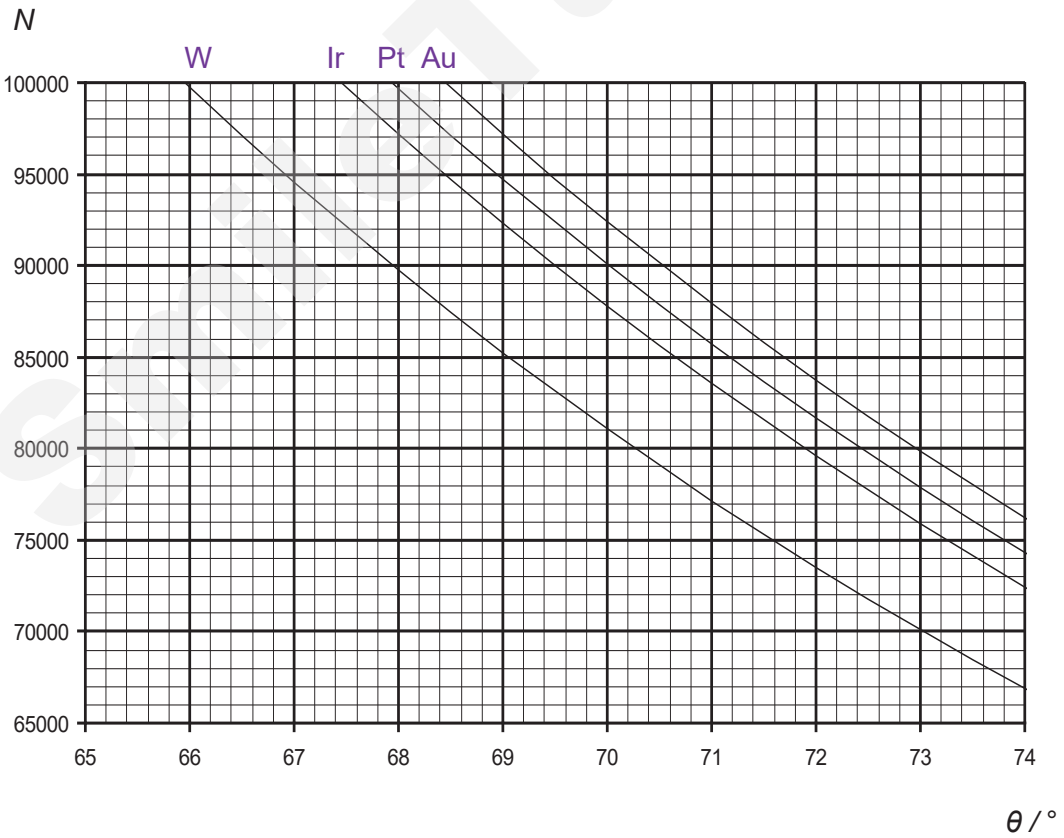


**Fig. 8.5**

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Without drawing a further graph, show that, at $\theta = 70^{o}$, the value of $N$ is directly proportional to $\square^2$, where $\square$ is the proton number of the target foil.

The proton number of W, Ir, Pt and Au are 74, 77, 78 and 79 respectively. [3]

**(e)** The overall relationship between $N$, $\square$ and $\theta$ may be expressed as

$$N = k\square^2(\sin(\theta / 2))^n$$

where $k$ is a constant.

Suggest two physical quantities that determine the value of $k$.

**1.** .....

.....

**2.** .....

.....[2]

**(f)** The experiment is repeated with a foil made from a heavier isotope of gold.

State and explain how the results in Fig. 8.2 would be different.

.....

.....

.....[2]

**END OF PAPER**

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DUNMAN HIGH SCHOOL
Preliminary Examinations
Year 6
Higher 2

CANDIDATE NAME

CLASS

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# PHYSICS

**9749/03**

Paper 3 Longer Structured Questions

**September 2019**

**2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

Write your class, index number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

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

**Section A**
Answer **all** questions.

**Section B**
Answer **one** question only.

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

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

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|---|---|
| 1 | /5 |
| 2 | /12 |
| 3 | /10 |
| 4 | /7 |
| 5 | /12 |
| 6 | /6 |
| 7 | /8 |
| 8 | /20 |
| 9 | /20 |
| Total | /80 |

This document consists of **24** printed pages and **0** blank page.


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**Data**

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

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**Formulae**

| | | | |
|---|---|---|---|
| uniformly accelerated motion, | $s$ | = | $ut + \frac{1}{2}at^2$ |
| | $v^2$ | = | $u^2 + 2as$ |
| work done on/by a gas, | $W$ | = | $p\Delta V$ |
| hydrostatic pressure, | $p$ | = | $\rho gh$ |
| gravitational potential, | $\phi$ | = | $-Gm/r$ |
| temperature, | $T$/K | = | $T$/°C + 273.15 |
| pressure of an ideal gas, | $p$ | = | $\frac{1}{3}\frac{Nm}{V}<c^2>$ |
| mean translational kinetic energy of an ideal gas molecule, | $E$ | = | $\frac{3}{2}kT$ |
| displacement of particle in s.h.m., | $x$ | = | $x_0 \sin \omega t$ |
| velocity of particle in s.h.m., | $v$ | = | $v_0 \cos \omega t$ |
| | | = | $\pm\omega\sqrt{x_o^2 - x^2}$ |
| electric current, | $I$ | = | $Anvq$ |
| resistors in series, | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel, | $1/R$ | = | $1/R_1 + 1/R_2 + \ldots$ |
| electric potential, | $V$ | = | $\frac{Q}{4\pi\varepsilon_o r}$ |
| alternating current / voltage, | $x$ | = | $x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire, | $B$ | = | $\frac{\mu_0 I}{2\pi d}$ |
| magnetic flux denxity due to a flat circular coil, | $B$ | = | $\frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid, | $B$ | = | $\mu_0 nI$ |
| radioactive decay, | $x$ | = | $x_0 \exp(-\lambda t)$ |
| decay constant, | $\lambda$ | = | $\frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

**1** **(a)** Make reasonable estimates of the following quantities.

**(i)** The mass of an adult.

mass = ..... kg

**(ii)** The weight of a hand phone at Earth's surface.

weight = ..... N

**(iii)** The energy required for an adult to climb up to the top row in the school auditorium.

energy = ..... J

**(iv)** The pressure on your feet at a depth of 1.0 m in an adult swimming pool.

pressure = ..... Pa

[2]

**(b)** **(i)** The theory of gas flow through small diameter tubes at low pressures is an important consideration of high vacuum technique.

One equation which occurs in the theory is

$$Q = \frac{kr^3(p_1 - p_2)}{L}\sqrt{\frac{M}{RT}}$$

where $k$ is a number without units, $r$ is the radius of the tube, $p_1$ and $p_2$ are the pressures at each end of the tube of length $L$, $M$ is the molar mass of the gas, $R$ is the molar gas constant and $T$ is the thermodynamic temperature.

Use the equation to find the base SI units of $Q$.

base SI units of $Q$ = ..... [2]

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**(ii)** The value of $r$ for the equation in **(b)(i)** is $(1.37 \pm 0.05) \times 10^{-4}$ m.

What percentage uncertainty does this introduce into the value of $Q$?

percentage uncertainty = ..... % [1]

**2** **(a)** State the two conditions necessary for a rigid body to be in equilibrium.

**1.** .....

.....

**2.** .....

.....[2]

**(b)** A horizontal force $F$ is applied on a cube which remains stationary, as shown in Fig. 2.1. G is the centre of mass of the cube and is located at its geometric centre. The line of action of $F$ is midway between G and the top of the cube.

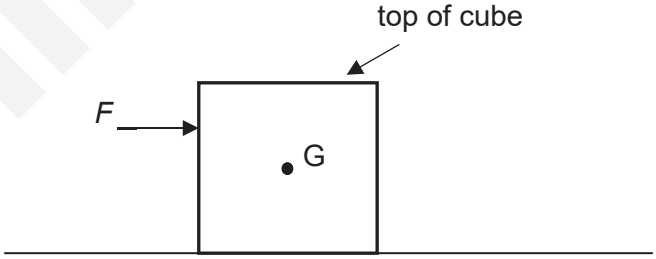


**Fig. 2.1**

**(i)** On Fig. 2.1, draw the following forces acting on the cube:

**1.** Weight of the cube, labelled as $W$. [1]

**2.** Resultant force, labelled as $R$, that the ground exerts on the cube. [2]

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**(ii)** If the mass of the cube is 200 g, calculate the maximum value of $F$ such that the cube does not rotate.

maximum value of $F$ = ..... N [2]

**(c)** A spring has an unstretched length of 8.0 cm. One end of the spring is fixed to a support and a mass of 140 g is attached to the other end of the spring. The length of the spring is now 10.8 cm.

Calculate the force constant of the spring.

force constant = ..... N $m^{-1}$ [2]

**(d)** The cube in **(b)** is now attached to one end of the spring in **(c)** and is submerged in a liquid, as shown in Fig. 2.2. The length of the spring is now 10.3 cm.

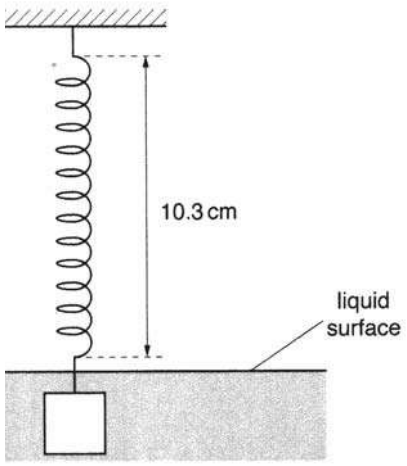


**Fig. 2.2**

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**(i)** Show that the upthrust acting on the cube is approximately 0.83 N. [1]

**(ii)** The cube is made of concrete which has a density of 2.4 g $cm^{-3}$.

Determine the density of the liquid.

density = …… kg $m^{-3}$ [2]

**3** **(a)** Define *gravitational potential energy*.

……

……

……[2]

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**(b)** Fig. 3.1 shows part of the orbit of a satellite round the Earth.

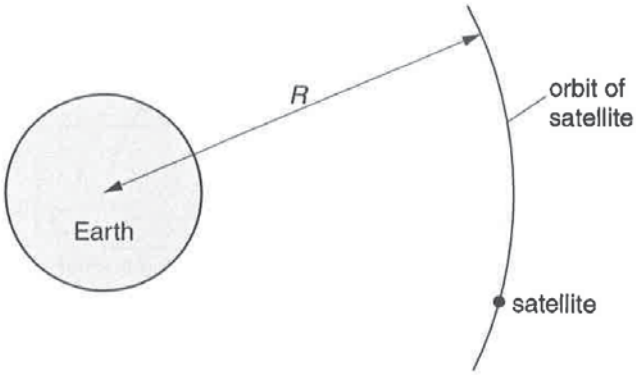


**Fig. 3.1**

The mass $M$ of the Earth is $6.0 \times 10^{24}$ kg. It may be assumed that the gravitational field of the Earth is the same as that of a point mass $M$ situated at the centre of the Earth.

**(i)** On Fig. 3.1 show, by means of an arrow, the direction of the gravitational force on the satellite. [1]

**(ii)** Explain why the satellite does not move in the direction of the gravitational force.

.....

.....

.....[1]

**(iii)** Show that $v$, the linear speed of the satellite in its orbit of radius $R$, is given by the expression

$$v = \sqrt{\frac{GM}{R}}$$

where $G$ is the gravitational constant. [1]

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**(c)** The satellite is orbiting the Earth with a radius $R$ of 6610 km at a speed $v$ of 7780 m $s^{-1}$.

The satellite is boosted into a higher orbit of radius 6890 km. Determine the speed of the satellite in the new orbit.

speed of satellite = ..... m $s^{-1}$ [2]

**(d)** The satellite has a mass of 120 kg. Using the data in **(c)**, calculate the change in

**(i)** kinetic energy, and

change in kinetic energy = ..... J [1]

**(ii)** gravitational potential energy.

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

**4** **(a)** Explain why exposure to steam at 100 °C produces a more severe burn than exposure to the same amount of hot water at 100 °C.

.....

.....

.....

.....

.....

.....[3]

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**(b)** For each of the following statements, explain whether it is correct, stating clearly your reasons.

**(i)** The specific latent heat of fusion of a substance is always less than the specific latent heat of vaporisation of the substance.

.....

.....

.....

.....[2]

**(ii)** For the same mass, volume and temperature, the pressure exerted by a real gas is the same as that exerted by an ideal gas.

.....

.....

.....

.....[2]

**5** **(a)** Two identical filament lamps are connected in series and then in parallel to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance, as shown in Fig. 5.1a and Fig. 5.1b respectively.

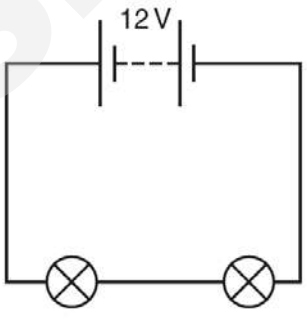


**Fig. 5.1a**

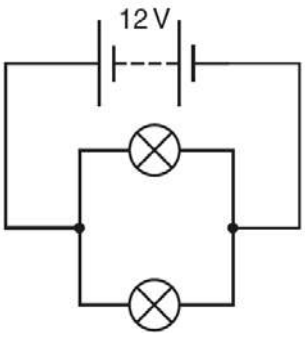


**Fig. 5.1b**

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The $I$-$V$ characteristic of each lamp is shown in Fig. 5.2.

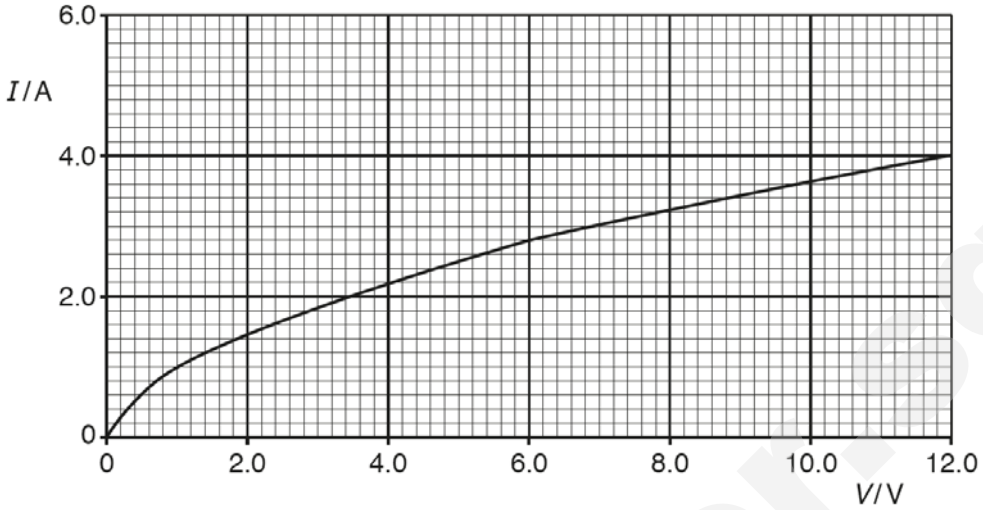


**Fig. 5.2**

**(i)** Use Fig. 5.2 to determine the current through the battery in the

**1.** circuit of Fig. 5.1a,

current = ..... A

**2.** circuit of Fig. 5.1b.

current = ..... A [2]

**(ii)** Calculate the total resistance in the

**1.** circuit of Fig. 5.1a,

resistance = ..... Ω

**2.** circuit of Fig. 5.1b.

resistance = ..... Ω [2]

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**(iii)** Calculate the ratio

$$\frac{\text{power dissipated in a lamp in the circuit of Fig. 5.1a}}{\text{power dissipated in a lamp in the circuit of Fig. 5.1b}}$$

ratio = ..... [2]

**(b)** A metal wire BD has a length of 100 cm and resistance of 4.0 Ω. The ends B and D of the wire are connected to a cell X as shown in Fig. 5.3.

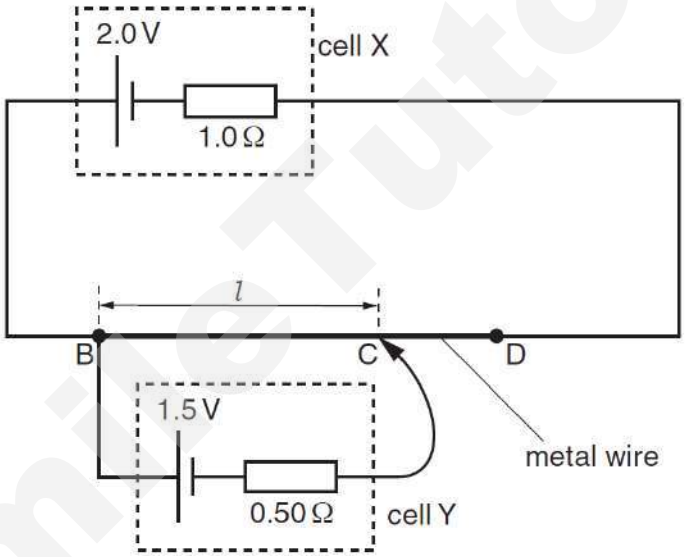


**Fig. 5.3**

The cell X has an e.m.f. of 2.0 V and internal resistance of 1.0 Ω.

A cell Y of e.m.f. 1.5 V and internal resistance 0.50 Ω is connected to the wire at points B and C, as shown in Fig. 5.3.

The point C is at a distance $l$ from point B. The current in cell Y is zero.

Calculate

**(i)** the current in cell X,

current = ..... A [1]

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**(ii)** the distance $l$.

$l$ = ..... m [3]

**(c)** The connection at C in **(b)** is moved so that $l$ is increased. Explain why the e.m.f. of cell Y is less than its terminal p.d.

.....

.....

.....[2]

**6** An ideal transformer is shown in Fig. 6.1.

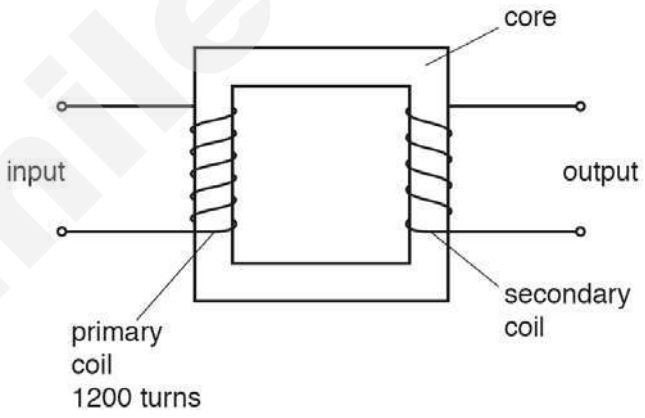


**Fig. 6.1**

**(a)** Explain why the core is

**(i)** made of iron,

.....

.....[1]

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**(ii)** laminated.

……

……[1]

**(b)** Use Faraday's law to explain the operation of the transformer.

……

……

……

……[2]

**(c)** An alternating voltage of peak value 150 V is applied across the 1200 turns of the primary coil. The variation with time $t$ of the e.m.f. $E$ induced across the secondary is shown in Fig. 6.2.

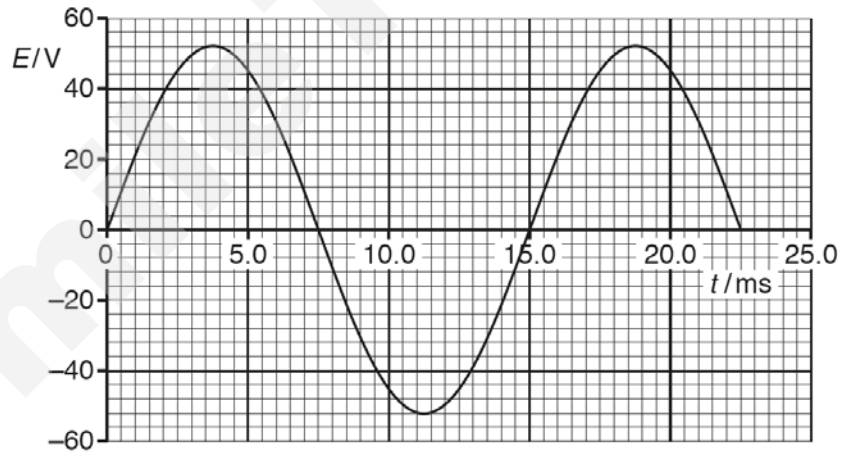


**Fig. 6.2**

Use data from Fig. 6.2 to

**(i)** calculate the number of turns of the secondary coil,

number = …… [1]

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**(ii)** state one time when the magnetic flux linking the secondary coil is a maximum.

time = ..... ms [1]

**7** Fig. 7.1 shows an X-ray spectrum produced by a medical X-ray tube operating at an accelerating potential of 40 kV.

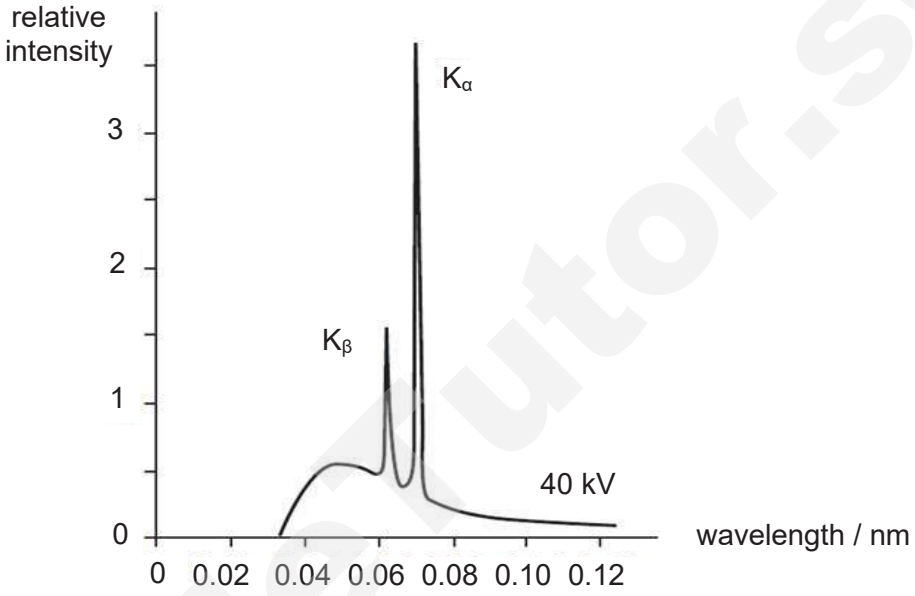


**Fig. 7.1**

**(a) (i)** Using Fig. 7.1, estimate the highest energy of the X-rays emitted by the tube.

highest energy = ..... J [2]

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**(ii)** Calculate the maximum velocity of the high energy electrons hitting the target atom when the tube operates at 40 kV.

maximum velocity = ..... m $s^{-1}$ [2]

**(iii)** Hence calculate the de Broglie wavelength of the electrons at maximum velocity.

de Broglie wavelength = ..... m [2]

**(b)** Explain how the characteristic X-ray lines $K_\alpha$ and $K_\beta$ are produced in Fig. 7.1.

……..……..

……..……..

……..……..

……..……[2]

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## Section B

Answer **one** question from this Section in the spaces provided.

**8** **(a)** Explain how stationary waves are formed.

……

……

……[2]

**(b)** A microphone that is connected to a cathode-ray oscilloscope (c.r.o.) is used by a student to detect the sound from a loudspeaker. Fig. 8.1 shows the trace on the screen of the c.r.o.

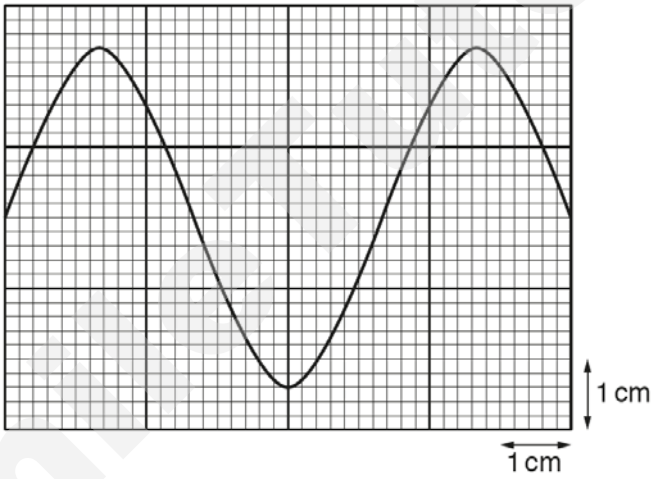


**Fig. 8.1**

In air, the sound wave has a speed of 330 m $s^{-1}$ and a wavelength of 0.18 m.

**(i)** Calculate the frequency of the sound wave.

frequency = …… Hz [1]

**(ii)** Determine the time-base setting, in s $cm^{-1}$, of the c.r.o.

time-base setting = …… s $cm^{-1}$ [1]

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**(iii)** The intensity of the sound from the loudspeaker is now halved. The wavelength of the sound is unchanged. Assume that the amplitude of the trace is proportional to the amplitude of the sound wave.

On Fig. 8.1, sketch the new trace shown on the screen of the c.r.o. [2]

**(c)** Next, the student fills a long tube, fitted with a tap, with liquid. The loudspeaker in **(b)** is held above the top of the vertical tube as the liquid is allowed to run out of the tube, as shown in Fig. 8.2.

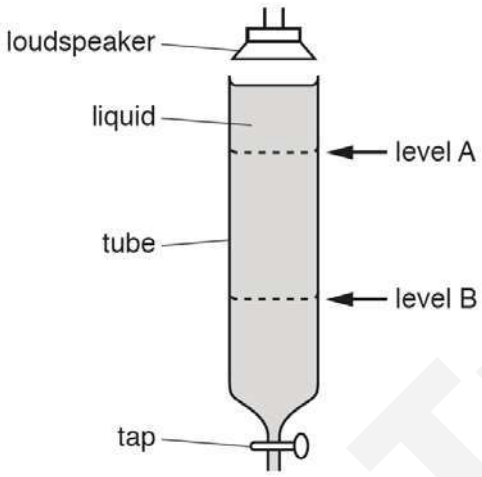


**Fig. 8.2**

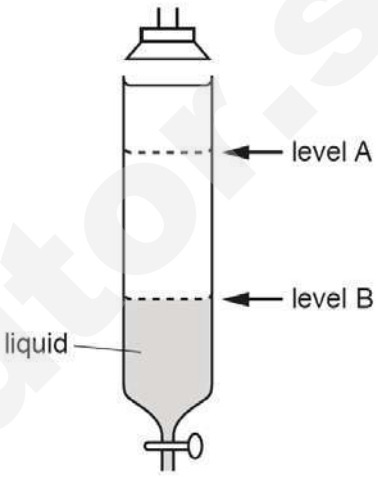


**Fig. 8.3**

A loud sound is first heard when the liquid level reaches level A and then heard again when the liquid level reaches B, as shown in Fig. 8.3.

**(i)** Calculate the vertical distance between level A and level B.

vertical distance = ..... m [1]

**(ii)** The mass of the liquid leaving the tube per unit time is 6.7 g $s^{-1}$. The tube has an internal cross-sectional area of 13 $cm^2$. The density of the liquid is 0.79 g $cm^{-3}$.

Calculate the time taken for the liquid to move from level A to level B.

time = ..... s [2]

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**(d)** The student sets up two loudspeakers $S_1$ and $S_2$ that are situated 100 cm apart in air, as shown in Fig. 8.4. A microphone M is situated a distance 140 cm from $S_1$ along a line that is normal to $S_1S_2$.

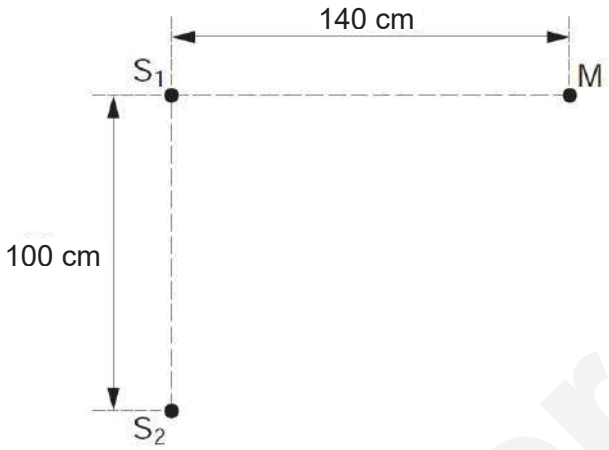


**Fig. 8.4**

The two loudspeakers always vibrate in phase and the frequency of vibration can be varied.

As the frequency of $S_1$ and $S_2$ is gradually increased, the microphone M detects maxima and minima of intensity of sound.

**(i)** State one condition that must be satisfied for the intensity of sound at M to be maximum.

……

……[1]

**(ii)** The speed of sound in air is 330 m $s^{-1}$.

The frequency of the sound from $S_1$ and $S_2$ is increased. Determine the number of maxima that will be detected at M as the frequency is increased from 1.0 kHz to 4.0 kHz.

number = …… [3]

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**(e)** The student moves on to explore with a laser of wavelength 633 nm. The laser is placed behind a glass microscope slide that has been painted black. A single vertical slit of width 0.0800 mm has been produced by scratching through the paint with a razor blade.

Light from the laser passes through the slit and hits a wall at a distance of 5.12 m from the slit. A light sensor connected to a data logger is moved across the wall and the variation with distance moved by the sensor of the intensity of light is shown in Fig. 8.5.

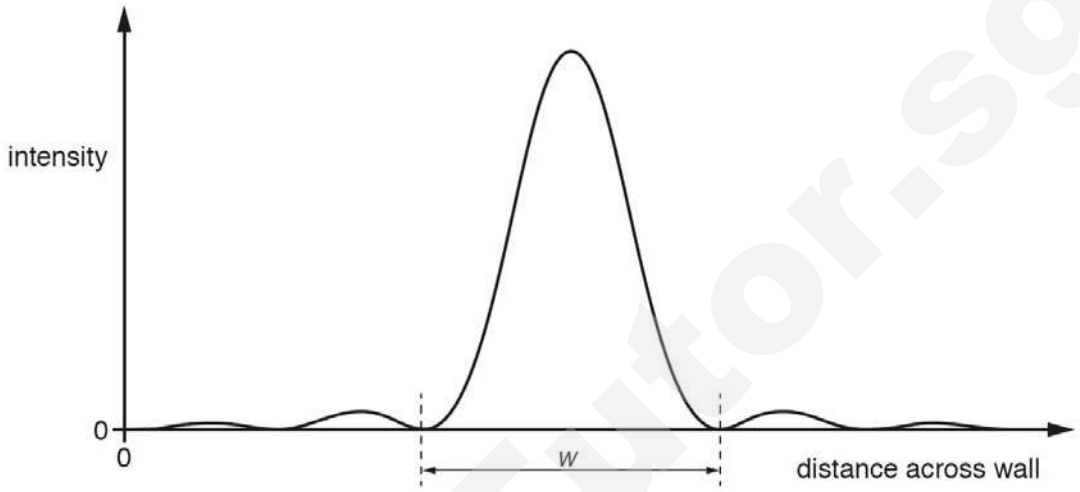


**Fig. 8.5**

The width *w* of the central patch is equal to the distance between the two minimum points on either side of the central patch where the intensity of the light is equal to zero.

**(i)** Determine *w*.

*w* = ..... m [2]

**(ii)** A second vertical slit of width 0.0800 mm is scratched across the slide. The second slit is parallel to the first and its centre is a horizontal distance of 0.240 mm away from the centre of the first slit.

The slide now acts as a double slit. At the centre of the double-slit interference pattern on the wall, there are bright and dark fringes which are uniformly spaced.

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1. Some parts of the screen that were brightly lit when only the first slit was present are now dark, even though the light is still passing through the first slit in the same way.

   Explain what causes this to happen.

   .....

   .....[1]

2. Determine the separation $x$ of the bright fringes.

   $x$ = ..... m [2]

3. Most of the bright fringes are separated from adjacent bright fringes by a distance $x$. In a few places, away from the centre, however, there are separations of $2x$ and there is no light in the middle of the gap where a bright fringe might be expected.

   Using the results from **(e)(i)** and **(e)(ii)2**, explain why there is no light at such places.

   .....

   .....

   .....

   .....[2]

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**9** **(a)** Explain what is meant by

**(i)** the *radioactive decay* of a nucleus, and

.....

.....[2]

**(ii)** *nuclear fusion*.

.....

.....[2]

**(b)** The nuclear fusion of two nuclei of deuterium is represented by the nuclear equation.

$$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n$$

Mass of a deuterium nucleus = $3.345 \times 10^{-27}$ kg

Mass of a helium nucleus = $5.008 \times 10^{-27}$ kg

Mass of a neutron = $1.675 \times 10^{-27}$ kg

**(i)** Calculate the energy released during the fusion reaction.

energy released = ..... J [2]

**(ii)** Calculate the energy released per kilogram of deuterium nucleus during the fusion reaction.

energy released per kg = ..... J kg$^{-1}$ [3]

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**(c)** Artificial pacemakers that are used to stimulate the heart may be designed to run on nuclear energy. Early types of such nuclear batteries contain 0.16 g of Plutonium-238 and produces 0.75 mW of power when new.

**(i)** Given that the half-life of Plutonium-238 is 88 years, calculate its decay constant.

decay constant = ..... $s^{-1}$ [2]

**(ii)** Hence determine the initial activity of 0.16 g of the Plutonium-238 source.

initial activity = ..... $s^{-1}$ [2]

**(iii)** One of the decay chain of Plutonium-238 involves a series of alpha decays which leads to Uranium-234, followed by Thorium-230 and then to Radium-226. The half-life of Uranium-234 is 246,000 years.

**1.** Determine the change in mass per Plutonium-238 decay into Uranium-234.

change in mass = ..... kg [2]

**2.** State one assumption made in **(iii)1**.

……

……[1]

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**(iv)** Suggest why it is important to investigate the decay chain of Plutonium-238 in the design of such a nuclear battery.

……..……..

……[1]

**(d)** Radioactivity as a source of radiation can have both good and bad effects. Some of the sources contributing to background radiation can be rocks and soil or medical treatment.

**(i)** Name another source of background radiation which makes a major contribution.

……

……[1]

**(ii)** Suggest why, when monitoring low radiation levels in the body for medical purposes, it is important to reduce background count rate to a minimum.

……

……

……

……[2]

**END OF PAPER**

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DUNMAN HIGH SCHOOL
Preliminary Examinations
Year 6
Higher 2

| | | | |
|---|---|---|---|
| CANDIDATE NAME | | | |
| CLASS | | INDEX NUMBER | |

# PHYSICS

**9749/04**

Paper 4 Practical

**29th August 2019**

**2 hour 30 minutes**

Candidates answer on the Question Paper.
Additional Materials: As listed on the Apparatus List

**READ THESE INSTRUCTIONS FIRST**

Write your class, 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.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| 1 | /13 |
| 2 | /10 |
| 3 | /20 |
| 4 | /12 |
| Total | /55 |

This document consists of **16** printed pages and **0** blank page.


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**1** In this experiment, you will investigate the movement of a metre rule on two sliding supports.

**(a)** Set up the apparatus with the metre rule resting on the rods of the clamps, as shown in Fig. 1.1. The metre rule should be parallel to the bench.

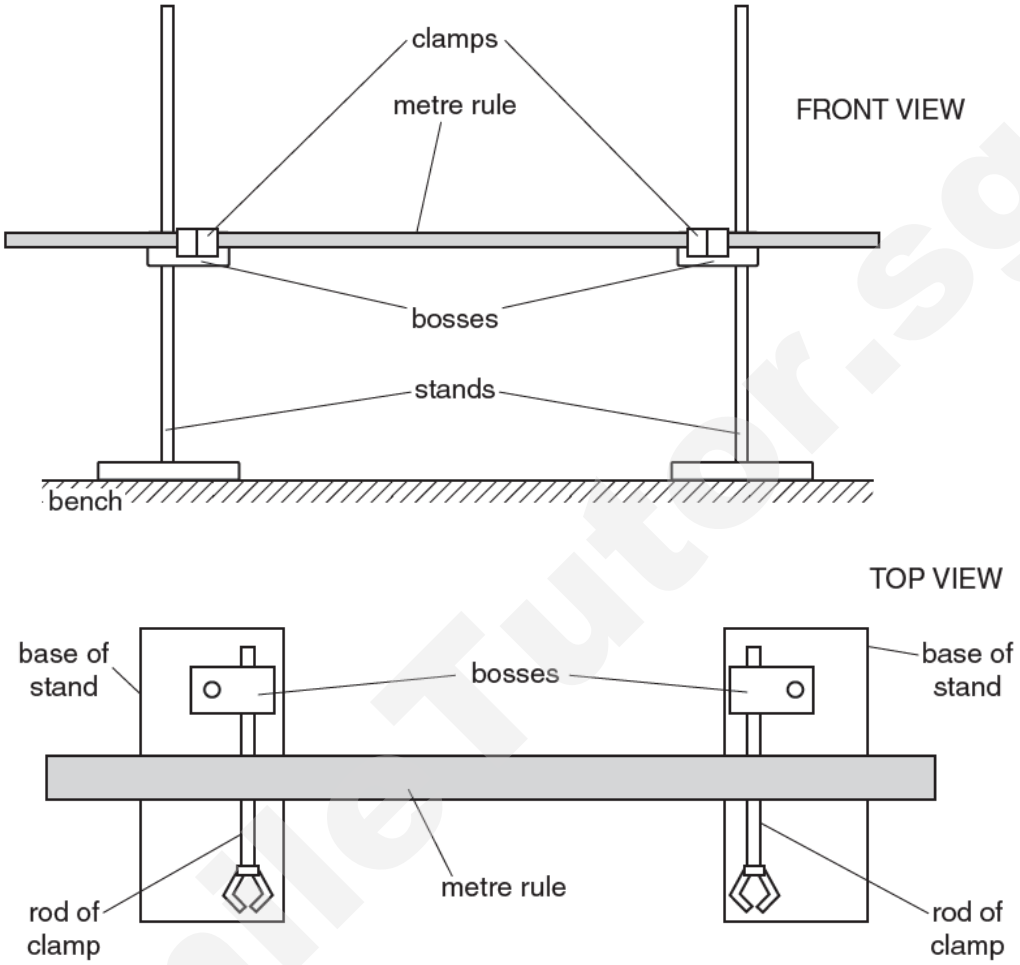


**Fig. 1.1**

**(b)** Measure and record the length (longest side) *L* of the wooden strip labelled A.

*L* = ..... [1]

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**(c) (i)** Position the stands so that the rod of one of the clamps is supporting the metre rule at the 10 cm mark, and the rod of the other clamp is supporting the metre rule at the 90 cm mark.

**(ii)** Using Blu-Tack, fix the wooden strip labelled A to the metre rule at the 0 cm end, as shown in Fig. 1.2.

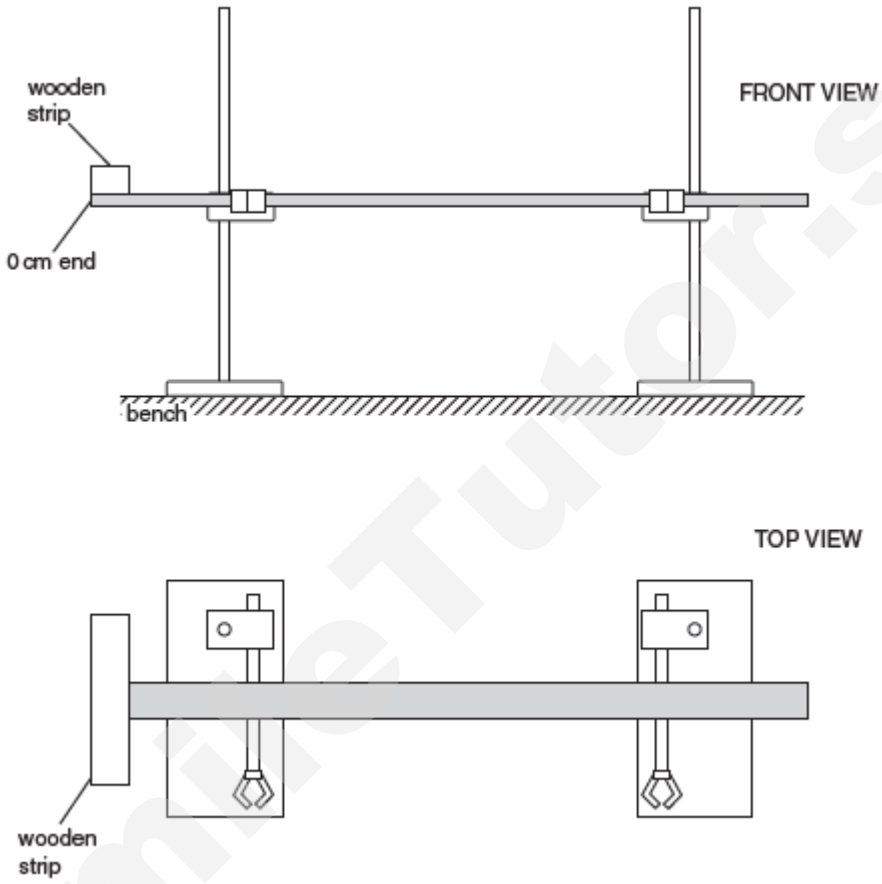


**Fig. 1.2** (not to scale)

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**(iii)** Without touching the metre rule, slowly slide the stands towards each other until their bases touch each other, as shown in Fig. 1.3.

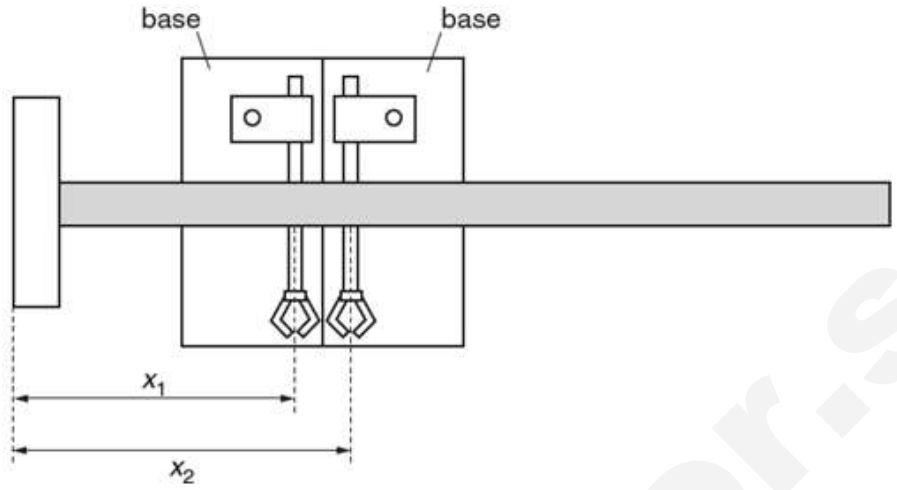


**Fig. 1.3** (not to scale)

**(iv)** Measure and record the distances $x_1$ and $x_2$ of the points of contact from the end of the rule, as shown in Fig. 1.3.

$x_1$ = .....

$x_2$ = ..... [2]

**(v)** Calculate the value of □, where $\square = \frac{x_1 + x_2}{2}$ .

□ = ..... [1]

**(d)** Estimate the percentage uncertainty in your value of □.

percentage uncertainty = ..... [1]

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**(e)** It is suggested that the relationship between $L$ and □ is

$$L\square = k(d - \square)$$

where $d$ = 50.0 cm and $k$ is a constant.

Use the wooden strip labelled B to take further measurements to investigate this suggestion.

State and explain whether your measurements support the suggested relationship.

Present your measurements and calculated results clearly.

……

……

……

……

…… [6]

**(f)** Suggest and explain the value of □ you would expect to obtain if the experiment was repeated with an identical wooden strip fixed at each end of the metre rule.

……

……

…… [2]

[Total: 13 marks]

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**2** In this experiment, you will investigate how the cooling rate of a hot liquid depends on the surface area of the liquid exposed to air.

**(a) (i)** Pour cold water into the beaker up to the 200 ml mark.

**(ii)** Pour the water into the cup and use the pen to place a mark on the inside surface of the cup, level with the water surface.

**(iii)** Empty out the cold water.

**(b) (i)** Pour boiling water into the cup up to the mark.

**(ii)** Bring the cup of boiling water and pour back into the beaker.

**(iii)** When the temperature of the water falls to approximately 75 °C, start the stopwatch. Record this starting temperature $\theta_0$.

$\theta_0$ = ..... [1]

**(iv)** After two minutes, measure and record the temperature $\theta$.

$\theta$ = ..... [1]

**(v)** Calculate the change in temperature $\Delta\theta = (\theta_0 - \theta)$.

$\Delta\theta$ = ..... [1]

**(c) (i)** Measure and record the diameter $d$ of the water surface.

$d$ = ..... [1]

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**(ii)** Estimate the percentage uncertainty in your value of $d$.

percentage uncertainty = ..... [1]

**(d)** It is suggested that the relationship between $\Delta\theta$ and $d$ is

$$\Delta\theta = kd^2$$

where $k$ is a constant.

**(i)** Using your data, calculate the value of $k$.

$k$ = ..... [1]

**(ii)** Justify the number of significant figures that you have given for your values of $k$.

.....

.....

..... [1]

**(e)** State two other significant factors that will affect the cooling rate of the hot liquid. Suggest changes that could be made to the experiment to reduce the effect of one of the factors on the experiment. You are not expected to conduct the experiment.

.....

.....

.....

.....

.....

..... [3]

[Total: 10 marks]

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

**(a) (i)** Measure and record the diameter $d$ of the short sample of wire that is attached to the card. Do not remove the wire from the card.

$d$ = ..... [1]

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

$A$ = ..... [1]

**(iii)** Determine the percentage uncertainty in $A$.

percentage uncertainty in $A$ = ..... [1]

**(b) (i)** Using the wire attached to the metre rule, set up the circuit shown in Fig. 3.1.

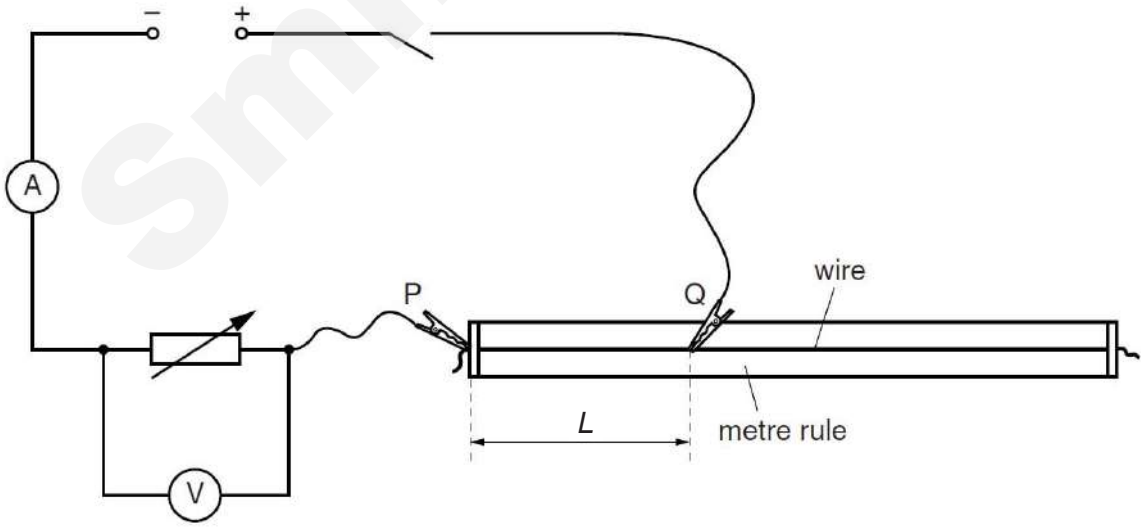


**Fig. 3.1**

There are two crocodile clips labelled as P and Q in Fig. 3.1.
P will remain in the same position throughout the experiment.
Q can be moved to different positions along the wire.

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**(ii)** Position the slider approximately half-way along the rheostat.

**(iii)** Attach Q approximately half-way along the wire.

**(iv)** Switch on the power supply.

**(v)** Measure and record the length $L$ of wire between P and Q.
Record the voltmeter reading $V$.

$L$ = .....

$V$ = ..... [2]

**(vi)** Record the ammeter reading $I$.

$I$ = .....

**(vii)** Switch off the power supply.

**(c)** **(i)** Reposition Q at a new distance $L$ from P.

**(ii)** Switch on the power supply.

**(iii)** Adjust the slider on the rheostat until the ammeter reading is the same value as in **(b)(vi)**.

**(iv)** Measure and record the length $L$ of the wire between P and Q.
Record the voltage reading $V$.

$L$ = .....

$V$ = .....

**(v)** Switch off the power supply.

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**(d)** Repeat **(c)** until you have six sets of readings of $L$ and $V$. [7]

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For each value of $L$, adjust the slider on the rheostat so that the ammeter reading $I$ remains constant at the value in **(b)(vi)**.
You may find it helpful to copy your value from **(b)(vi)** here.

$I$ = .....

**(e)** Theory suggests that

$$\frac{V}{L} = \frac{a}{L} - b$$

where $a$ and $b$ are constants.

Plot a suitable graph to determine the values of $a$ and $b$.

$a$ = .....

$b$ = ..... [7]

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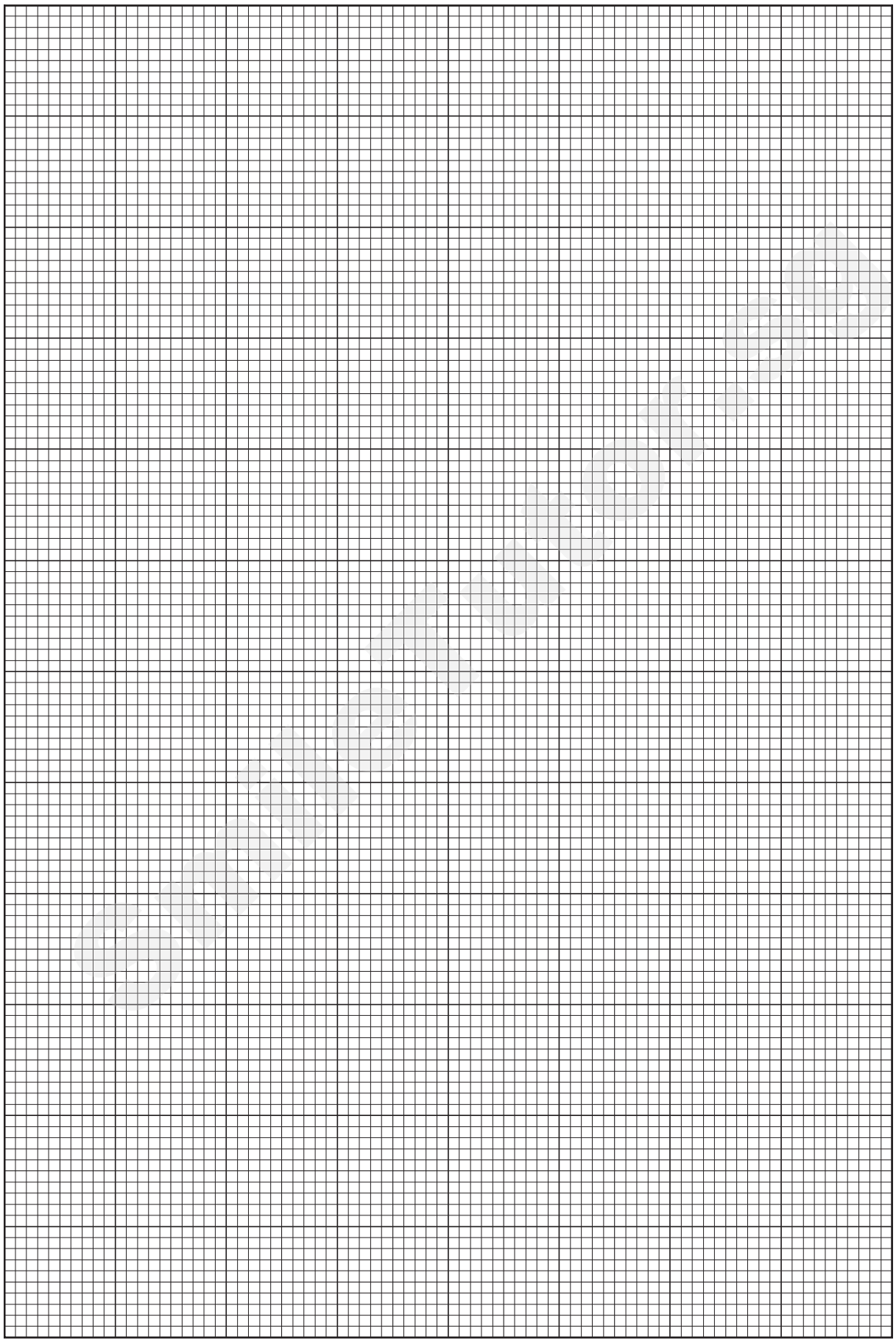



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**(f)** The resistivity $\rho$ of the material of the wire, in Ω m, can be found using the relationship

$$\rho = \frac{bA}{I}$$

Using your answers in **(a)(ii)**, **b(vi)** and **(e)**, calculate a value for $\rho$.

$\rho$ = ……..…….. Ω m [1]

[Total: 20 marks]

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**4** A fairground ride carries passengers in chairs which are attached by metal rods to a rotating central pole, as shown in Fig 4.1. When the pole rotates with angular velocity ω, the rods make an angle θ to the vertical.

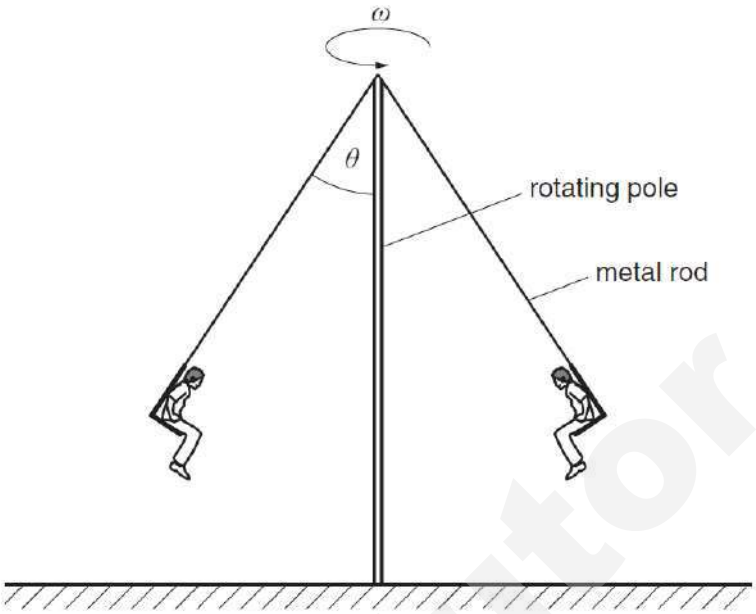


**Fig. 4.1**

It is suggested that cos $\theta$ is inversely proportional to $\omega^2$.

Design a laboratory experiment, using a small object to represent an occupied chair, to test the relationship between $\theta$ and $\omega$. You should draw a diagram, on page 14, showing the arrangement of your equipment.

In your account, you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken.

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**Diagram**

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**Dunman High School 2019 Year 6 Prelim Exam H2 Physics Answers**

**Paper 1**

| | |
|---|---|
| 1 | C |
| 2 | D |
| 3 | B |
| 4 | A |
| 5 | D |
| 6 | C |
| 7 | D |
| 8 | A |
| 9 | A |
| 10 | D |

| | |
|---|---|
| 11 | A |
| 12 | B |
| 13 | B |
| 14 | B |
| 15 | D |
| 16 | D |
| 17 | A |
| 18 | C |
| 19 | A |
| 20 | C |

| | |
|---|---|
| 21 | C |
| 22 | A |
| 23 | D |
| 24 | C |
| 25 | D |
| 26 | D |
| 27 | C |
| 28 | A |
| 29 | B |
| 30 | C |

**Paper 2**

| | | | |
|---|---|---|---|
| **1** | **(a)** | time = 0.43 / 1.1 = 0.39 s. | **A1** |
| | **(b)** | height = ½ $gt^2$ = ½ (9.81)(0.39)$^2$<br>= 0.75 m<br>displacement = $\sqrt{0.43^2 + 0.75^2}$ = 0.86 m | **C1**<br>**C1**<br>**A1** |
| | **(c) (1)**<br>**(2)** | horizontal line at a non-zero value of *a*.<br>curved line from origin with increasing gradient. | **A1**<br>**A1** |
| | **(d)** | Distance is the actual (curved) path followed by the ball and<br>Displacement is the straight line / minimum distance A to B. | **B1** |
| | **(e)** | acceleration (of free fall) is unchanged / not dependent on mass<br>and so no effect on time taken. | **B1** |

| | | | |
|---|---|---|---|
| **2** | **(a)** | The rotating drum exerts a **normal reaction force** on the clothes and water which acts towards the centre of the rotation.<br><br>**No such force is possible at the holes** and so the water over each hole, according to Newton's 1st law, flies off at a **tangent** to the drum's motion.<br><br>While the **water can pass through the holes in the drum, the clothes are too large to do this**, so water is removed from the clothes during the spin-dry cycle.<br><br>**OR**<br><br>The clothes cannot provide sufficient centripetal force for the water, through their mutual attraction, at the holes. | **B1**<br><br>**B1**<br><br>**B1** |
| | **(b)** | $\omega$ = 1000 rev per min = 1000 x 2π / 60 = 105 rad s$^{-1}$ | **A1** |

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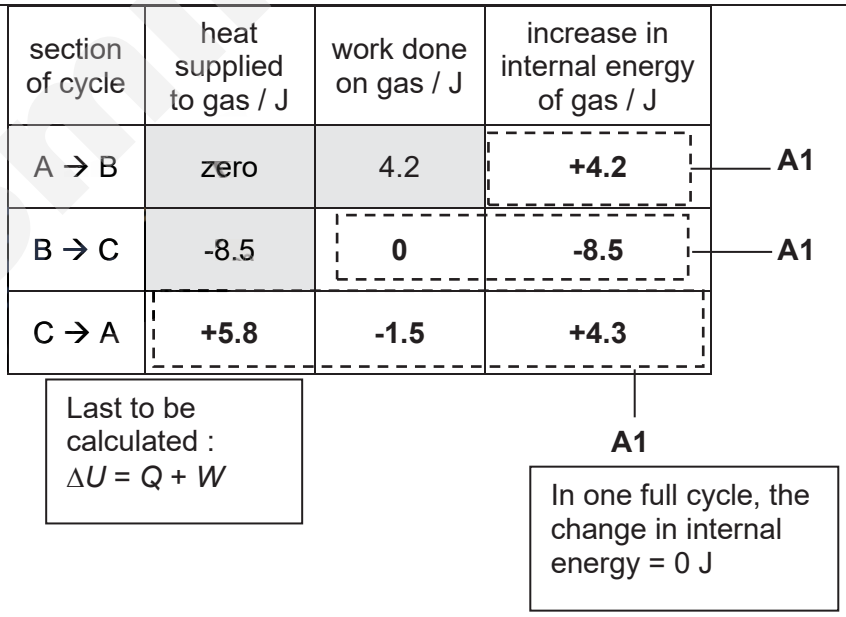
| | | | |
|---|---|---|---|
| | | $F = m r \omega^2$ = 0.500 x 0.125 x $104.72^2$<br>= 685 N | **C1**<br>**A1** |
| | **(c)** | When the inner drum is rotating, a purpose of the springs is to<br><br>prevent **damage** to the machine / **excessive noise** by **damping** the shock of the vibrations<br><br>**OR**<br><br>When the inner drum is not rotating, a purpose of the springs is to<br><br>maintain the drums and clothes as a system in **equilibrium** position via **tension** in the top springs and **compression** in the bottom springs.<br><br>**OR**<br><br>Any other suggestions with explanation based on good physics. | <br><br>**B1**<br>**B1** |

| | | | |
|---|---|---|---|
| **3** | **(a)** | The internal energy of a substance is the sum of the **kinetic energy due to the random motion of the molecules** and<br><br>**potential energy due to intermolecular forces of attraction.** | **A1**<br><br>**A1** |
| | **(b)(i)** | Work done by gas = area under CA<br>= **$(1 \times 10^5)(20-5)\times10^{-6}$**<br>= **1.5 J** | **C1**<br>**A1** |
| | **(b)(ii)** |  | |
| | **(c)** | Temperature is a measure of the mean kinetic energy of the molecules of an object, i.e. it is the intrinsic property of **one system** only, but heat is a measure of energy transferred between **two systems**. | **B1** |

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| | | | |
|---|---|---|---|
| | | Temperature can be measured using a **thermometer directly**, but heat **cannot be measured using a measuring instrument directly**.<br><br>**OR**<br><br>Any other differences based on good physics. | **B1** |

| | | | |
|---|---|---|---|
| **4** | **(a)** | magnitudes of maximum displacements / accelerations are different<br>graph is curved / not a straight line (at both ends of graph) | **B1**<br>**B1** |
| | **(b) (i)** | Simple harmonic motion so $a = -\omega^2 x$ where $\omega$ is the angular frequency<br>$\omega^2 = (2)(64)/(0.810)$<br>$\omega = 12.57$ rad $s^{-1}$<br>$f = \omega / 2\pi$<br>$= 2.0$ Hz | **B1**<br><br>**B1** |
| | **(b)(ii)** | max speed $= \omega x_o$<br>$= (12.57)(0.016)$<br>$= 0.20$ m $s^{-1}$ | <br>**C1**<br>**A1** |
| | **(iii)** | momentum is conserved (horizontally), $m_{trolley}\ v_{trolley} = m_{total}\ v_{max}$<br>max speed decreases<br>Or perfectly inelastic collision, energy is lost,<br>so max speed decreases | **M1**<br>**A1** |
| | | perfectly inelastic collision so energy lost<br>less elastic potential energy so amplitude decreases | **M1**<br>**A1** |

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| **5** | **(a)** | Both the alpha particle and the gold nucleus are **positively charged**.<br><br>When the alpha particle travels head-on towards the gold nucleus,<br><br>**all** the **kinetic energy of the alpha particle is converted to the electric potential energy of the system of the alpha particle and gold nucleus**.<br><br>**OR**<br><br>the repulsive force between the alpha particle and the gold nucleus causes **deceleration** in the alpha particle<br><br>until it is at its closest approach where it is instantaneously at rest. | **B1**<br><br><br><br>**B1** |

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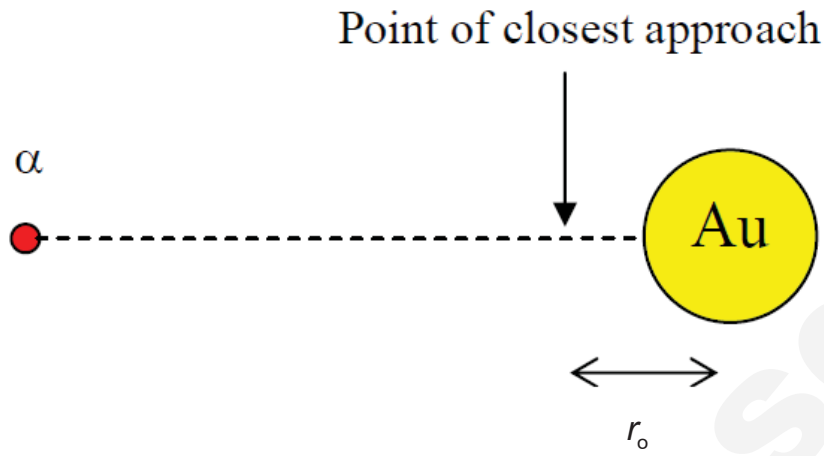
| | | | |
|---|---|---|---|
| | **(b)(i)** |  | |
| | | Loss in K.E. = gain in E.P.E.<br>$5.75(10^6)(1.6 \times 10^{-19}) = \frac{q_\alpha q_{Au}}{4\pi\varepsilon_o r_o}$<br>$\rightarrow r_o = \frac{(9.0 \times 10^9)(2e)(79e)}{(9.2 \times 10^{-13})} \approx 4.0 \times 10^{-14}$ m | **C1**<br>**A1** |
| | **(b)(ii)** | $F = \frac{q_\alpha q_{Au}}{4\pi\varepsilon_o r_o^2} = \frac{(9.0 \times 10^9)(2e)(79e)}{(3.96 \times 10^{-14})^2} = 23.3$ N | **A1** |
| | **(c)1./2.** | The $^{197}_{79}Au$ nucleus remains stationary during the interaction between $^{197}_{79}Au$ and the $\alpha$-particle.<br>$^{197}_{79}Au$ and the $\alpha$-particle are very far apart initially.<br>$^{197}_{79}Au$ and the $\alpha$-particle are point charges.<br>The system consists of $^{197}_{79}Au$ and the $\alpha$-particle only. The radium nucleus and its daughter nuclide is not part of the system. (Thus, conservation of energy applies for the defined system and the radium nucleus and its daughter nuclide cannot provide an external force on the system.)<br>The gravitational force between the $^{197}_{79}Au$ and the $\alpha$-particle is negligible compared to the electric force between them.<br>**Any TWO** | **A1**<br>**A1** |

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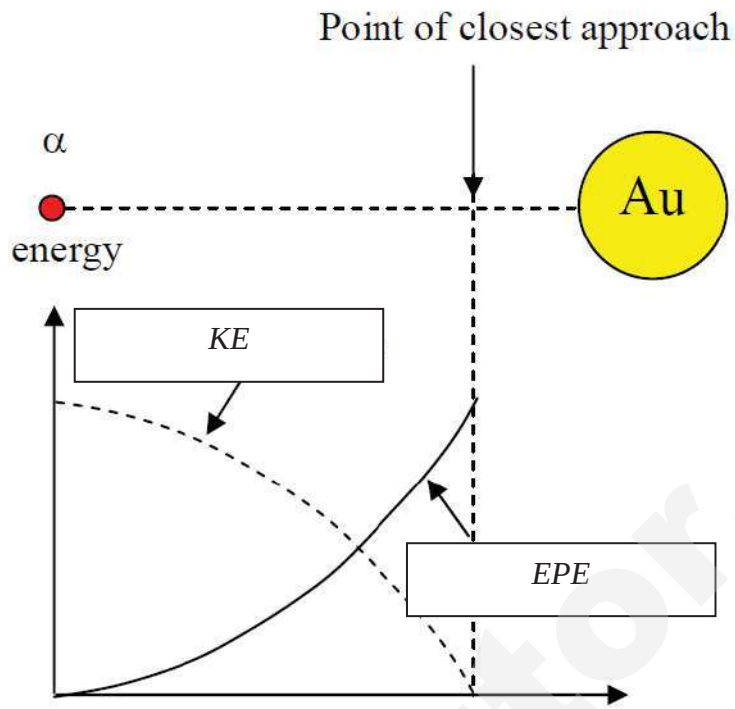
| | **(d)** |  | **A1 - *KE***<br>**A1 - *EPE*** |

| | | | |
|---|---|---|---|
| **6** | **(a)** | uniform electric (E) and magnetic fields (B) normal to each other AND charged particle enters region normal to both fields<br>correct *B* direction w.r.t. *E* for zero deflection<br>For no deflection, $v = E/B$ | **B1**<br>**B1**<br>**B1** |
| | **(b)** | magnetic force provides the centripetal force<br>$BQv = mv^2/r$<br>$r = mv / BQ$ | **M1**<br>**A1** |
| | **(c)** | curve of larger radius starting from common entry point into the field | **A1** |
| | **(d)** | $r = mv / BQ$ , so B proportional to m<br>$B = (0.680) \times (87/86) = 0.6879$ T<br>$\Delta B = 7.9 \times 10^{-3}$ T | **C1**<br>**A1** |

| | | | |
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| **7** | **(a)** | $P = \frac{Nhf}{t}$<br>$3.8 \times 10^{-3} = (N/t)(4.7 \times 1.6 \times 10^{-19})$<br>$N/t = 5.1 \times 10^{15}$ s$^{-1}$ | **C1**<br>**A1** |
| | **(b)** | $I = \frac{Ne}{t}$<br>$0.800 \times 10^{-8} = (N/t)(1.6 \times 10^{-19})$<br>$N/t = 5.0 \times 10^{10}$ s$^{-1}$ | **A1** |
| | **(c)** | 1. Most of the photons are reflected from the metal surface.<br>2. Atoms are made up of mostly empty space and thus the probability of a photon hitting a surface electron is very small. Instead, photons may hit electrons which are deeper below the surface, and these electrons may lose all its kinetic energy on its way up to the | **Any two** |

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| | | | |
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| | | surface. (due to collisions with the metallic ion core)<br><br>3. Electrons emitted may travel at an angle away from the normal and may not be collected at the anode. | |
| | **(d)** | $eV_s = \frac{1}{2}mv^2$<br><br>$(1.6 \times 10^{-19})(0.500) = (1/2)(9.11 \times 10^{-31})v^2$<br>$v = 4.19 \times 10^5$ m s$^{-1}$ | **C1**<br><br>**C1**<br>**A1** |

| | | | |
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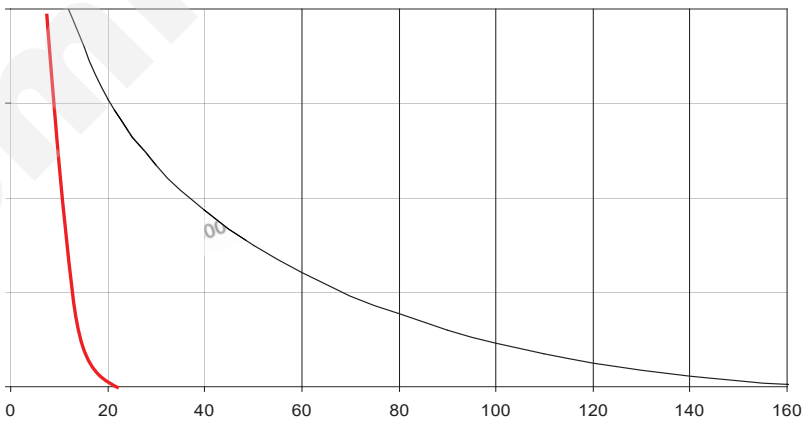
| **8** | **(a)(i)** | The alpha particles has only **limited range in air** which is only a **few centimetres** (~ 5 cm).<br><br>This is because alpha particles are highly ionizing and **lose their kinetic energies** very quickly over a short distance due to the interaction with air particles. | **B1**<br><br>**B1** |
| | **(a)(ii)** | *N* values have a very **wide range** (from 0 to $10^8$).<br><br>Thus, it is **difficult to plot smaller *N* values** if vertical axis is non-logarithmic.<br><br>OR<br><br>It **compresses the scale**<br><br>so that **widely differing values** can be **shown easily** on one graph. | **B1**<br><br>**B1** |
| | **(b)** |  <br>- steep graph at small angles- no scattering at large angles. | **A1** |
| | **(c)(i)** | From Fig. 8.3, when $\theta = 72$, $N = 84000$.<br>lg sin( (72/2) / º) = -0.231, lg 84000 = 4.92 | |

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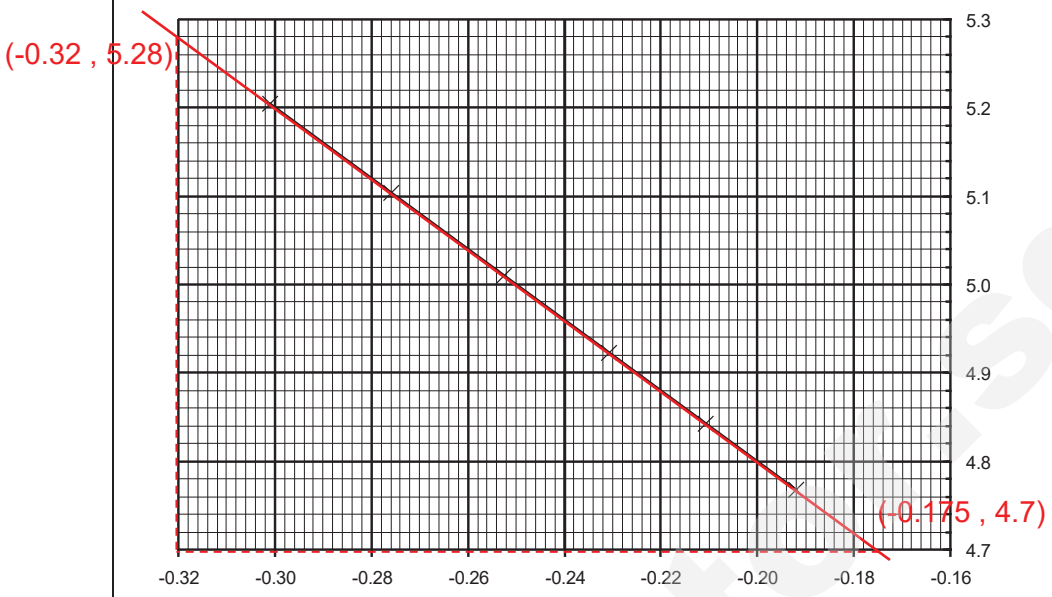
|---|---|---|
| **1. (c)(i)2.** | From Fig. 8.3, when $\theta = 72$, $N = 84000$.<br>lg sin( (72/2) / º) = -0.231, lg 84000 = 4.92<br>  <br> | **A1** - accurate plotted point<br><br>**A1** - best fit line passes through all plotted points |
| | | |
| **(c)(ii)** | Gradient<br>= (5.28 - 4.7)/(-0.32 – (-0.175))<br>= - 4 | **M1**<br>**A1** |
| **(c)(iii)** | Since $N \propto (\sin(\theta/2))^n$ , $\lg N = \lg A + n\lg(\sin(\theta/2))$ where $A$ **is a constant.**<br><br>Thus if a graph of $\lg N$ is plotted against $\lg(\sin(\theta/2))$ and a straight line graph is obtained, then $n$ **represents the gradient.**<br><br>$n = -4$ | **M1**<br><br>**A1** - Answer must an integer |
| **(d)** | For Au, $92500/79^2 = 14.8$<br>For Pt, $90000/78^2 = 14.8$<br>For Ir, $88000/77^2 = 14.8$<br>For W, $81000/74^2 = 14.8$<br><br>Since the constant of proportionality is (approximately) the same to 3 significant figures, $N$ is proportional to □$^2$.<br>(based on all the values of constant) | **A1** - Correct N values for the 4 data points<br><br>**A1** – showed all the values of the constant<br><br>**A1** – conclusion |

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| | | |
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| **(e)** | The actual relationship between $N$ and $\theta$ is<br>$N = \left( \frac{A" N_i n L C^2 e^4}{4 r^2 K E^2} \right) Z^2 (\sin(\theta/2))^{-4}$<br>where $k = \frac{A" N_i n L C^2 e^4}{4 r^2 K E^2}$ and<br>$A"$ = cross sectional area of detector that the scattered alpha particles are incident on<br>$N_i$ = number of incident alpha particles<br>$n$ = number of gold atoms per unit volume in thin gold foil<br>$L$ = thickness of gold foil<br>$e$ = electron charge<br>$r$ = gold foil-to-detector distance<br>$KE$ = kinetic energy of alpha particles<br>$C = \frac{1}{4\pi\varepsilon_0}$ = Coulomb's constant, $\varepsilon_0$ = permittivity of free space | **A1** - any one physical quantities boxed<br>**A2** - any two physical quantities boxed |
| **(f)** | There would be **no** (significant) **change**<br><br>because the **scattering angle** $\theta$ **is** (approximately) **independent on the mass of the isotope** of gold that made up the foil. | **B1**<br><br>**B1** |

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**Paper 3**

| | | | |
|---|---|---|---|
| 1 | (a) | The mass of an adult: 40 - 100 kg<br>The weight of a hand phone at Earth's surface: 1.0 - 2.0 N<br>The energy required for an adult to climb up to the top row in the school auditorium: 1200 - 3000 J<br>The total pressure on your feet at a depth of 1.0 m in an adult swimming pool: $1.02 \times 10^5$ Pa - $1.11 \times 10^5$ Pa | **A1**<br>**A1** |
| | (b)(i) | Units of $\frac{kr^3(p_1-p_2)}{l}\sqrt{\frac{M}{RT}} = \frac{m^3 Pa}{m}\sqrt{\frac{kg\ mol^{-1}}{J\ K^{-1}\ mol^{-1} K}}$<br>$= kgms^{-2}\sqrt{\frac{kg\ s^2}{kgm^2}}$<br>$= kgs^{-1}$ | **C1**<br>**A1** |
| | (ii) | $\frac{\Delta Q}{Q} x100 = \frac{3\Delta r}{r} x100 = \frac{3\times 0.05}{1.37} x100$<br>$= 11\ \%$ | **A1** |

| | | | |
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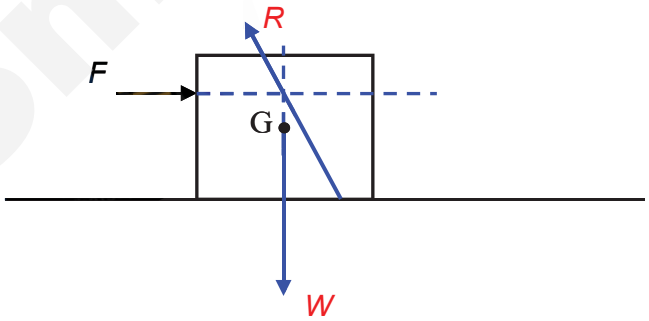
| 2 | (a) | The conditions are<br>▪ resultant force acting on a rigid body must be zero in any direction.<br>▪ resultant torque acting on a rigid body must be zero about any axis of rotation. | **A1**<br>**A1** |
| | (b)(i)1.<br>(b)(i)2. |  | **A1 - *W***<br>**A1 - direction of *R***<br>**A1 – line of action of 3 forces meet at the same point** |
| | (b)(ii) | Let the cube has side *a*,<br>taking moments about the corner of the cube at X,<br>$F\left(\frac{3}{4}a\right) = W\left(\frac{1}{2}a\right)$ | **C1**<br>**A1** |

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| | | | |
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| | | ➔ $F = \left(\frac{2}{3}\right)\left(\frac{200}{1000}\right)g \approx 1.3$ N | |
| | **(c)** | Using Hooke's Law i.e. $F = ke$,<br>➔ $k = \frac{F}{e}$<br>➔ $k = \frac{(140)/1000(9.81)}{(10.8-8)/100} \approx 49$ N m$^{-1}$ | **C1**<br>**A1** |
| | **(d)(i)** | Upthrust + Tension = Weight of Cube<br>➔ Upthrust = $\left(\frac{200}{1000}\right)g - (49.05)\left(\frac{10.3-8}{100}\right) \approx 0.83$ N | **B1** |
| | **(d)(ii)** | Mass of block = density of block x volume of block<br><br>Moreover,<br>upthrust<br>= density of liquid displaced x volume of block x acceleration of free fall<br>➔ 0.83 = density of liquid x (200/1000)/2400 x 9.81<br>➔ density of liquid ≈ 1000 kg m$^{-3}$<br><br>Note:<br>This is the approximate density of water. | **C1**<br>**A1** |

| | | | |
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| **3** | **(a)** | The gravitational potential energy at a point is defined as the work done in bringing<br>a small test mass from infinity to that point. | **B2** |
| | **(b) (i)** | Correct direction | **B1** |
| | **(ii)** | The gravitational force provides the centripetal force for the circular orbit of the satellite. | **B1** |
| | **(iii)** | $\frac{mv^2}{R} = \frac{GMm}{R^2}$<br><br>$v = \sqrt{\frac{GM}{R}}$ | **C1** |
| | **(c)** | $\frac{v^2}{7780^2} = \frac{6610}{6890}$<br>v = 7620 m s$^{-1}$ | **C1**<br><br>**A1** |
| | **(d)(i)** | $\frac{1}{2}m(7620^2 - 7780^2) = -1.48x10^8 J$ | **A1** |
| | **(ii)** | $-\frac{GMm}{R_f} - \left(-\frac{GMm}{R_i}\right) = mv_i{}^2 - mv_f{}^2$<br>$m(7780^2 - 7620^2) = 2.96x10^8 J$ | **C1**<br><br>**A1** |

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| **4** | **(a)** | Consider the same mass of steam *m* and the same mass of water *m* at 100 °C. When in contact, both steam and skin reaches a **thermal equilibrium**.<br><br>The same happens for boiling water with skin. However, the difference is that for steam, the **process of condensation occurs prior to the drop in temperature**.<br><br>$Q_{steam} = ml_v + mc\Delta\theta$<br>$Q_{hotwater} = mc\Delta\theta$<br><br>When steam condenses into water at 100 °C, there is a release of a large amount of thermal energy. Since **specific latent heat of vaporisation of water is far greater than specific heat capacity of water**, the thermal energy transferred to the skin due to steam condensing is greater than that due to boiling water. | **A1**<br><br>**B1 - for stating the difference between the processes**<br><br>**A1** |
| | **(b)(i)** | True.<br><br>When a **solid melts**, the **increase in potential energy is less** than the increase that occurs when a **liquid vaporises**.<br><br>**Significant work** is also **done against external pressure** when a **liquid vaporises** compare to when a **solid melts**. | **A1**<br><br>**A1** |
| | **(b)(ii)** | False.<br><br>Pressure of a real gas is **less** than that of an ideal gas for the same mass, volume and temperature. This is because **attractive** forces exist **between the atoms/molecules** in a real gas and not in an ideal gas.<br><br>Thus, **the molecules** of a real gas **hit the wall of a container with less force** compare to an ideal gas as they are held back by attractive forces. | **A1**<br><br>**A1** |

| | | | |
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| **5** | **(a)(i)** | current = 2.8 A<br>4.0 A in each lamp, total current in circuit = 8.0 A | **A1**<br>**A1** |
| | **(ii)** | series, resistance = 2.1 + 2.1 = 4.2 or 4.3 Ω<br>parallel, resistance 1.5 Ω | **A1**<br>**A1** |
| | **(iii)** | power = $IV$ or $V^2R$ or $I^2R$<br>ratio = (2.8 × 6.0) / (4.0 × 12) = 0.35 | **C1**<br>**A1** |
| | **(b) (i)** | $I = V/R$ = 2.0 / 5.0 = 0.40 A | **A1** |
| | **(ii)** | p.d. across BD = 4 × 0.40 = 1.6 V<br>p.d. across BC = 1.5 V<br>$l$ = 1.5/1.6 × 1.00 = 0.94 m | **C1**<br>**C1**<br>**A1** |

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| | | | |
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| | **(c)** | p.d. across BC not at balancing e.m.f.<br>Cell Y has current going from left to right through cell, so total terminal p.d. higher. | **B1**<br>**B1** |

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| **6** | **(a) (i)** | to reduce flux loss/ to increase flux linkage with secondary coil | **B1** |
| | **(ii)** | to reduce heat/energy losses caused by eddy currents (in core) | **B1** |
| | **(b)** | changing current in primary gives rise to changing flux in core<br>flux links by core to the secondary coil, and<br>changing flux (in secondary) induces e.m.f. in secondary | **B1**<br>**B1** |
| | **(c) (i)** | N = (52/150) 1200 = 416 turns | **A1** |
| | **(ii)** | time = 0 ms or 7.5 ms or 15.0 ms or 22.5 ms | **A1** |

| | | | |
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| **7** | **(a)(i)** | Estimate wavelength about 0.030nm to 0.035 nm<br><br>$c = f\lambda$, $E=hc/\lambda$<br>$E = 6.6 \times 10^{-34} \times 3.0 \times 10^{8} \div (0.032 \times 10^{-9})$<br>$E = 6.6 \times 10^{-15}$ J to $5.6 \times 10^{-15}$J (35 keV to 41 keV) | **B1**<br><br><br><br>**A1** |
| | **(ii)** | $eV = ½ mv^2$<br>$v = \sqrt{\frac{2eV}{m}}$<br>$= \sqrt{2 \times 1.6 \times 10^{-19} \times 40000 \div (9.11 \times 10^{-31})}$<br>$= 1.2 \times 10^{8}$ m s$^{-1}$ | <br><br><br>**C1**<br>**A1** |
| | **(iii)** | $\lambda = h/p$<br>$= h/mv$<br>$= \square\square \times 10^{-34} \div (9.11 \times 10^{-31} \times 1.2 \times 10^{8})$<br>$= \square 1 \times 10^{-12}$ m | <br><br>**C1**<br>**A1** |
| | **(b)** | When an inner shell electron is knocked out by a bombarding electron<br>and an outer shell electron fills in this vacancy, this transition results in X-ray photons of a specific frequency to be emitted. | <br>**B1**<br>**B1** |

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| **8** | **(a)** | two waves of the same kind travelling in opposite directions overlap<br>waves have same frequency/wavelength and speed | **B1**<br>**B1** |
| | **(b) (i)** | v=fλ<br>f= 330/0.18 = 1800 Hz | <br>**A1** |
| | **(ii)** | T = 1/1800<br>time base = $(1.5 \times 5.5 \times 10^{-4}) / 8.0$ or $1/(1800 \times 5.3)$<br>$= 1.0 \times 10^{-4}$ s cm$^{-1}$ | **A1** |
| | **(iii)** | waveform drawn with same period as original waveform<br>waveform drawn with amplitude of 1.7 cm | **B1**<br>**B1** |
| | **(c) (i)** | distance = λ / 2 = 0.090 m | **A1** |

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| | **(ii)** | m = ρAx<br>= 0.79 × 13 × 9.0 = 92.4<br>time = 92.4 / 6.7 =14 s | <br>**C1**<br>**A1** |
| | **(d) (i)** | Waves must meet in phase / path difference is nλ, n is integer | **B1** |
| | **(ii)** | path difference = $\sqrt{140^2 + 100^2} - 140 = 32\ cm$<br>freq changes from 1kHz to 4kHz so λ changes from 33 to 8.25 cm<br>when λ =33, path diff (32 cm) is 0.96 λ, and λ =8.25, path diff is 3.87 λ<br>so 3 maxima (when λ = 32, 16 and 10.7 cm) | **B1**<br><br>**C1**<br><br>**A1** |
| | **(e) (i)** | bsinθ = λ ➔ sinθ = 633 × $10^{-9}$ / (0.0800 × $10^{-3}$), θ = 0.453°<br>w = 2 × 5.12 × tanθ = 2 × 5.12 × tan(0.453°) = 0.0810 m | **C1**<br>**A1** |
| | **(ii) 1.** | light from second slit meets anti-phase with light from first slit or destructive interference for lights from both slits | **B1** |
| | **2.** | $x$ = 633 × $10^{-9}$ × 5.12 / 0.240 × $10^{-3}$<br>= 0.0135 m | **C1**<br>**A1** |
| | **3.** | At these places are single slit minimums<br>No light to interfere (a factor of 3 recognised)<br>(Note: 3$x$ = 0.0405 m which is equal to $w$/2) | **B1**<br>**B1** |

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| **9** | **(a)(i)** | The radioactive decay of a nucleus is the spontaneous and random emission of alpha, beta and gamma rays from the nucleus with the release of energy. | **B2** |
| | **(ii)** | Nuclear fusion is the combining of 2 smaller nuclei to form a larger and more stable nucleus with the release of energy in the process. | **B2** |
| | **(b)(i)** | Energy released ,<br>E = (2 × 3.345 × $10^{-27}$ - 5.008 × $10^{-27}$ - 1.675 × $10^{-27}$) × (3 × $10^8$)$^2$<br>= 6.3 × $10^{-13}$J | <br>**M1**<br>**A1** |
| | **(ii)** | number of nuclei in 1kg of deuterium ≈ 1/ (3.345 × $10^{-27}$) ≈ 2.99 × $10^{26}$<br>number of fusion reactions =2.99 × $10^{26}$ /2 = 1.495 × $10^{26}$<br>Energy released per kg = 1.495 × $10^{26}$ × 6.3 × $10^{-13}$J<br>= 9.42 × $10^{13}$J | **C1**<br><br>**C1**<br><br>**A1** |
| | **(c)(i)** | *λ = 0.□93/t½ = 0.□93 / (88 × 3□5 × 24 × □0 × □0)*<br>*□□□ = 2.5 × $10^{-10}$ $s^{-1}$* | **C1**<br>**A1** |
| | **(ii)** | *N = 0.1□ / 238 × $N_A$ = 4.05 × $10^{20}$*<br>*A = λN*<br>*= 2.5 × $10^{-10}$ × 4.05 × $10^{20}$ = 1.01 × $10^{11}$ Bq* | **C1**<br><br>**A1** |
| | **(iii)1.** | *0.75 mW ÷ 1.01 × $10^{11}$*<br>*= 7.43 × $10^{-15}$* □released per Plutonium atom decayed<br><br>*m = E/$c^2$ = 8.25 × $10^{-32}$* kg converted to energy per Plutonium decay | **C1**<br><br>**A1** |
| | **(iii)2.** | Battery is 100% efficient OR<br>U234 does not contribute to power generated due to long half-life | **B1** |
| | **(iv)** | Check for alpha or beta decay due to the needs to shield patient from its harmful effects OR check for battery lifespan | **B1** |

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| | **(d)(i)** | Cosmic radiation | **B1** |
| | **(d)(ii)** | Variations in body radiation levels might go undetected as a result of random variation in background count.<br>The total count rate is the sum of count rate due to trace elements in the body and background count rate. For low radiation count rate, the background count rate become significant. | **B1**<br><br>**B1** |
| | | | |

**Paper 4**

| Qns | | | Skills Assessed and Marking Instructions | | M |
|---|---|---|---|---|---|
| **1** | **b** | | $L$ in range 4.4 cm to 4.6 cm to the nearest mm, with unit. | | 1 |
| | **c** | **(iv)** | Values for $x_1$ and $x_2$ to nearest mm and $x_2 > x_1$. | | 1 |
| | | | Evidence of repeat readings of $x_1$ and $x_2$. | | 1 |
| | | **(v)** | Correct calculation of □ (□1). | | 1 |
| | **d** | | Absolute uncertainty in □ in range 2 mm to 10 mm (1.s.f.).<br>Correct method of calculation to obtain percentage uncertainty. | | |
| | | | Percentage uncertainty recorded to 2.s.f. | | 1 |
| | **e** | | Measurement and record of second value of $L$ ($L_2$).<br>$L_2$ in range 6.4 cm to 6.6 cm to the nearest mm, with unit. | E1 | 1 |
| | | | Value of second pair of $x_1$ and $x_2$ ($x_3$ and $x_4$ respectively; $x_4 > x_3$). | E2 | 1 |
| | | | Correct calculation of second □ (□2).<br>Quality of result: larger $L_2$ gives smaller □2. | E3 | 1 |
| | | | Determination of a constant of proportionality $k$ (two values of $k$ where $k = L□/(d - □)$), with unit. | E4 | 1 |
| | | | | E5 | 1 |
| | | | Draw conclusion based on the calculated values of $k$.<br>Candidate must test against a specified criterion (e.g. 20 % difference in values of $k$, with reference to the uncertainty calculated $(d)$). | E6 | 1 |
| | | | e.g.<br>For □1, $\frac{\Delta k_1}{k_1} = \frac{\Delta L_1}{L_1} + \frac{\Delta □_1}{□_1} + \frac{\Delta(d - □_1)}{d - □_1}$ | | |

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| | | | | | |
|---|---|---|---|---|---|
| | | | ➔ $\frac{\Delta k_1}{k_1} = \frac{\Delta L_1}{L_1} + \frac{\Delta \square_1}{\square_1} + \frac{\Delta \square_1}{d - \square_1} = \frac{0.2}{4.5} + (\text{ans in (d)})/100 + \frac{0.2}{50.0 - (\text{ans in (c)(v)})}$<br><br>Note:<br>1. The % error in $k_1$ is ~ 12 % (theoretical). Candidate must verify that $k_2$ is outside this range.<br><br>2. A has dimensions 4.5 cm ($L_1$) x 4.5 cm x 1.0 cm and a mass of 15.4 g; B has dimensions 6.5 cm ($L_2$) x 5.2 cm x 3.1 cm and a mass of 49.2 g. Since A and B have different cross-sectional areas, theoretically the expression, based on the conservation of moments, is not valid!<br><br>3. The metre rule has dimensions 1 m x 2.7 cm x 0.5 cm and a mass of 95.5 g. | | |
| | **f** | | Value for □ = 50.0 cm<br><br>Due to symmetry and uniform density of the objects, the centre of gravity of the system should be at its geometric centre. | | 1<br><br>1 |

| Qns | | | Skills Assessed and Marking Instructions | M |
|---|---|---|---|---|
| **2** | **b** | **(iii)** | Value of $\theta_0$ to the nearest degree Celsius in range between 70 °C to 80 °C. | 1 |
| | | **(iv)** | Value of $\theta$ to the nearest degree Celsius with unit, $\theta < \theta_0$ | 1 |
| | | **(v)** | Correct calculation of ( $\theta_0$ - $\theta$) | 1 |
| | **c** | **(i)** | Value of raw $d$ with unit to the nearest mm. | 1 |
| | | **(ii)** | Absolute uncertainty in 2mm < $d$ < 5 mm<br><br>If repeated readings have been taken, then the absolute uncertainty can be half the range. Correct method shown to find the percentage uncertainty. | 1 |
| | **d** | **(i)** | Values of $k$ calculated correctly with units. | 1 |
| | | **(ii)** | Justification of s.f. in $k$ linked to significant figures in $d$ and $\Delta\theta$ | 1 |

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| | | | | |
|---|---|---|---|---|
| | | **(iii)** | Heat lost through sides and /or bottom.<br>Temperature difference between the exposed area and the surroundings<br>Mass of water<br>Specific heat capacity of liquid<br>(Any two mentions)<br><br>Lag/insulate<br><br>Use of lid/heat loss in warming cup/draughts/heat loss to surroundings. | 1<br>1<br><br><br><br><br>1<br><br>0 |

| **Qns** | | | **Skills Assessed and Marking Instructions** | | **M** |
|---|---|---|---|---|---|
| **3** | **a** | **(i)** | Value of *d* in the range 0.25 mm to 0.45 mm.<br><br>*d* read to the nearest 0.01 mm with unit | | 1 |
| | | **(ii)** | Area calculated correctly with the correct unit | | 1 |
| | | **(iii)** | Correct calculation of percentage uncertainty in A.<br>Δdiameter = 0.01 mm and percentage uncertainty can be calculated using ΔArea/Area = 2Δdiameter/diameter | | 1 |
| | **b** | **(v)** | Value of *L* in range 0.1 m < L < 1 m and value of *V* in range 0.1 V to 2.0 V.<br><br>Correct units are given for both *L* and *V*. | | 1<br><br>1 |

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| | | | | | |
|---|---|---|---|---|---|
| | **d** | | • Award 2 marks if student has successfully collected 6 or more sets of data (*V, L*) without assistance/intervention.<br>• 5 sets one mark.<br>• 4 or fewer sets zero mark.<br>• Deduct 1 mark if minor help from supervisor, deduct 2 if major help.<br>• Deduct 1 mark if wrong trend in *L* (or *V*). *V* decreases with increase in *L*. | D1 | 2 |
| | | | Each column heading must contain a quantity and a unit where appropriate. Ignore units in the body of the table. There must be some distinguishing mark between the quantity and the unit i.e. solidus is expected, $V/L$ / V $m^{-1}$. Do not allow V(V) / *L* (m). | D2 | 1 |
| | | | Consistency of raw readings. All values of raw *L* must be given to the nearest mm. All values of *V* given to nearest 0.001 V. | D3 | 1 |
| | | | Range of L: $\Delta L \geq 60$ cm | D4 | 1 |
| | | | For each calculated value, the number of d.p in calculated value should reflect the number of s.f. in the raw readings.<br>All values must be given to an appropriate number of s.f. for this mark to be awarded. | D5 | 1 |
| | | | Correctly calculated values of *V/L, 1/L*. | D6 | 1 |
| | **e** | | Linearising equation and deriving expressions that equate e.g. gradient to a and *y*-intercept to -b. | E1 | 1 |
| | | | ***Graph:***<br>Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. Scales must be chosen so that the plotted points occupy at least half the graph grid in both *x* and *y* directions. Scales must be labeled with the quantity which is being plotted. | E2 | 1 |
| | | | All observations must be correctly plotted. Work to an accuracy of half a small square. Diameter of the plotted point must be less than half the small square. | E3 | 1 |
| | | | Line of best fit – judge by scatter of points about the candidate's line. There must be a fair scatter of points either side of the line. Allow only one anomalous point if clearly indicated (i.e. labelled or circled) by the | E4 | 1 |

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| | | | | | |
|---|---|---|---|---|---|
| | | | student. Line must not be kinked or thicker than half a small square. | | |
| | | | Gradient – the hypotenuse of the Δ must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square. Check for $\Delta y/\Delta x$ (i.e. do not allow $\Delta x/\Delta y$). | E5 | 1 |
| | | | y-intercept – must be read off to nearest half a small square or determined from $y=mx+c$ using a point on the line.<br>The value of b must be positive. | E6 | 1 |
| | | | Values of *a* and *b* calculated correctly with units. | E7 | 1 |
| | **f** | | Answer in range: $2.0 \leq \rho \leq 20.0 \times 10^{-7}$ Ω m. Consistent with units. | | 1 |

**4**

| Code | Description | | |
|---|---|---|---|
| A | *Basic Procedure*<br>✓ Labelled diagram of apparatus: small object, pole attached to a rotating device (motor or turntable)<br>✓ Procedure OK (i.e. measure period/frequency; change frequency and measure new angle for at least 8 sets of readings). | 1<br>1 | A1<br>A2 |
| | ✓ Method to change the speed of rotating device (e.g. change power of motor)<br>✓ Use fiducial mark or light gates perpendicular to motion of object | 1<br>1 | A3 |
| | ✓ $w = 2\pi f = 2\pi/T$<br>✓ frequency or period of rotation or $w$ is the independent variable and $\theta$ is the dependent variable or vary $f$ or $T$ or $w$ and measure $\theta$ | 1 | A4 |
| B | *Method of measuring Independent Variable*<br>✓ Stopwatch to time number of oscillation, light gates connected to a timer/frequency meter, rev counter/tachometer | 1 | B1 |
| B | *Method of measuring Dependent Variable*<br>✓ Use protractor or rule for measurements for trigonometry methods | 1 | B2 |
| B | *Processing and Analy□ing Experimental Data*<br>✓ Plot a graph of the dependent variable (cos $\theta$ ) against the independent variable ($1/w^2$).<br>✓ Relationship is valid if straight line through the origin. | 1 | B3 |
| C | *Method of keeping Variables Constant (note: do NOT use control of variables)*<br>✓ Keep the length of the rigid rod constant; ignore the reference to mass | 1 | |

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| | | | |
|---|---|---|---|
| | . | | C1 |
| C | *Safety Aspect*<br>✓ Use a protective screen in case mass detaches from the pole. Do not use goggles. | 1 | C2 |
| D | *Additional Details in Procedure*<br>✓ Large motor speed to produce measurable $\theta$<br>✓ Additional detail on measuring angle. e.g. large protractor fixed to pole<br>✓ Projection method, slow motion freeze frame video, camera with detail<br>✓ cos $\theta$ = h/*l* or equivalent<br>✓ method of checking pole is vertical – use a set square<br>✓ additional detail on measuring angular velocity, e.g. time at least 10 rotations/timing greater than 20 s<br>✓ wait for motion to become stable<br><br>Do not allow vague computer method | Max 2 | D1<br>D2<br>D3<br>D4<br>D5<br>D6<br>D7 |
| | **Total** | **12** | |

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| | | | |
|---|---|---|---|
| **CANDIDATE NAME** | | **CT GROUP** | **18S** |
| **CENTRE NUMBER** | | **INDEX NUMBER** | |

# PHYSICS

**9749/01**

**Paper 1 Multiple Choice**

**26 September 2019**

**60 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 **thirty** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the OMS.

Each correct answer will score one mark. A mark will **not** be deducted for a wrong answer.

Any rough working should be done in this booklet.

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## Data

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

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

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}$ F m$^{-1}$
$\approx (1/(36\pi)) \times 10^{-9}$ F m$^{-1}$

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

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

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

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

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

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

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

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

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

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

## Formulae

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

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**1** The rate of energy transfer $H$ through a conducting slab is given by

$$H = kA\left|\frac{\Delta T}{l}\right|$$

where the proportionality constant $k$ is the thermal conductivity of the material, $A$ is the cross-sectional area of the slab, $l$ is the length of the slab and $\Delta T$ is the temperature difference at opposite faces of the slab.

Which of the following is the unit of $k$ in ***base SI units***?

**A** W $m^{-1}$ $K^{-1}$

**B** W $m^{-2}$ $K^{-1}$

**C** kg $m^{5}$ $s^{-2}$ $K^{-1}$

**D** kg m $s^{-3}$ $K^{-1}$

**2** A tennis ball travelling at 4.0 m $s^{-1}$ due east strikes a surface and bounces off at 3.0 m $s^{-1}$ due north. The change in velocity of the tennis ball is

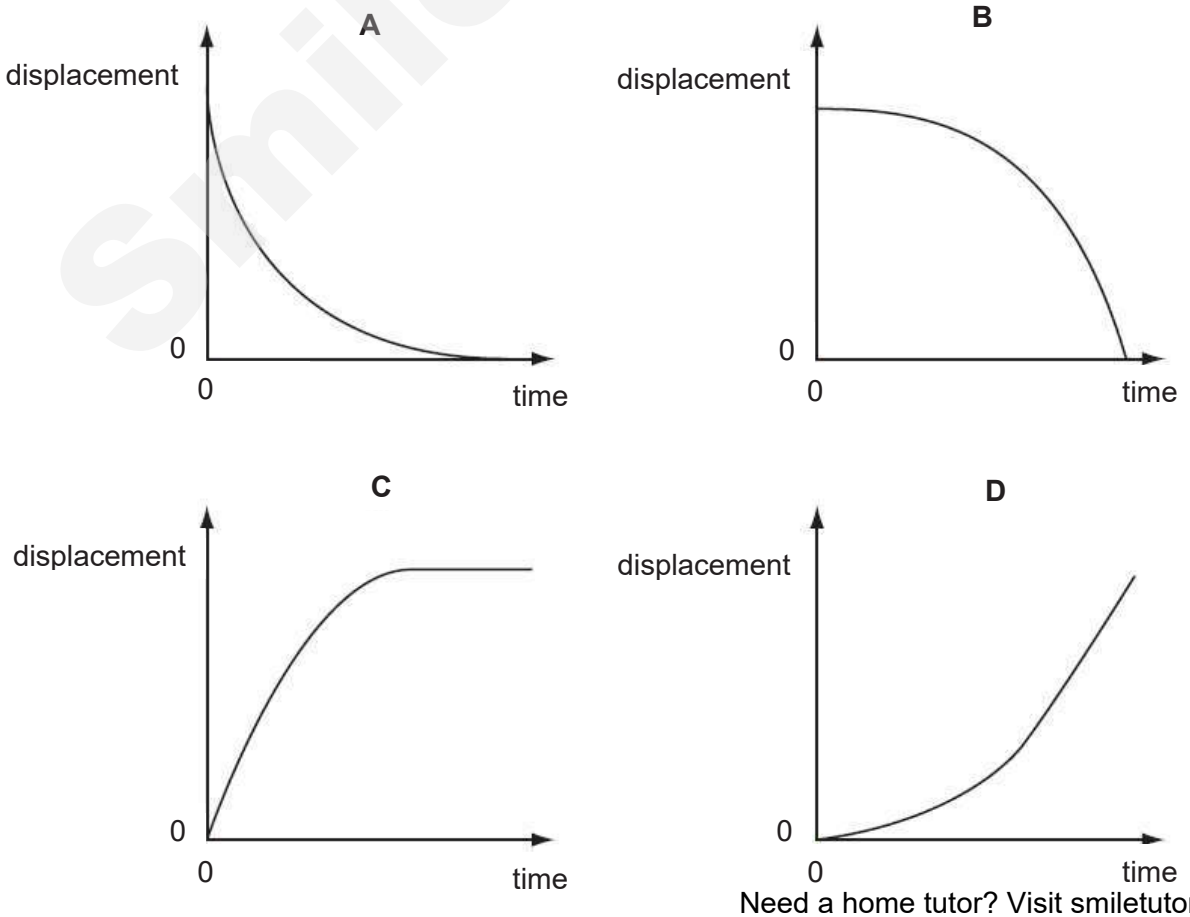
**A** 1.0 m $s^{-1}$ at 37° east of north

**B** 1.0 m $s^{-1}$ at 53° west of south

**C** 5.0 m $s^{-1}$ at 37° east of south

**D** 5.0 m $s^{-1}$ at 53° west of north

**3** An object is released from rest and falls vertically. Eventually it reaches terminal velocity. Which graph best represents how the displacement of the object varies with time?

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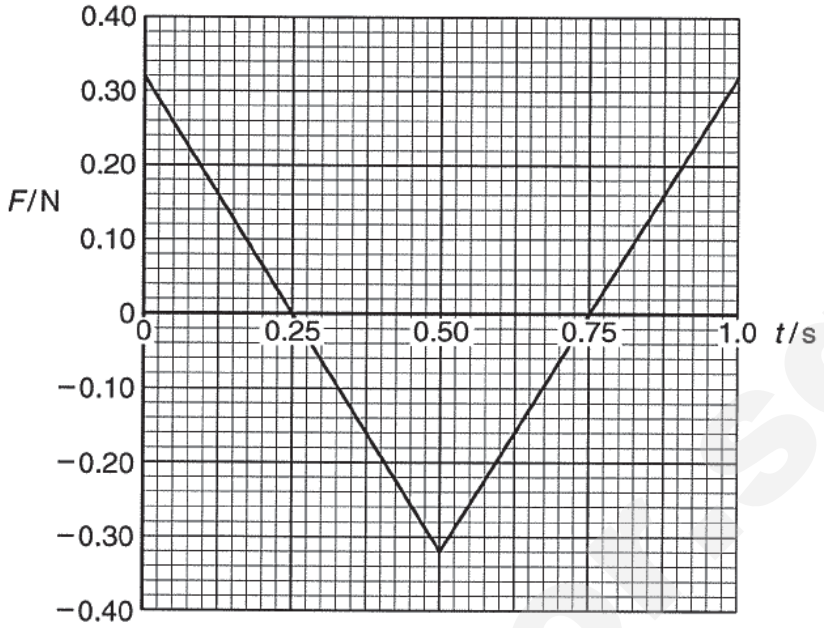
**4** A resultant force $F$ acts on a mass $m$. The variation with time $t$ of $F$ is as shown.




Mass $m$ is 150 g. At time $t$ = 0, the mass is at rest.

Which of the following statements is ***incorrect***?

**A** The mass slowed down at a decreasing rate from $t$ = 0.25 s to $t$ = 0.50 s.

**B** The mass is momentarily at rest at $t$ = 0.50 s.

**C** The mass reversed direction at $t$ = 0.50 s and sped up at a decreasing acceleration from $t$ = 0.50 s to $t$ = 0.75 s.

**D** The magnitude of the change in velocity of the mass from $t$ = 0.25 s to $t$ = 0.75 s is 0.53 m $s^{-1}$.

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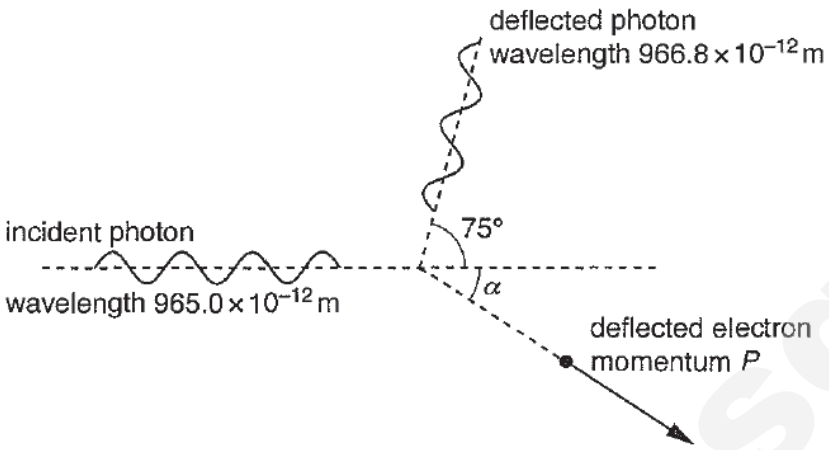
**5** An X-ray photon of wavelength 965.0 x$10^{-12}$ m collides elastically with a stationary electron.

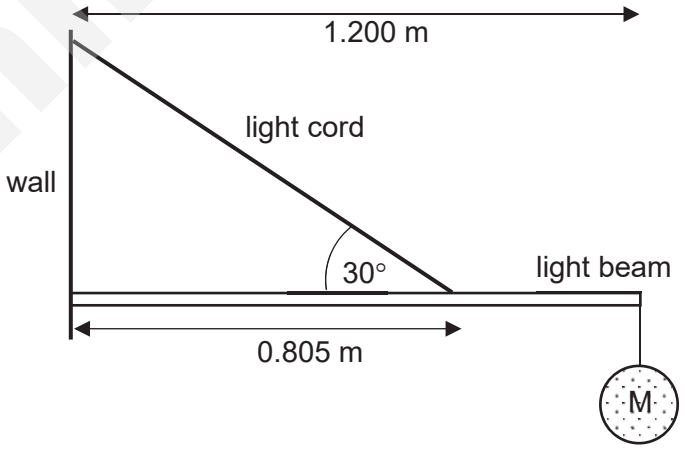



The photon is deflected through an angle of 75° and has a wavelength of 966.8 x$10^{-12}$ m. Given that the momentum carried by the deflected electron is 8.362 x $10^{-25}$ N s.

What is the deflection angle $\alpha$ of the electron?

**A** 12° **B** 38° **C** 52° **D** 78°

**6** A 1.200 m light beam carries a mass M at one end. A light cord affixed to the wall is supporting the beam at 0.805 m from the wall as shown.




What is the maximum mass M that can be supported if the maximum allowed tension in the cord is 300 N?

**A** 10.3 kg **B** 17.8 kg **C** 20.5 kg **D** 30.5 kg

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**7** A helium balloon of volume $V$ carrying a light weather instrument rises into the atmosphere. The total mass of the balloon skin and the weather instrument is $M$ kg. Given the gravitational field strength is $g$, the density of air is $\rho_{air}$, and the density of helium is $\rho_{He}$, the net force acting on the balloon is

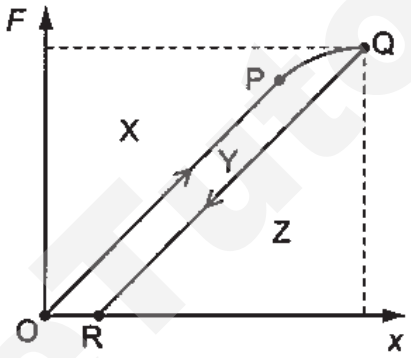
**A** $(\rho_{air} - \rho_{He})Vg$

**B** $(\rho_{air})Vg - Mg$

**C** $(\rho_{air} - \rho_{He})Vg - Mg$

**D** $(\rho_{He} - \rho_{air})Vg - Mg$

**8** 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 force and extension is indicated by line QR.




Which of the following correctly represents the work done by the force $F$ in stretching the wire to Q and the corresponding elastic potential energy stored in the wire?

| | **Work done by the force *F* in stretching the wire to Q** | **Elastic potential energy stored in the wire** |
|---|---|---|
| **A** | Y+X | X |
| **B** | Y | Z |
| **C** | Y+Z | Z |
| **D** | Y+Z | Y+Z |

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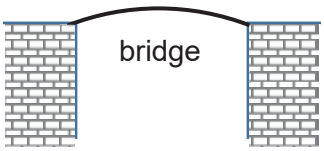
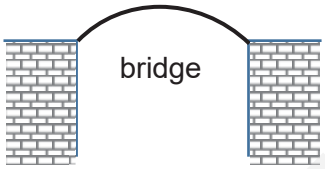
**9** A car moves with the same speed over each of the 4 bridges shown below. In which of the bridges is the force which the car exerts on the bridge the smallest?

**A**




**B**




**C**




**D**




**10** An isolated spherical planet has mass $M$ and radius $R$. The acceleration of free fall on the surface of the planet is $g$. What is the work done to move a small mass $m$ from the surface to a height $2R$ above the surface?

**A** 0.50 $mgR$

**B** 0.67 $mgR$

**C** $mgR$

**D** 2.0 $mgR$

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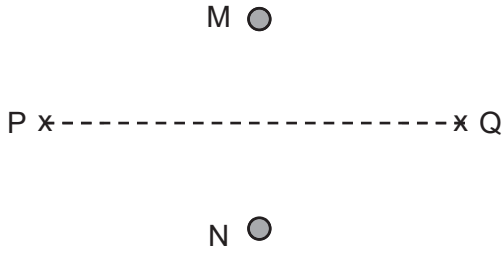
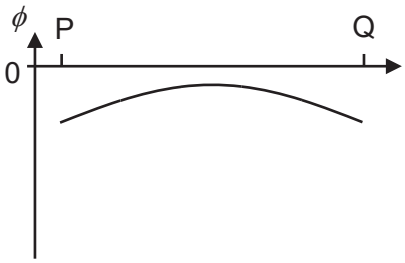
**11** M and N are two stars of equal mass. The points P and Q are equidistant from M and N.

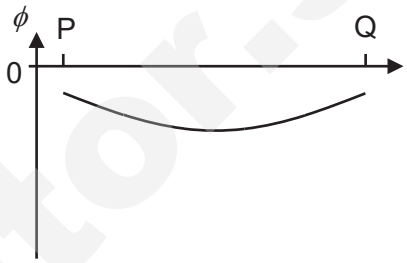



Which graph best shows the variation in the gravitational potential $\phi$ due to the stars between P and Q?

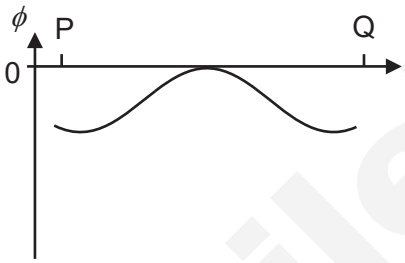
**A**



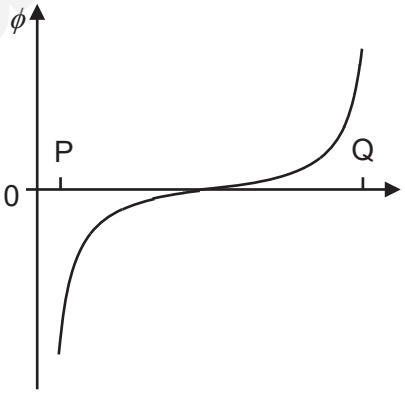

**B**




**C**




**D**

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**12** A fixed mass of ideal gas has pressure of $1.2 \times 10^5$ Pa at 50 °C. After a sudden compression, its pressure increases to $6.0 \times 10^5$ Pa at 200 °C.
What is the ratio of the compressed volume to the original volume?

**A** 0.80 **B** 0.29 **C** 0.14 **D** 0.05

**13** Consider the following:

S: 1 kg of ice at 0 °C
L1: 1 kg of water at 20 °C
L2: 1 kg of water at 40 °C
G: 1 kg of steam at 100 °C

Which of the following statements is ***false***?

**A** L2 contains molecules with higher average kinetic energies than L1.

**B** S has higher potential energy than G.

**C** There is positive work done on G when G condenses.

**D** The amount of thermal energy S must gain in order to melt is less than the amount of thermal energy G must lose in order to condense.

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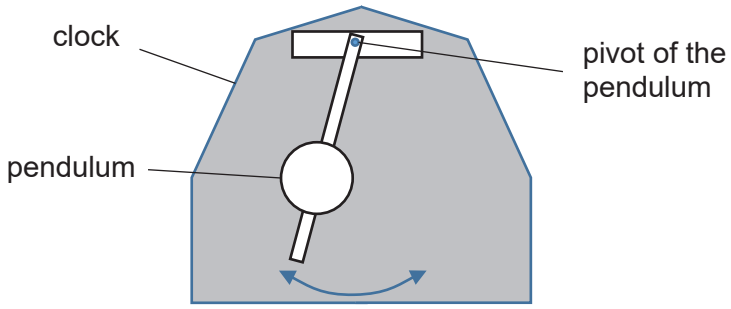
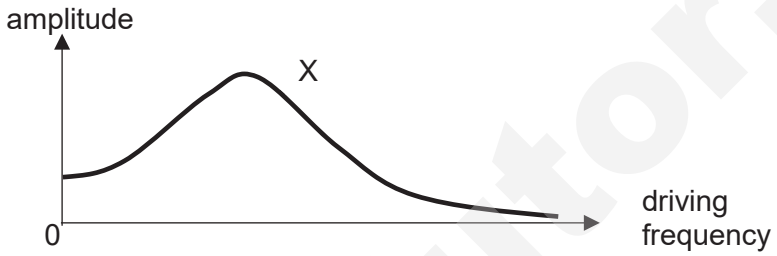
**14** The amplitude of oscillations of a pendulum in a clock below is observed to decay with time. To maintain the amplitude, an electric motor is attached to the pivot of the pendulum to drive it periodically.

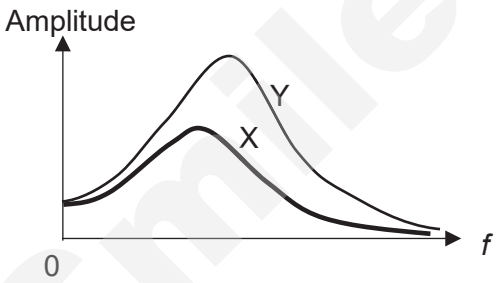



As the frequency *f* of the periodic force provided by the motor varies, the amplitude of oscillations vary with *f* as shown.

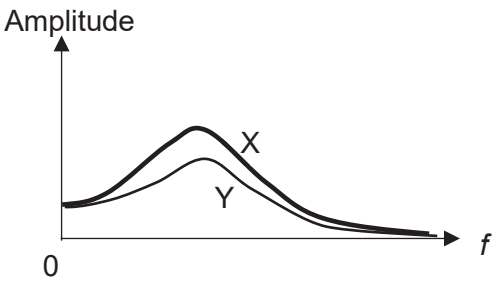



Over the years, the friction in the pivot increased.
Which of the following would be the new graph Y showing the variation of amplitude with *f*?

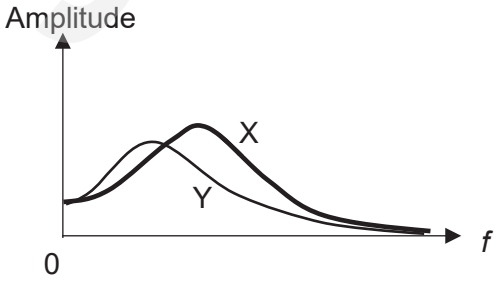
**A**



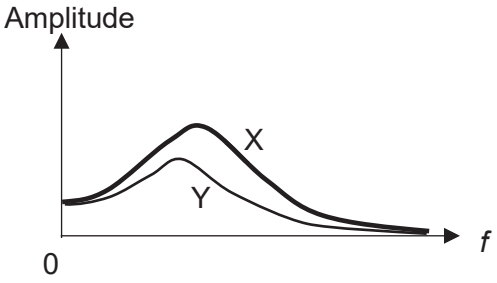

**B**




**C**




**D**

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**15** A wave is travelling on a string in the x-direction.

Fig. (a) and Fig. (b) show the variation with distance $x$ of the displacement $y$ of the string.

Fig. (a) corresponds to time $t$ = 0.00 s while Fig. (b) corresponds to time $t$ = 0.20 s.

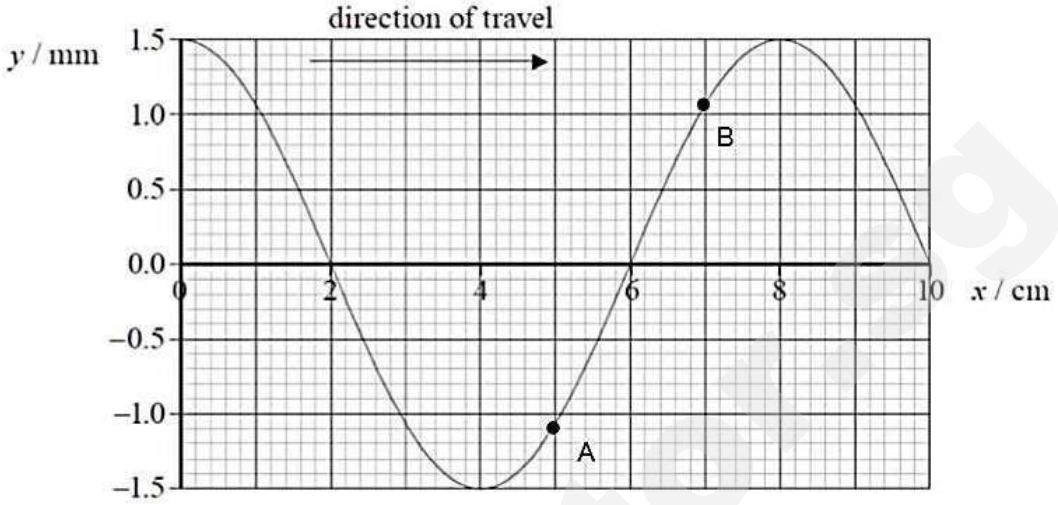


**Fig. (a)**

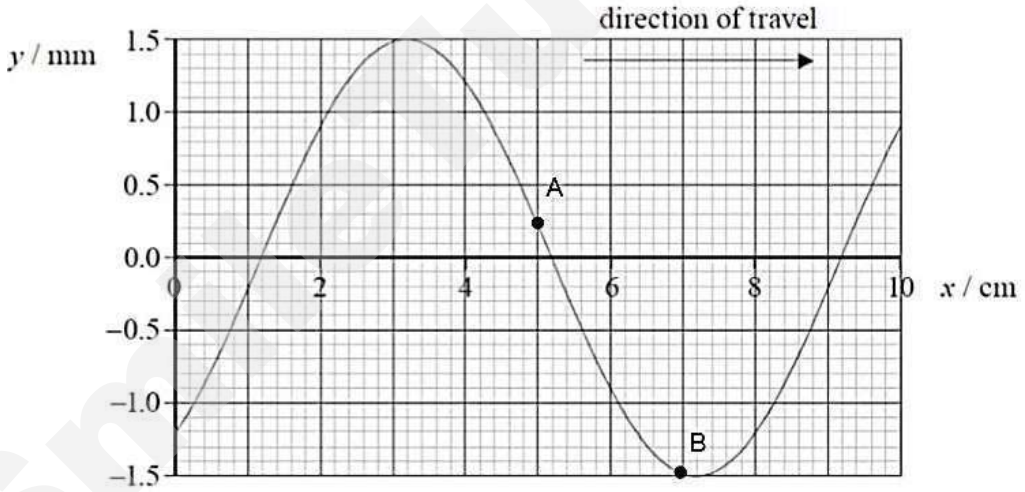


**Fig. (b)**

Which of the following is correct about the speed of the wave and the phase difference between A and B?

| | **speed / m s$^{-1}$** | **phase difference / radians** |
|---|---|---|
| **A** | 0.16 | $0.5\pi$ |
| **B** | 0.16 | $0.25\pi$ |
| **C** | 6.8 | $0.5\pi$ |
| **D** | 6.8 | $0.25\pi$ |

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**16** Which region of the electromagnetic spectrum includes waves with a frequency of $10^7$ MHz?

**A** infra-red waves

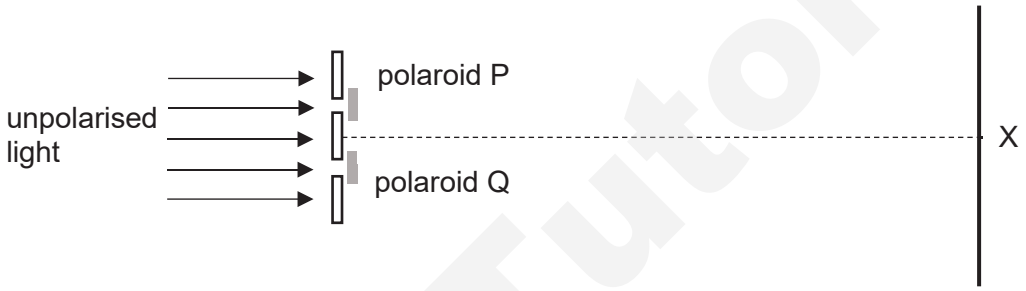
**B** radio waves

**C** ultraviolet waves

**D** X-rays

**17** Two sheets of polaroid P and Q are placed in front of a double slit such that their directions of polarization are parallel to each other.

When unpolarised light is incident normally on the double slit, the central bright fringe at X has an amplitude 2*A*.




What is the amplitude at X when polaroid P is turned through an angle of 60°?

**A** 0.5*A* **B** 1.5*A* **C** 1.7*A* **D** 2*A*

**18** A parallel beam of monochromatic light of wavelength $\lambda$ is incident normally on a diffraction grating. The angle between the directions of the two second-order diffracted beams is $\theta$.

What is the spacing of the lines on the grating?

**A** $\dfrac{\lambda}{\sin\theta}$ **B** $\dfrac{\lambda}{\sin\left(\frac{\theta}{2}\right)}$ **C** $\dfrac{2\lambda}{\sin\theta}$ **D** $\dfrac{2\lambda}{\sin\left(\frac{\theta}{2}\right)}$

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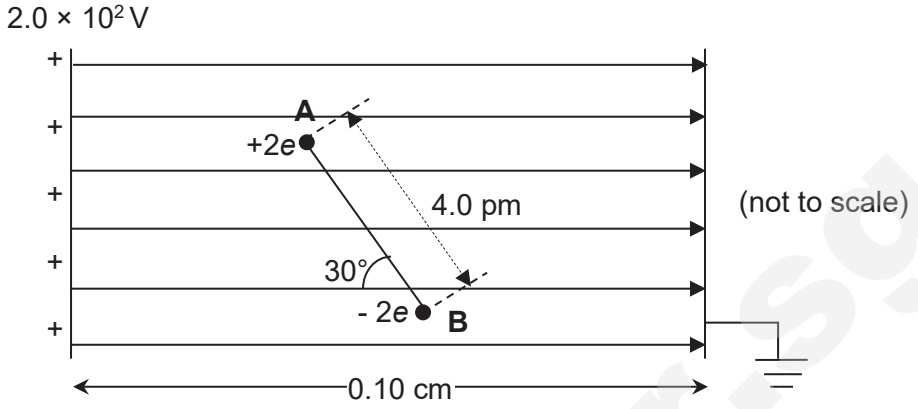
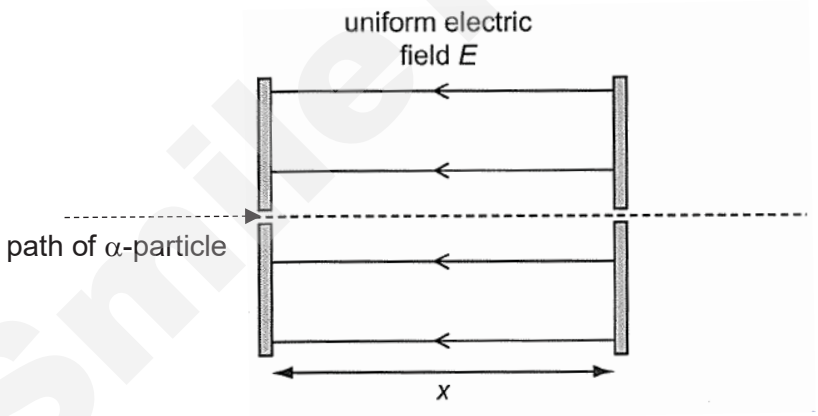
**19** Two ions **A** and **B,** at a distance of 4.0 pm apart, are linked to form a molecule. They are situated between a pair of charged parallel plates placed a distance of 0.10 cm apart. The left plate has a potential of $2.0 \times 10^2$ V and the right plate is earthed. The line joining **A** and **B** is at an angle of 30° to the direction of the electric field as shown in the diagram below.




What is the torque on the molecule **AB**?

**A** $1.3 \times 10^{-25}$ N m **B** $2.2 \times 10^{-25}$ N m **C** $2.6 \times 10^{-25}$ N m **D** $5.1 \times 10^{-25}$ N m

**20** An alpha particle travels through a uniform electric field of field strength *E*. It enters the field with velocity *v* and then travels a distance *x* in a direction opposite to the field, as shown.




Given that *e* is the elementary charge, *u* is the unified atomic mass constant.
What will be the speed of the alpha particle when it leaves the field?

**A** $v - \sqrt{\frac{eEx}{2u}}$

**B** $\sqrt{v^2 - \frac{eEx}{2u}}$

**C** $v - \sqrt{\frac{eEx}{u}}$

**D** $\sqrt{v^2 - \frac{eEx}{u}}$

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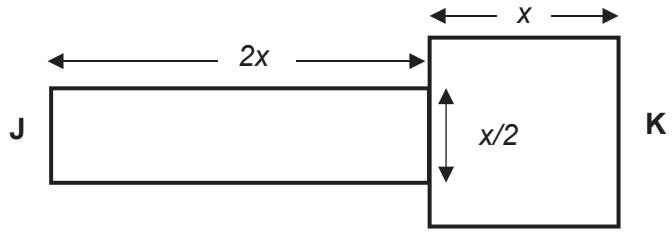
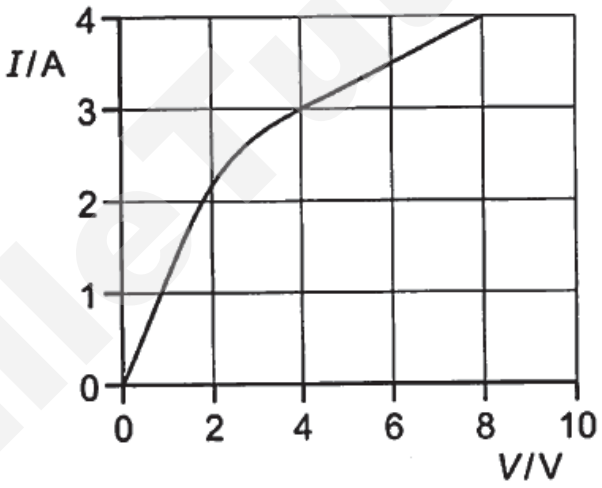
**21** A thin rectangular sheet of metal of uniform thickness and of length $2x$ and width $\frac{x}{2}$ is connected to another square sheet of the same metal of the same thickness, which has a resistance of 8.0 Ω measured between opposite edges.




What is the resistance between edges **J** and **K**?

**A** 6.4 Ω **B** 16 Ω **C** 32 Ω **D** 40 Ω

**22** The graph plots current $I$ against potential difference $V$ for a filament lamp.




What are the correct resistance values at 1 V and 6 V potential difference?

| | resistance at 1 V | resistance at 6 V |
|---|---|---|
| **A** | less than 1.0 Ω | 1.7 Ω |
| **B** | greater than 1.0 Ω | 1.7 Ω |
| **C** | less than 1.0 Ω | 4.0 Ω |
| **D** | greater than 1.0 Ω | 4.0 Ω |

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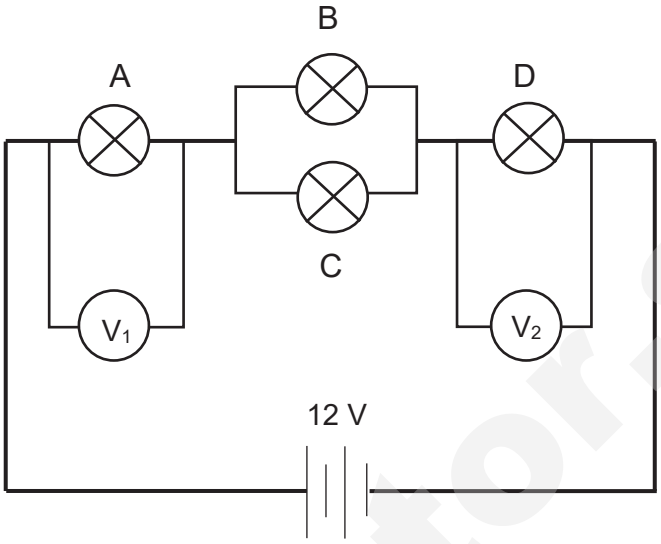
**23** A cell of e.m.f. 12 V is connected across four similar bulbs A, B, C and D.

The bulb D has a broken filament.

Voltmeters $V_1$ and $V_2$ of infinite resistance are placed in the circuit as shown below.




Which of the following correctly shows the voltmeter readings?

| | **Voltmeter $V_1$ / V** | **Voltmeter $V_2$ / V** |
|---|---|---|
| **A** | 0 | 0 |
| **B** | 0 | 12 |
| **C** | 12 | 0 |
| **D** | 8 | 4 |

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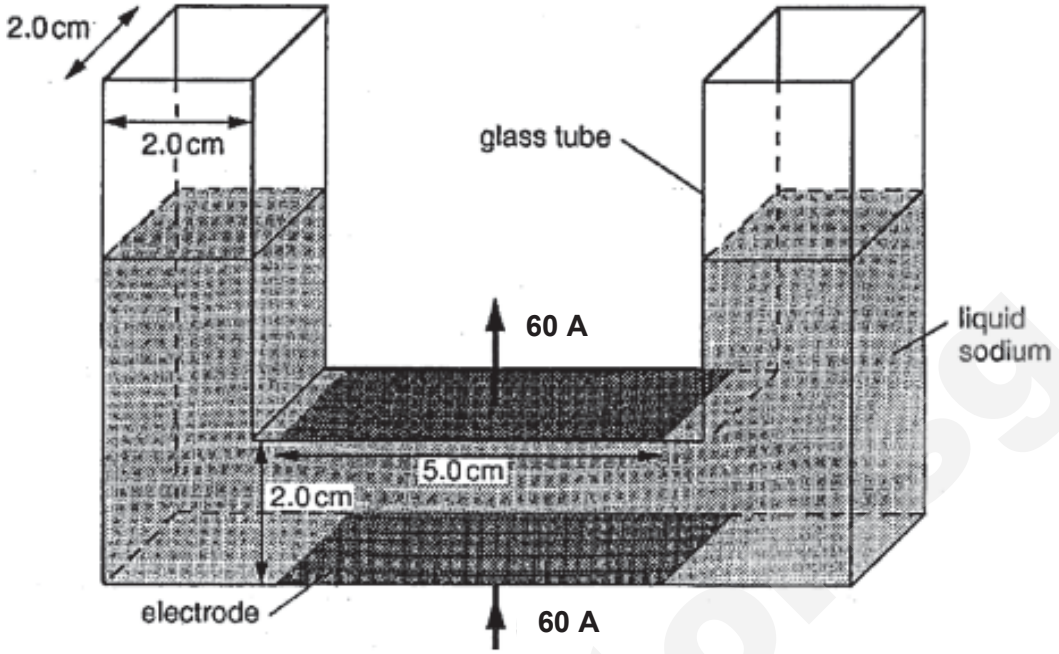


**Fig. a**

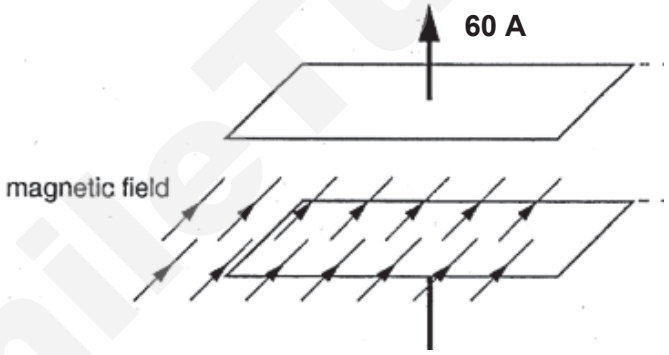


**Fig. b**

The U-tube shown above contains liquid sodium of density 960 kg $m^{-3}$. Electrodes are set into the upper and lower faces of the horizontal section and a current of 60 A is sent through the liquid as shown in Fig. a.

When a uniform magnetic field is applied as shown in Fig. b, the liquid in the left arm rises by 1.0 cm while the liquid in the right arm lowers by 1.0 cm.

What is the magnetic flux density of the applied magnetic field?

**A** 0.013 T **B** 0.025 T **C** 0.031 T **D** 0.063 T

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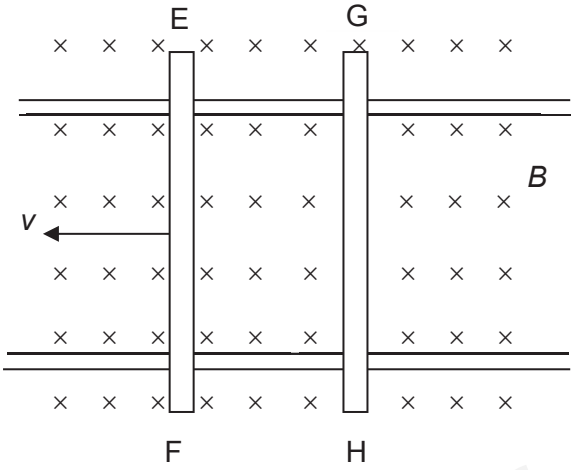
**25** Two conducting rods EF and GH can slide along two parallel copper bars in a uniform magnetic field *B* perpendicular to the plane as shown.




If rod EF is given an initial speed v to move to the left, rod GH will

**A** move to the right.

**B** move to the left.

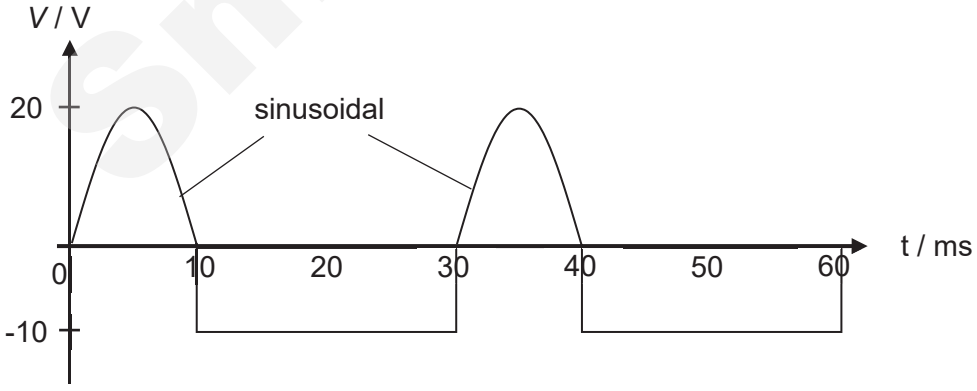
**C** move to the right first, then to the left.

**D** move to the left first, then to the right.

**26** A rectangle coil of 800 turns has an area of 0.050 $m^2$. It is placed at right angles to a magnetic field of flux density 4.0 x $10^{-5}$ T. It is then rotated through 180° in 0.20 s. The average emf induced in the coil is

**A** 0.000 V **B** 0.016 V **C** 0.025 V **D** 0.046 V

**27** An alternating voltage is connected to a resistor of resistance 5.0 Ω.




What is the mean power dissipated by the resistor?

**A** 16 W **B** 27 W **C** 120 W **D** 800 W

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**28** In an experiment to demonstrate the photoelectric effect, light of intensity $L$ and frequency $f$ is incident on a metal surface. The maximum photoelectric current is $I$ and the stopping potential is $V_S$.

What change, if any, will occur in the maximum photoelectric current and the stopping potential if light of the same intensity $L$ but of frequency $2f$ is incident on the surface?

| | Maximum photoelectric current | Stopping potential |
|---|---|---|
| **A** | $I$ | greater than $2V_S$ |
| **B** | less than $I$ | greater than $2V_S$ |
| **C** | $I$ | equal to $2V_S$ |
| **D** | less than $I$ | equal to $2V_S$ |

**29** Which of the following statements is ***incorrect***?

In an alpha decay of a stationary nucleus,

**A** the daughter nucleus and the alpha particle always move off in opposite directions.

**B** total kinetic energy is not conserved.

**C** the parent nucleus has a larger mass defect than the daughter nucleus.

**D** the parent nucleus has a larger binding energy per nucleon than the daughter nucleus.

**30** The table below shows the count-rate recorded by a Geiger-Müller counter at a point in a laboratory at various times, with and without a radioactive source in position.

| time / days | count rate / $s^{-1}$ | |
|---|---|---|
| | *with source* | *without source* |
| 10 | 60 | 20 |
| 30 | 30 | 20 |
| 90 | 20 | 20 |

From these readings, what is the half-life of the source?

**A** 10 days **B** 15 days **C** 20 days **D** 30 days

**END OF PAPER**

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**Higher 2**

| | | | |
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| **CANDIDATE NAME** | | **CT GROUP** | **18S** |
| **CENTRE NUMBER** | | **INDEX NUMBER** | |

# PHYSICS

**9749/02**

**Paper 2 Structured Questions**

**19 September 2019**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

## INSTRUCTIONS TO CANDIDATES

Write your **name, CT class** and **tutor's name** 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.

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

Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.
You are reminded of the need for good English and clear presentation in your answers.

| For Examiner's Use | | |
|---|---|---|
| **P1 (15%)** | | **30** |
| **Paper 2** | | |
| **1** | | **9** |
| **2** | | **10** |
| **3** | | **10** |
| **4** | | **12** |
| **5** | | **10** |
| **6** | | **10** |
| **7** | | **19** |
| **Deductions** | | |
| **P2 (30%)** | | **80** |

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## Data

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

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

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}$ F m$^{-1}$
$\approx (1/(36\pi)) \times 10^{-9}$ F m$^{-1}$

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

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

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

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

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

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

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

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

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

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

## Formulae

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

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**1** A large metal ball is hung from a crane by means of a cable of length 5.8 m as shown in Fig. 1.1.

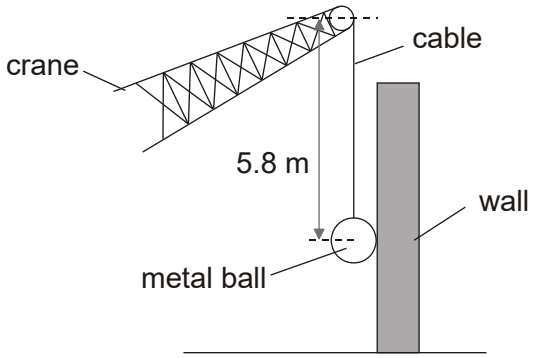


**Fig. 1.1**

To knock down a wall, the metal ball of mass 350 kg is pulled away from the wall while keeping the cable taut, and then released. The crane does not move. Fig. 1.2 shows the variation with time *t* of the speed *v* of the ball after release.

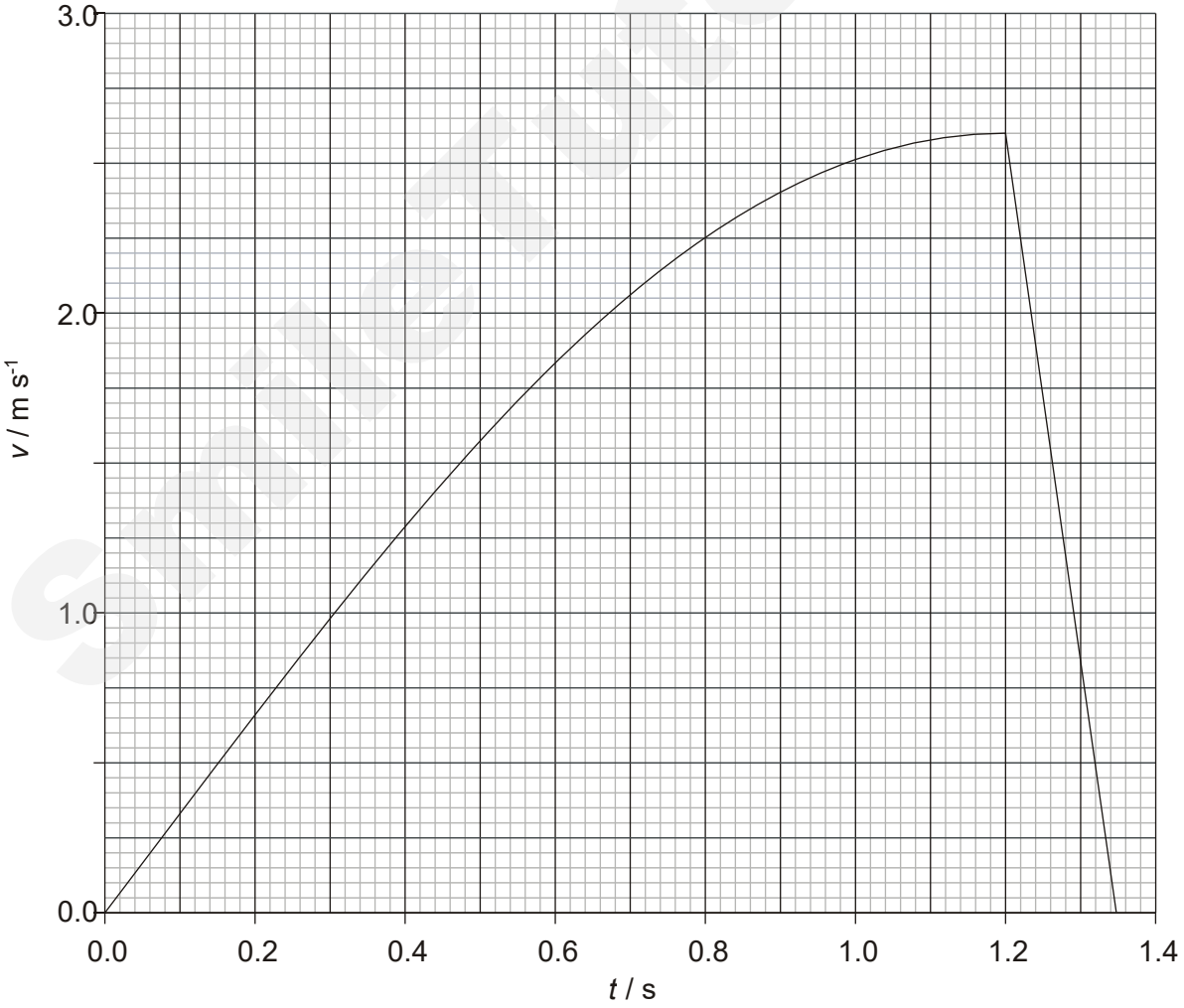


**Fig. 1.2**

The ball contacts the wall when the cable from the crane is vertical.

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**(a)** At the instant just before the ball hits the wall,

**(i)** explain why the tension in the cable is not equal to the weight of the ball;

……

…… [1]

**(ii)** by reference to Fig. 1.2, estimate the tension in the cable.

tension = …….…….. N [2]

**(b)** For the collision between the ball and the wall, determine the average force exerted by the ball on the wall.

average force exerted by the ball on the wall = …….…….. N [2]

**(c)** The metal ball has lost momentum.
State the principle of conservation of linear momentum and discuss whether it applies to this situation.

……

……

……

…… [2]

**(d)** During the impact of the ball with the wall, 12% of the total kinetic energy of the ball is converted into thermal energy in the ball. The metal of the ball has specific heat capacity 450 J $kg^{-1}$ $K^{-1}$. Determine the average rise in temperature of the ball as a result of colliding with the wall.

average rise in temperature = …….…….°C [2]

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**2** **(a)** Explain what is meant by *upthrust*.

……

…… [1]

**(b)** Before a small balloon is inflated, its mass is 1.30 g as recorded on an electronic mass balance. The balloon is inflated with air so that it is spherical in shape with a diameter of 22.0 cm.

**(i)** The density of air is 1.21 kg $m^{-3}$. Calculate the mass of air displaced by the balloon.

mass of air displaced = …….. g [2]

**(ii)** The inflated balloon gives reading of 1.55 g when placed on the balance. Calculate the mass of air in the balloon.

mass of air in balloon = …… g [2]

**(iii)** Explain why the value in **(b)(ii)** is larger than the value in **(b)(i).**

……..

…….. [1]

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**(c)** A 2.10 g nut is now tied to the balloon with a light cotton thread. The balloon is dropped from a height of 4.00 m.

**(i)** Calculate the acceleration of the balloon and nut at the start of their descent.

acceleration = …….. m $s^{-2}$ [2]

**(ii)** Explain why the acceleration will approach zero as the balloon descends.

……..

……..

……..

…….. [2]

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**3 (a)** Explain what is meant by a *polarised light*.

……..……..

……..……..

……..……[1]

**(b)** A beam of polarised light of intensity $I_0$ incident on polariser A as shown in Fig. 3.1.

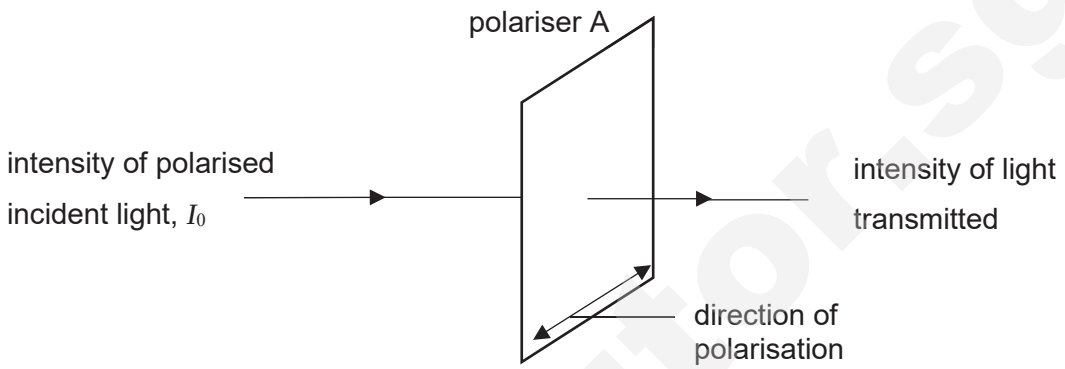


**Fig. 3.1**

Polariser A is arranged such that the intensity of light transmitted through it is ***zero***.

**(i)** With reference to the arrangement in Fig. 3.1, by placing another polariser X before polariser A with both planes in parallel, the intensity of light transmitted may now be greater than zero. Explain why this is so.

……

……

……

……

……..... [2]

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**(ii)** Initially, the directions of polarisation of polariser X and A are parallel.
Polariser X is then rotated about the axis of the light beam while keeping the planes of the polarisers parallel.

The angle between the direction of polarisation of polariser X and of polariser A is $\theta$.

**1.** Complete the table below. You may use the space below for your working. [2]

| $\theta$ | **Intensity of light transmitted through polariser A (in terms of $I_o$ )** |
|---|---|
| 0° | 0 |
| 45° | |
| 60° | |

**2.** Polariser X is rotated through 360° about the axis of the light beam.
Sketch on the axes of Fig. 3.2 the variation with the angle of rotation $\theta$ of the intensity $I$ of the light after passing through polariser A. [2]

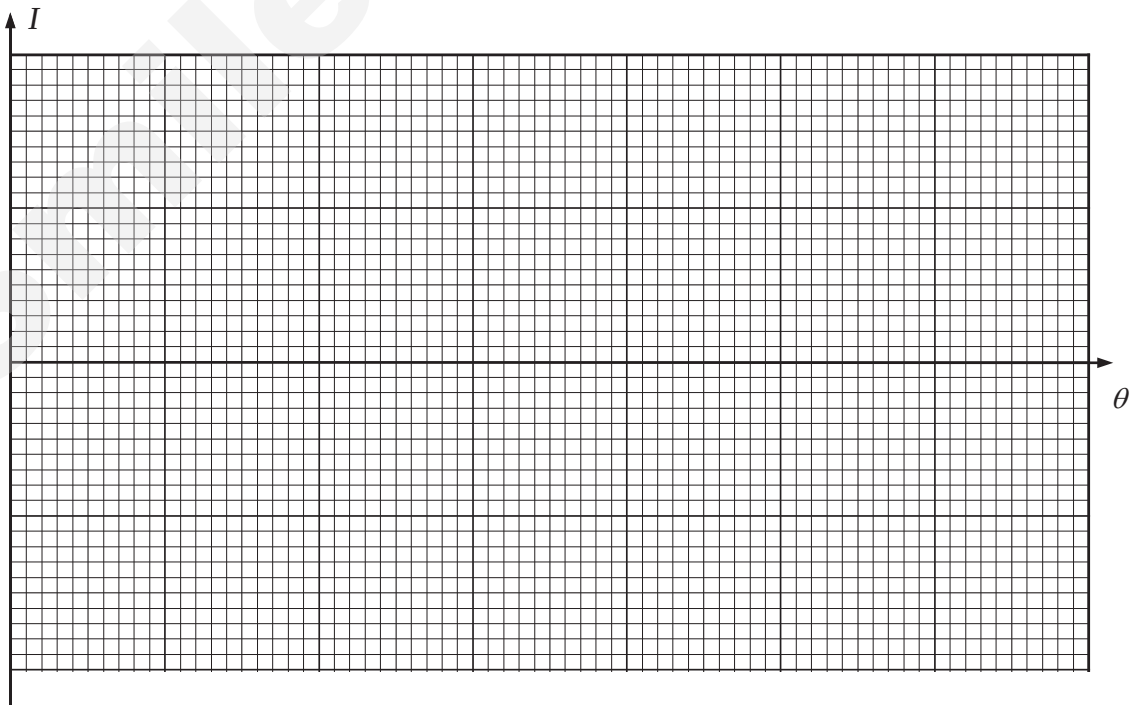


**Fig. 3.2**

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**(c)** A speaker of a public address system radiates sound uniformly in all directions.
The intensity of the sound wave detected by a microphone located 78.0 m away from the speaker is 0.026 $Wm^{-2}$.

**(i)** Determine the detected intensity if the same microphone is moved to a position 300.0 m away from the speaker.

intensity = ..... W $m^{-2}$ [2]

**(ii)** Find the power received at the position 300.0 m by the microphone diaphragm which has an area of 3.20 $cm^2$.

power = ..... W [1]

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**4 (a) (i)** Define the term *electric potential*.

.....

.....

..... [2]

**(ii)** Write down the relationship between electric field strength and electric potential.

.....

..... [1]

**(b)** Fig. 4.1 is a map of equipotential lines drawn to scale. The potentials in the region mapped are set up by a system of small stationary charged spheres in a plane, three of which carrying charge of $q_1$, $q_2$ and $q_3$ are shown. All the charged spheres are fixed in their locations.

Potential values are given in volts (V). Note the signs (+/–).

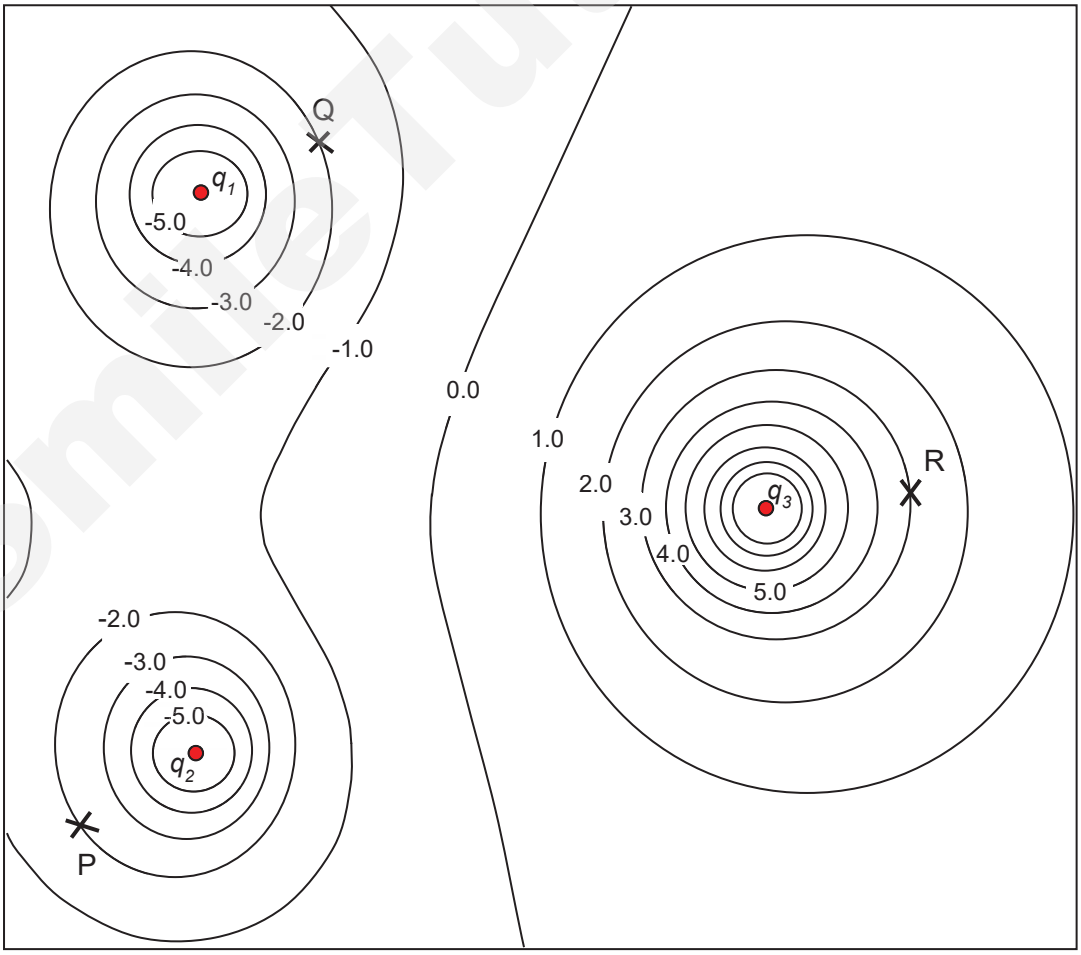


**Fig. 4.1**

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Based on Fig. 4.1, state with reasons whether the charge $q_1$, $q_2$ and $q_3$ are positive or negative.

……

……

……

……

[2]

**(c)** **(i)** Draw on Fig. 4.1 an arrow at P to indicate the direction of the electric field strength at P. Label the arrow as *E*. [1]

**(ii)** Estimate the magnitude of electric field strength at point P.

magnitude of electric field strength = …….…….. $Vm^{-1}$ [1]

**(d)** Calculate the work required to move an electron from point P to point R without a gain in kinetic energy.

work = …….…….. J [2]

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**(e)** Sketch on Fig. 4.2 the variation of the electric field strength $E$ along a straight line from the sphere carrying charge $q_1$ to the sphere carrying charge $q_3$.

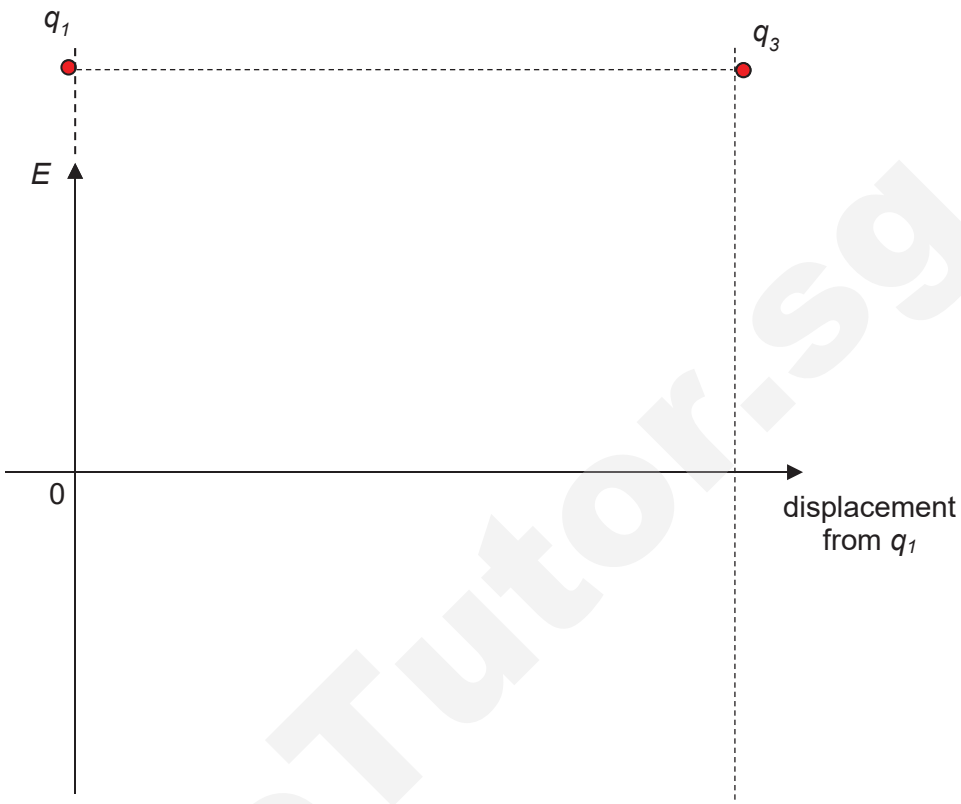


**Fig. 4.2**

[3]

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**5** Fig.5 illustrates the connection between the copper and filament wires of a lamp. The diameter of the copper wire is 1.50 mm and the diameter of the filament wire is 0.020 mm.

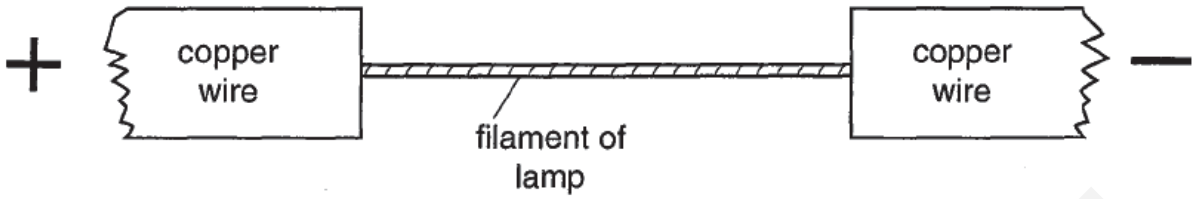


**Fig. 5**

The number density of charge carriers in copper is 8.49 x $10^{28}$ $m^{-3}$, and the number density of charge carriers in tungsten is 3.40 x $10^{28}$ $m^{-3}$. The uncoiled filament wire is 1.5 m long and has a resistance of 300 Ω.

**(a)** State and explain whether the current in the copper wire and tungsten filament are the same.

……

……

……[1]

**(b)** Calculate the resistivity of the filament wire.

resistivity = …… Ω m [2]

**(c)** **(i)** The drift velocity of electrons in the copper wire is 0.021 x $10^{-3}$ m $s^{-1}$.
Determine the drift velocity of electrons in the tungsten filament.

drift velocity = …… m $s^{-1}$ [3]

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**(ii)** Use your answers to **(c)(i)** to explain why the filament of the lamp gets hot but the copper leads stay relatively cold.

……

……

……

……

……

…… [2]

**(iii)** The filament wire is now replaced with another tungsten wire of the same length, but twice its diameter. The potential difference (p.d.) across the wire is unchanged. The temperature of both wires is the same.

Without any calculations, state and explain the change, if any, to the drift velocity of the charge carriers in the second filament wire.

……

……

……

……

……

…… [2]

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**6 (a)** A battery B, a variable resistor R and a uniform resistance wire XY are connected in series, as shown in Fig. 6.1.

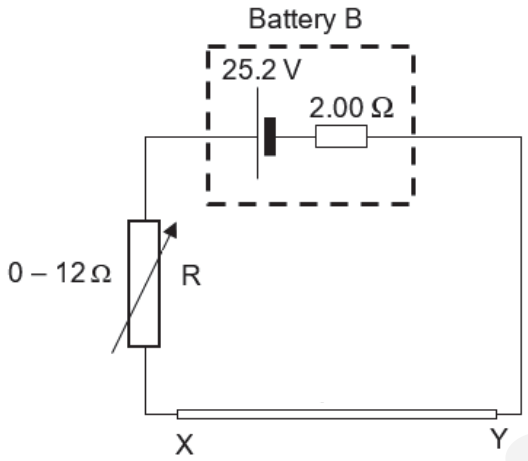


**Fig. 6.1**

Battery B has electromotive force (e.m.f.) 25.2 V and internal resistance 2.00 Ω. Wire XY is made of constantan and has resistance 40.0 Ω.

**(i)** The resistance of R is varied from 0.0 to 12.0 Ω.
Describe and explain the variation in the terminal potential difference (p.d.) across B.
Numerical values are not required.

……

……

……

……

…… [3]

**(ii)** The resistance of R is set at 4.00 Ω. Calculate the terminal p.d. across B.

p.d. = …… V [2]

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**(b)** A thermistor T is connected in series with a resistor of resistance 1.50 kΩ and a battery, as shown in Fig. 6.2. The e.m.f. of the battery is 6.00 V and its internal resistance is negligible.

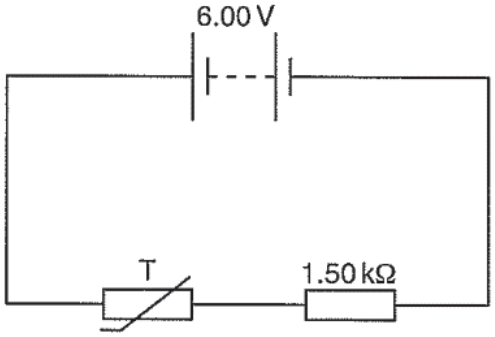


**Fig 6.2**

The variation with temperature $\theta$ of the resistance R of the thermistor is shown in Fig. 6.3.

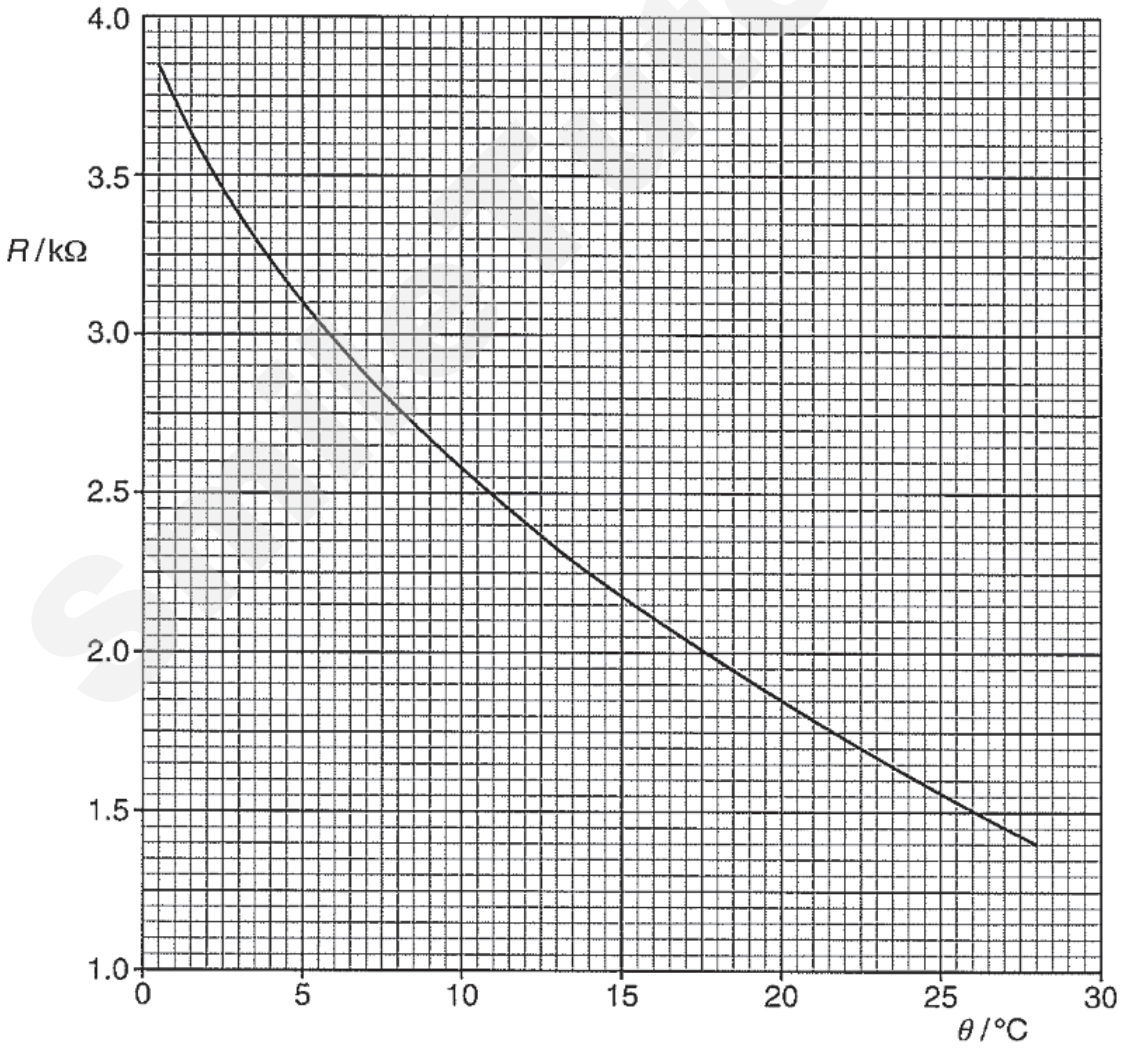


**Fig. 6.3**

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**(i)** At one temperature $t$ of the thermistor, the current in the circuit is 1.60 mA. Determine the temperature $t$.

$t$ = ……..……°C [3]

**(ii)** Determine the p.d. across the fixed resistor when the temperature is 5 °C.

p.d. = ……..V [2]

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**7** Read the following article then answer the questions that follow.

**Compton Scattering**

Besides the photoelectric effect, a number of other experiments were carried out in the early twentieth century which also supported the photon theory. One of these was the Compton effect named after its discoverer. Compton scattered X-rays from various materials. He found that the scattered light had a slightly longer wavelength than the incident light. He was able to explain this result based on the quantum theory of light. Light is seen as particles colliding with the electrons of the material (Fig. 7.1).

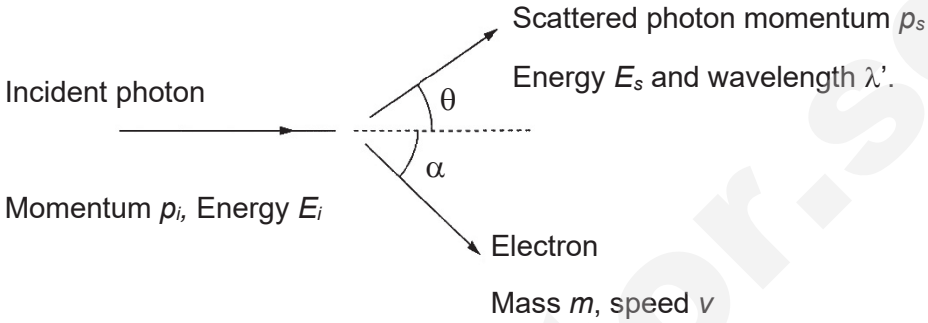


**Fig 7.1**

The incident photon has momentum $p_i$ and energy $E_i$ The photon is scattered through an angle $\theta$ and, after scattering, has momentum $p_s$ and energy $E_s$. The electron of mass $m$ which was originally stationary, moves off with speed $v$ at an angle $\alpha$ to the original direction of the incident photon.

Compton applied the laws of conservation of energy and momentum to the collision and obtained the following equation for the wavelength of the scattered photons.

$$\lambda' = \lambda + \frac{h}{mc}(1 - \cos\theta)$$

where $m$ is the mass of the electron. The quantity $\frac{h}{mc}$ has the dimension of length and is called the Compton wavelength of the electron, whose accepted value is $2.43 \times 10^{-12}$ m.

The predicted wavelength of the scattered photons depends on the angle $\theta$ at which they are detected. Compton's measurements of 1923 were consistent with this formula.

In an experiment to provide evidence to justify Compton's theory, measurements were made of the wavelength $\lambda$ of the incident photon, the wavelength $\lambda'$ of the scattered photon and the angle $\theta$ of scattering. Some data from this experiment are given in Fig. 7.2.

| $\lambda$ / $10^{-12}$ m | $\lambda'$ / $10^{-12}$ m | $\theta$ |
|---|---|---|
| 191.92 | 193.27 | 59° |
| 965.04 | 966.84 | 75° |

**Fig. 7.2**

The wave theory of light does not predict such a shift: an incoming EM wave of frequency $f$ should set electrons into oscillation at frequency $f$, and such oscillating electrons would re-emit EM waves of this same frequency. Hence Compton effect adds to the firm experimental foundation for the photon theory of light.

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**(a)** Explain what is meant by a *photon.*

……

……[1]

**(b)** The inelastic collision between a photon and a stationary electron may be represented by Fig. 7.1.

**(i)** Write down equations (in terms of $p_i$, $p_s$ $E_i$, $E_s$, $m$, $v$, $\theta$ and $\alpha$) that represent

1. the conservation of energy. [1]

2. the conservation of momentum along the direction of the incident photon. [1]

**(ii)** Using quantum theory of light, explain why a scattered photon has a wavelength longer than that of the incident photon.

……

……

……

……

…… [2]

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**(c)** In the Compton scattering experiment, the uncertainty in the measurement of $\theta$ is ± 5°. Determine the value of cos $\theta$ with its uncertainty, for the angle $\theta$ = 75° ± 5°.

*cos θ* = ..... ± ..... [2]

**(d)** Given that $\Delta\lambda = \lambda' - \lambda$, additional data for the variation of $\Delta\lambda$ against cos $\theta$ are shown in Fig. 7.3.

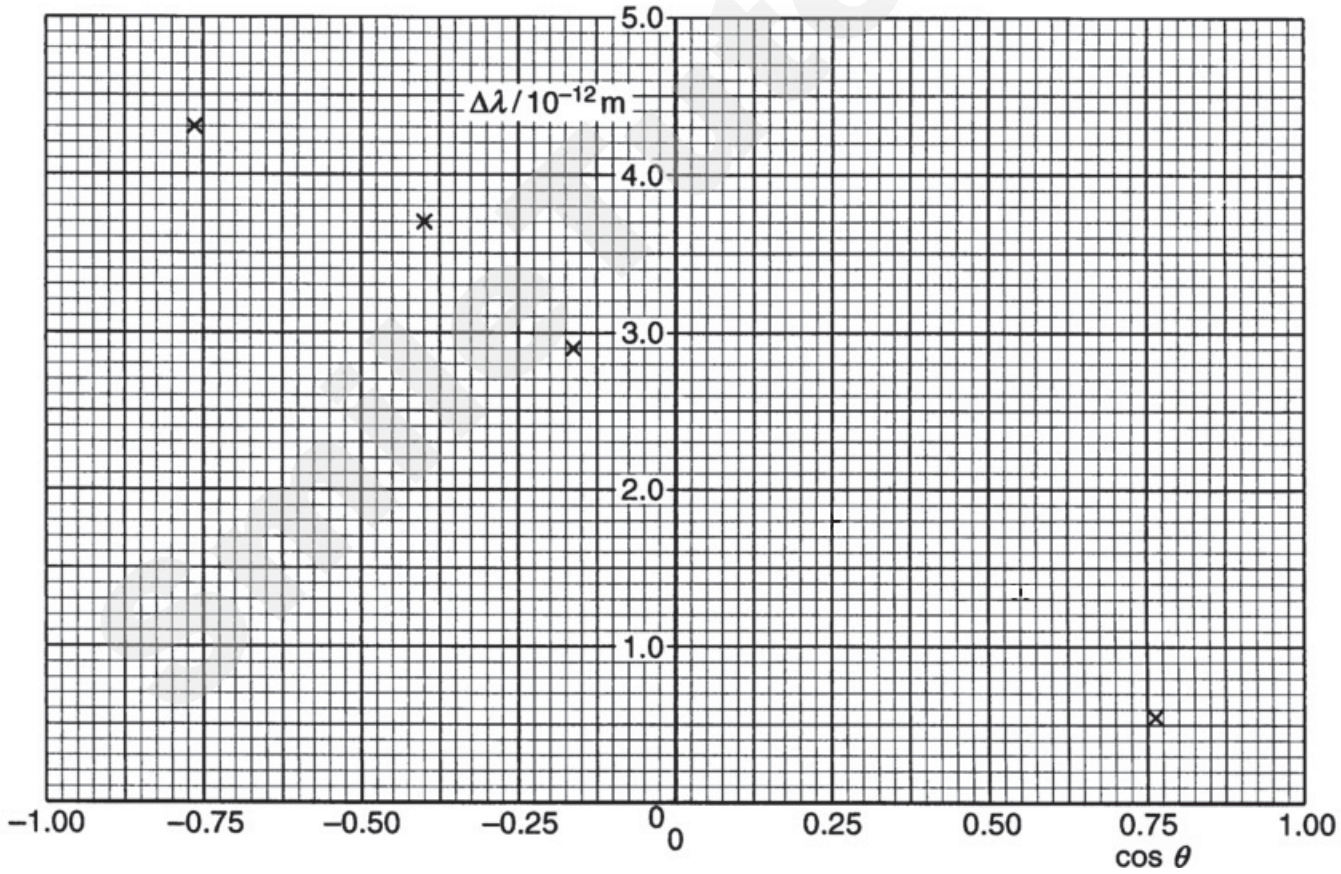


**Fig. 7.3**

**(i)** Plot the data given in Fig 7.2 on Fig 7.3. [3]

**(ii)** Draw the best-fit line for the points on Fig. 7.3. [1]

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**(iii)** State and explain one way to determine the Compton's wavelength from Fig. 7.3.

……

……

……

…… [2]

**(iv)** Determine the Compton's wavelength using the method described in **d (iii)**.

Compton's wavelength = …… [2]

**(e)** In another Compton scattering experiment, 19.0 keV X-ray photons scatter off a carbon target.

**(i)** Find the wavelength of the scattered photon if the scattered angle is 30°.

wavelength = …….. [2]

**(ii)** For a carbon atom, the binding energy of an electron is of the order of a few eV.

Compton's theory assumes that the electrons are not bound in the atoms but are free. Suggest whether this assumption is justified.

……

……

……

…… [2]

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**Higher 2**

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| **CENTRE NUMBER** | | **INDEX NUMBER** | |

# PHYSICS

**9749/03**

**Paper 3 Longer Structured Questions**

**24 September 2019**

**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 **one** question only. **Circle** the question number on the cover page.

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

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

You are reminded of the need for good English and clear presentation in your answers.

| For Examiner's Use | | |
|---|---|---|
| **SECTION A** | | |
| 1 | | 8 |
| 2 | | 11 |
| 3 | | 8 |
| 4 | | 8 |
| 5 | | 8 |
| 6 | | 9 |
| 7 | | 8 |
| **SECTION B** | | |
| 8 | | 20 |
| 9 | | 20 |
| Deductions | | |
| Total (35%) | | 80 |

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## Data

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

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

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}$ F m$^{-1}$
$\approx (1/(36\pi)) \times 10^{-9}$ F m$^{-1}$

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

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

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

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

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

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

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

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

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

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

## Formulae

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

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## Section A

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

**1** **(a)** A fixed amount of ideal monatomic gas is contained in a cylinder as shown in Fig. 1.1.

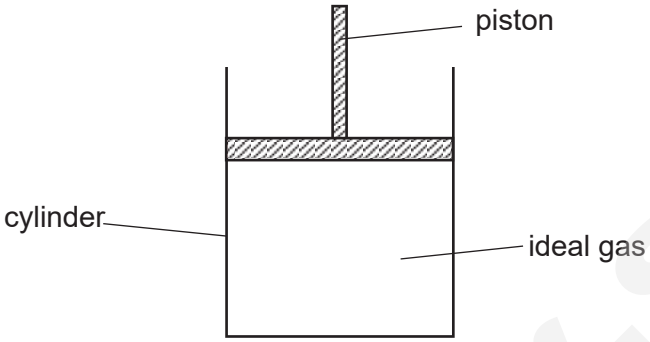


**Fig. 1.1**

The cylinder is fitted with a movable piston which is light and frictionless. When the piston is moved down to compress the gas, both the temperature and pressure of the gas are observed to increase.

Use the kinetic theory of gases to explain,

**(i)** the increase in temperature.

……..

……..

…….. [1]

**(ii)** the increase in pressure.

……..

……..

……..

…….. [2]

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**(b)** The gas in the cylinder is made to undergo a cycle of changes A → B → C→ A, as shown in Fig. 1.2.

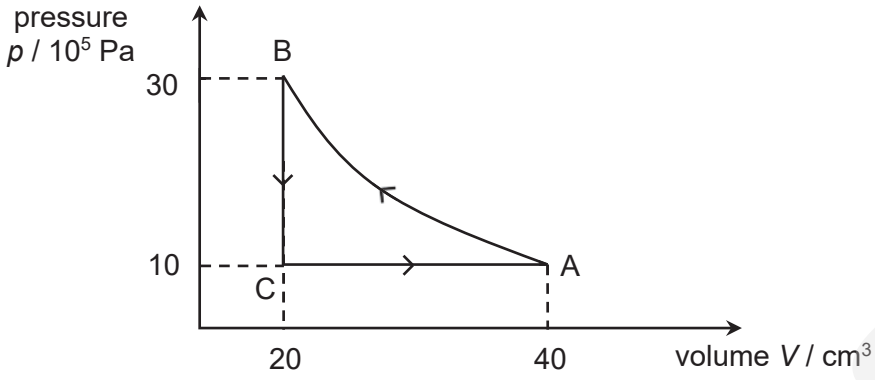


**Fig. 1.2**

**(i)** Show that the increase in internal energy of the gas during the change A → B is 30 J.

[2]

**(ii)** Calculate the heat supplied to the gas during the change B → C → A.

heat supplied = …… J [3]

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**2** A light spring hangs from a fixed point. A 0.850 kg mass is then attached to the free end of the spring, which eventually comes to a rest at an equilibrium position 0.220 m below its original position, as shown in Fig. 2.1.

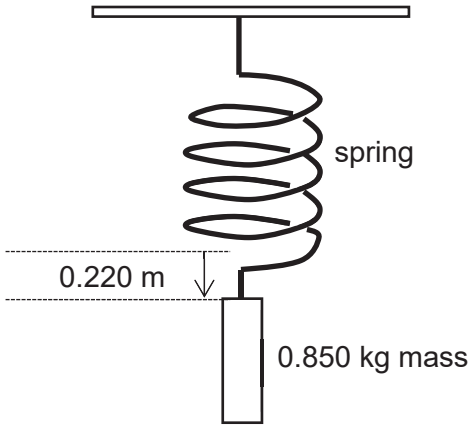


**Fig. 2.1**

**(a)** Show that the force constant, $k$ is 37.9 N m$^{-1}$.

[1]

**(b)** The mass is pulled vertically down a distance of 0.110 m from its equilibrium position. When the mass is released, it performs a simple harmonic motion.

**(i)** Calculate the acceleration of the mass just after it is released at the bottom.

acceleration = ..... m s$^{-2}$ [2]

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**(ii)** Calculate the frequency of oscillation.

frequency = …….. Hz [2]

**(iii)** On the axes of Fig. 2.2, sketch a graph to show the variation of the velocity $v$ of the mass with its vertical displacement $x$.

Label the axes with appropriate values.

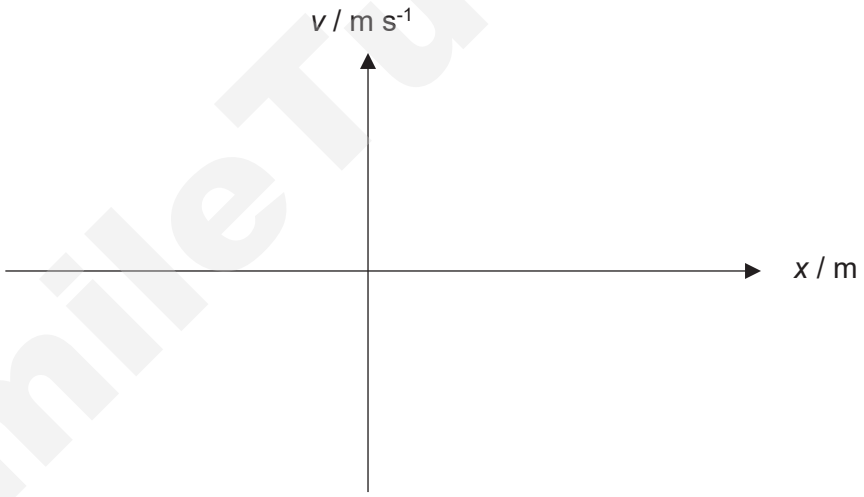


**Fig. 2.2**

[2]

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**(iv)** On the axes of Fig. 2.3, sketch a graph to show the variation with time of the kinetic energy of the mass for one complete oscillation after the mass was released at the bottom.

Include appropriate values on the axes.




[2]

**Fig. 2.3**

**(v)** If the system undergoes light damping, sketch on Fig. 2.2 the velocity-displacement graph expected. Assume the oscillation starts at $x = +x_0$ . [2]

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**3** Fig. 3.1 shows the arrangement of a mass spectrometer, which is an instrument to measure the masses of ions. An ion of mass $m$ and charge $+q$ from the ion source $S$ is accelerated from rest through a potential difference $V$. The ion then passes through a slit into a region of uniform magnetic field of flux density $B$, which is directed perpendicularly out of the paper.

In the field, it moves in a semicircle, striking and producing a spot on a photographic plate at a distance $x$ from the entry slit.

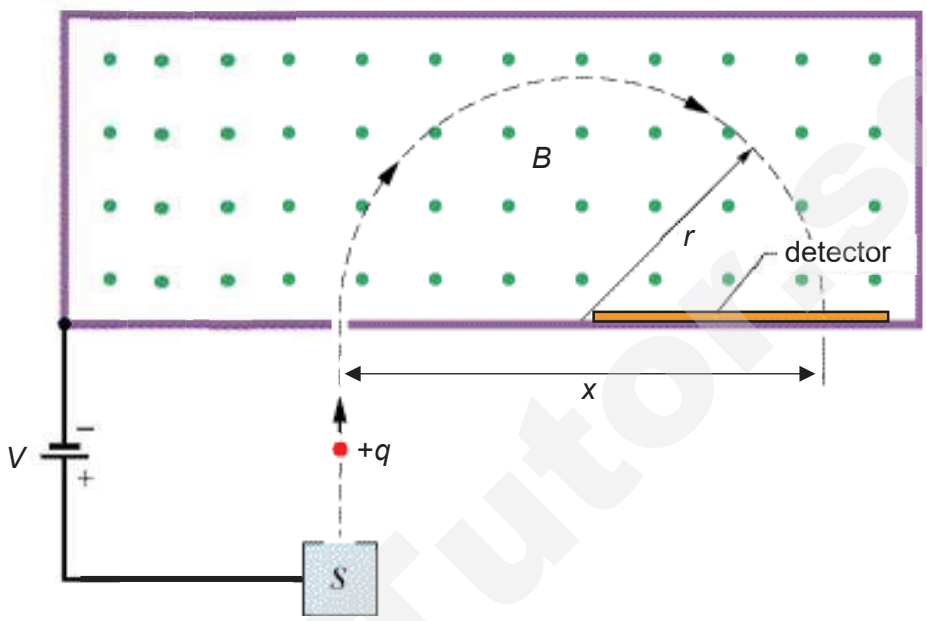


**Fig. 3.1**

**(a)** Show that the ion enters the magnetic field with a velocity, $v = \sqrt{\frac{2qV}{m}}$.

[1]

**(b)** Describe and explain the effects of the magnetic field on the velocity of the ion upon its entry into the magnetic field.

……

……

……

…… [2]

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**(c)** Two singly and positively charged ions are accelerated through a potential difference $V$ of 4.0 kV and enter the magnetic field of flux density $B$ of 0.50 T.

If the masses of the ions are $12u$ and $14u$, calculate the distance $\Delta x$ between the two spots they make on the photographic plate.

$\Delta x$ = ……..... m [3]

**(d)** If an electron were to be introduced into the mass spectrometer, briefly describe and explain, if any, changes to the path if the magnitude of the accelerating potential and the magnetic field remained unchanged.

……..…..

……

……

……

…… [2]

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**4** Fig. 4.1 shows a large rectangular coil used in a power station generator. The coil, with 38 turns, each 2.0 m long and 1.2 m wide, is rotating at 50 revolutions per second in a magnetic field of flux density 0.29 T.

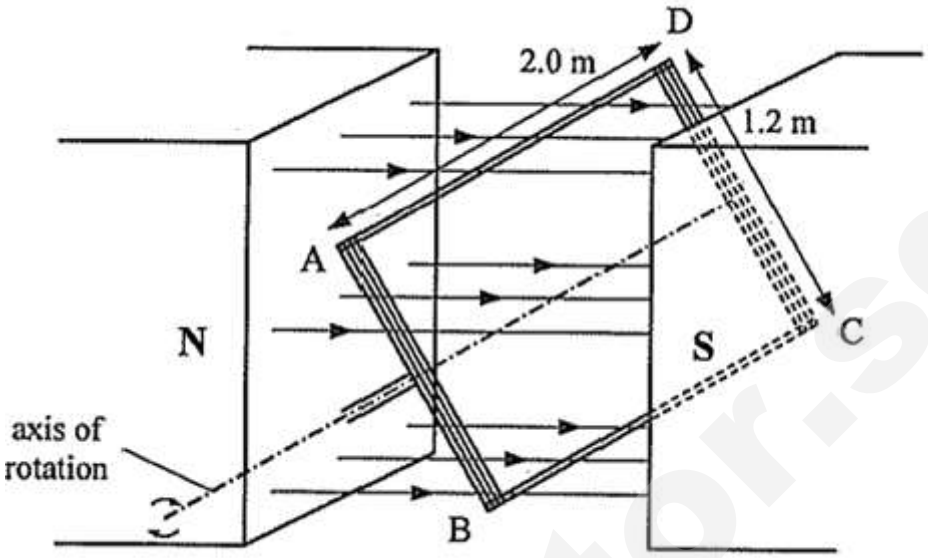


**Fig. 4.1**

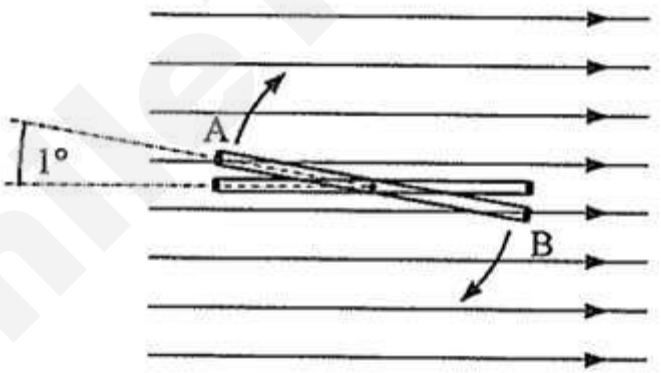


**Fig. 4.2**

Fig. 4.2 shows the coil from the side view, near the time when maximum e.m.f. occurs.

Consider the coil rotating through an angle of 1°.

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**(a)** Show that the time taken for it to rotate 1.0° is $5.6 \times 10^{-5}$ s.

[1]

**(b)** Determine the change in flux linkage of the coil in $5.6 \times 10^{-5}$ s.

change in flux linkage = ..... Wb turns [2]

**(c)** Hence, determine the e.m.f. generated by the coil during the $5.6 \times 10^{-5}$ s.

e.m.f. = ..... kV [1]

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**(d)** State the direction of the current induced in side AD as a result of this e.m.f. Explain your answer using the laws of electromagnetic induction.

……

……

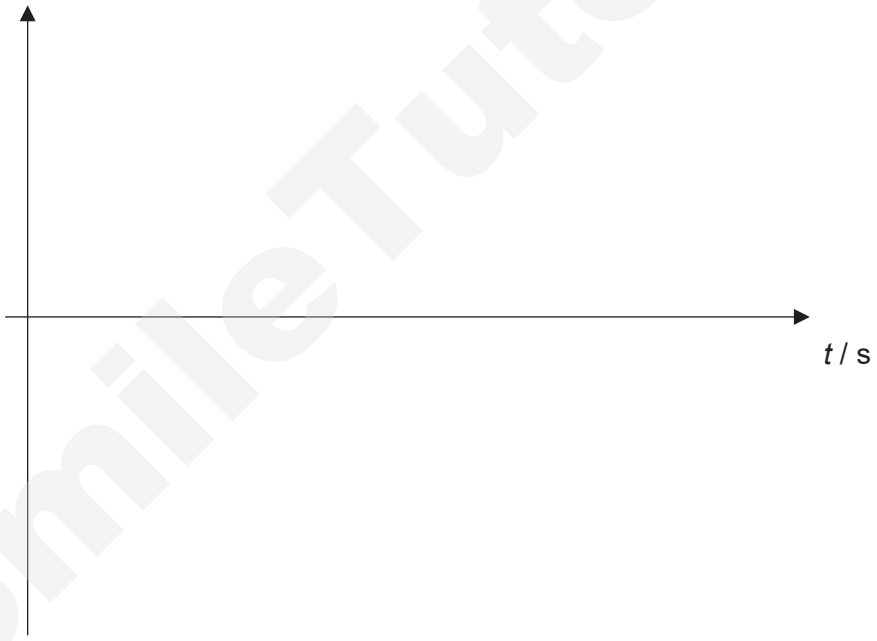
……

…… [2]

**(e)** Given that at time $t = 0$ the coil is parallel to the plane of the magnetic field, sketch on the same axes, the variation with time in one cycle of the

**1.** magnetic flux linkage,
**2.** induced current

Label your graphs (1) and (2) clearly.




[2]

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**5** **(a)** The variation of an alternating voltage $V_P$ in volts with time $t$ in seconds is given by

$$V_P = 170 \sin (314t)$$

Determine

**(i)** the r.m.s. potential difference $V_{r.m.s.}$

$V_{r.m.s.}$ = ..... V [1]

**(ii)** the period, $T$ of the voltage supply.

$T$ = ..... s [1]

**(b)** The alternating voltage $V_P$ is connected to the primary coil of a transformer as shown in Fig. 5.1.

An electric heater with resistance 130 Ω is connected to the secondary coil of the transformer.

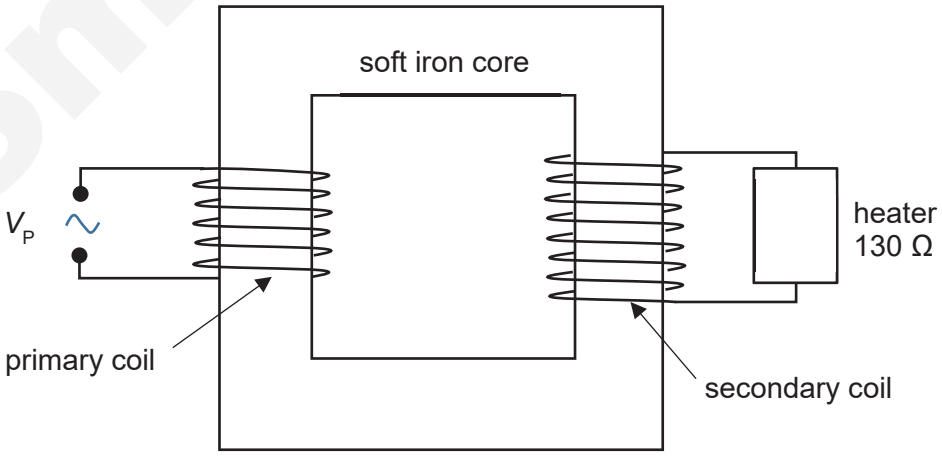


**Fig. 5.1**

The primary coil consists of 2000 turns and the secondary coil consists of 3500 turns.

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**(i)** Determine peak potential difference, $V_S$ of the secondary coil.

$V_S$ = ..... V [2]

**(ii)** Determine the peak current, $I_P$ in the primary coil.

$I_P$ = ..... A [2]

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**(c)** A diode and another identical heater are connected to the secondary coil as shown in Fig. 5.2.

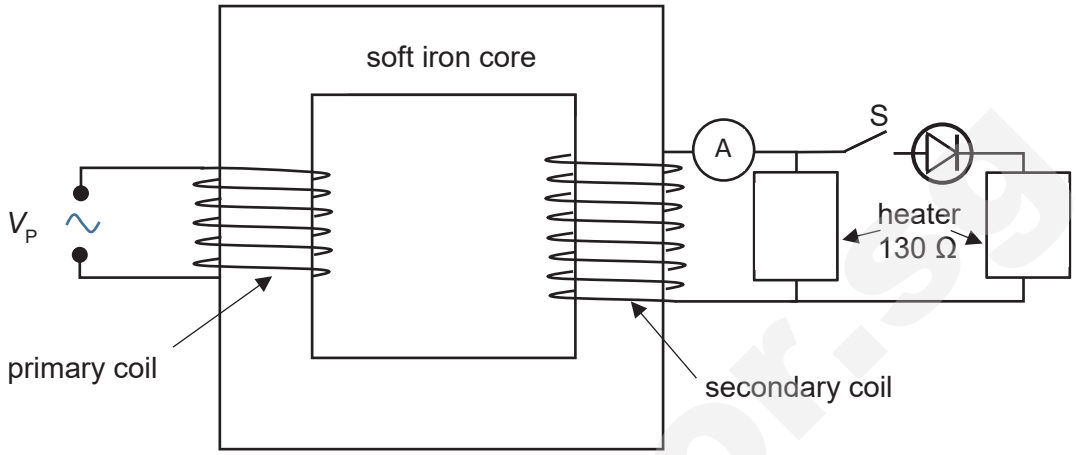


**Fig. 5.2**

Sketch on the axes of Fig. 5.3, the variation with time of the current $I$ in the secondary coil when switch S is closed. Label the axes with appropriate values, Include on your graph a time equal to two periods of the alternating potential difference.




**Fig. 5.3**

[2]

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**6** Fig 6.1 shows some of the electron energy levels in an isolated atom of lithium.

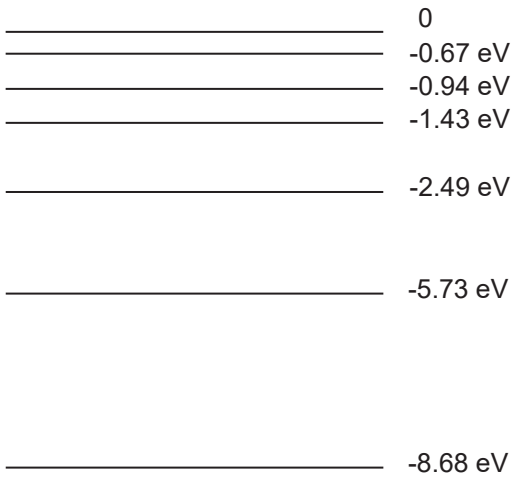


**Fig. 6.1**

The outer electron of a lithium atom is in the lowest energy level shown.

Electrons of energy 7.50 eV are directed at a discharge tube of lithium gas.

**(a)** Calculate the de Broglie wavelength of the electrons directed at the gas.

de Broglie wavelength = ……..…….. m [2]

**(b)** State the range of energy of the recoiling electrons.

…… eV ≤ energy ≤ ……. eV [1]

**(c)** Sketch on Fig. 6.1 the transitions that represent the photons produced from the lithium gas, having electrons of 7.50 eV directed at it. [1]

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**(d)** Calculate the wavelength of the most energetic photon produced and state the region of electromagnetic spectrum to which it belongs.

wavelength = …….. m

region = …….. [3]

**(e)** The ionization energy of lithium atom is 8.68 eV. Suggest and explain whether the work function of lithium metal is larger or smaller than 8.68 eV.

……

……

……

…… [2]

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**7** The radioactive isotope strontium-90 decays into yttrium-90, emitting a beta-particle. Strontium-90 has a half-life of 28.0 years and the energy produced in each decay is 0.546 MeV.

**(a)** The beta-particles produced from the decay of strontium-90 are found to possess a range of kinetic energies as shown in Fig. 7.1.

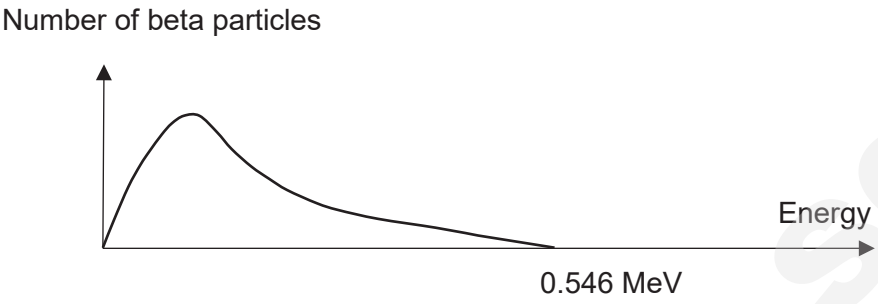


**Fig. 7.1**

Explain why this suggests an extra particle is emitted.

……

……

……

……

…… [2]

**(b)** **(i)** Explain what is meant by half-life.

……

…… [1]

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**(ii)** Determine the decay constant, $\lambda$ of Strontium-90,

$\lambda$ = ..... $s^{-1}$ [2]

**(iii)** Determine the mass of strontium-90 present, for an activity of $6.40 \times 10^9$ Bq.

mass = ..... g [3]

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## Section B

Answer **one** question from this Section in the space provided.

**8** **(a)** State Newton's law of gravitation.

.....

.....

.....

..... [2]

**(b)** A satellite of mass $m$ moving at speed $v$ in a circular orbit of radius $r$ about the Earth (as shown in Fig. 8.1) behaves as though the Earth's mass $M$ were concentrated at its centre.

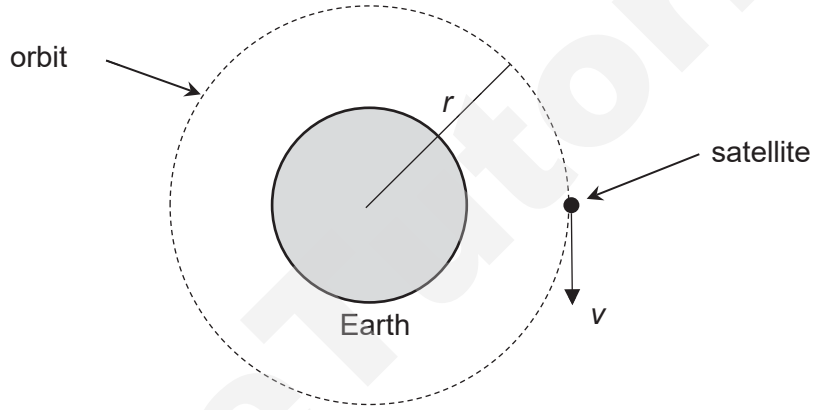


**Fig. 8.1 (not drawn to scale)**

**(i)** Show that the satellite's potential energy $E_p$ and kinetic energy $E_k$ are related by the expression $E_p = -2E_k$.

[3]

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**(ii)** Sketch on Fig. 8.2 the variation with orbital radius of the satellite's

1. gravitational potential energy $E_p$,
2. kinetic energy $E_k$
3. total energy $E_T$




[2]

**Fig. 8.2**

**(c)** It is given that $r = 6.70 \times 10^6$ m, $m = 1.80 \times 10^3$ kg and $M = 5.98 \times 10^{24}$ kg.

**(i)** Calculate the satellite's orbital speed.

orbital speed = ..... km $h^{-1}$ [2]

**(ii)** For the satellite to be geostationary at this orbital radius, it must orbit at a speed of about 487 m $s^{-1}$. Explain, in terms of centripetal force, why the geostationary orbit is not possible at this orbital radius.

.....

.....

..... [1]

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**(d)** As a result of atmospheric friction, the radius of the satellite's orbit about the Earth decreases by 0.2% in a week.

**(i)** State the energy conversion taking place during the orbital decay.

……

……

…… [2]

**(ii)** Assuming that the orbit remains circular, determine the percentage change in the satellite's total energy in a week. The total energy of the satellite is given by $E_T = -\frac{GMm}{2r}$.

percentage change = ……% [1]

**(iii)** By considering the satellite's rate of loss of energy and your answer to **(c)(i)**, show that the frictional force acting on the satellite is 0.023 N.

[3]

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**(e)** To counter orbital decay, the satellite carries a small booster motor. The force exerted by the motor is equal to $u$□where □is the rate at which fuel is burnt (mass per unit time), and $u$ has a value of $2.00 \times 10^3$ N s kg$^{-1}$.

**(i)** Draw in Fig. 8.3 labelled arrows showing (at this particular instant)

**1.** the direction of the satellite's change in velocity (label X) and
**2.** the direction of the force exerted by the booster motor (label Y).

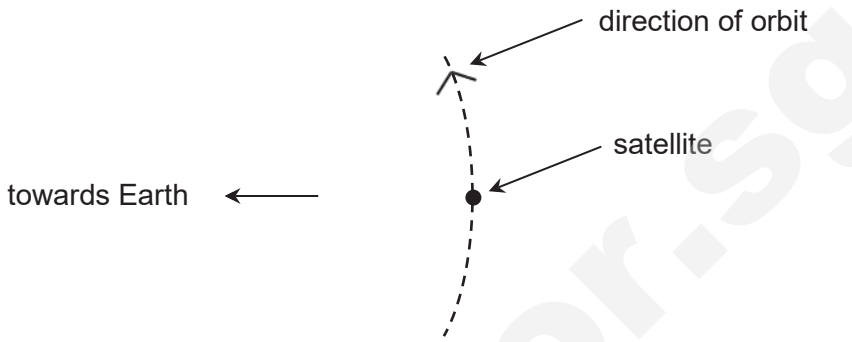


**Fig. 8.3**

[2]

**(ii)** Determine the amount of fuel necessary for the satellite to maintain its orbit for 24 hours.

amount of fuel = ……kg [2]

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**9** **(a)** State the principle of superposition.

……

……

…… [2]

**(b)** A stationary wave (in solid line) is produced by the superposition of two progressive waves, P and Q. Fig. 9.1 shows the positions of the stationary wave and one of the two progressive waves, P, at a particular instant in time.

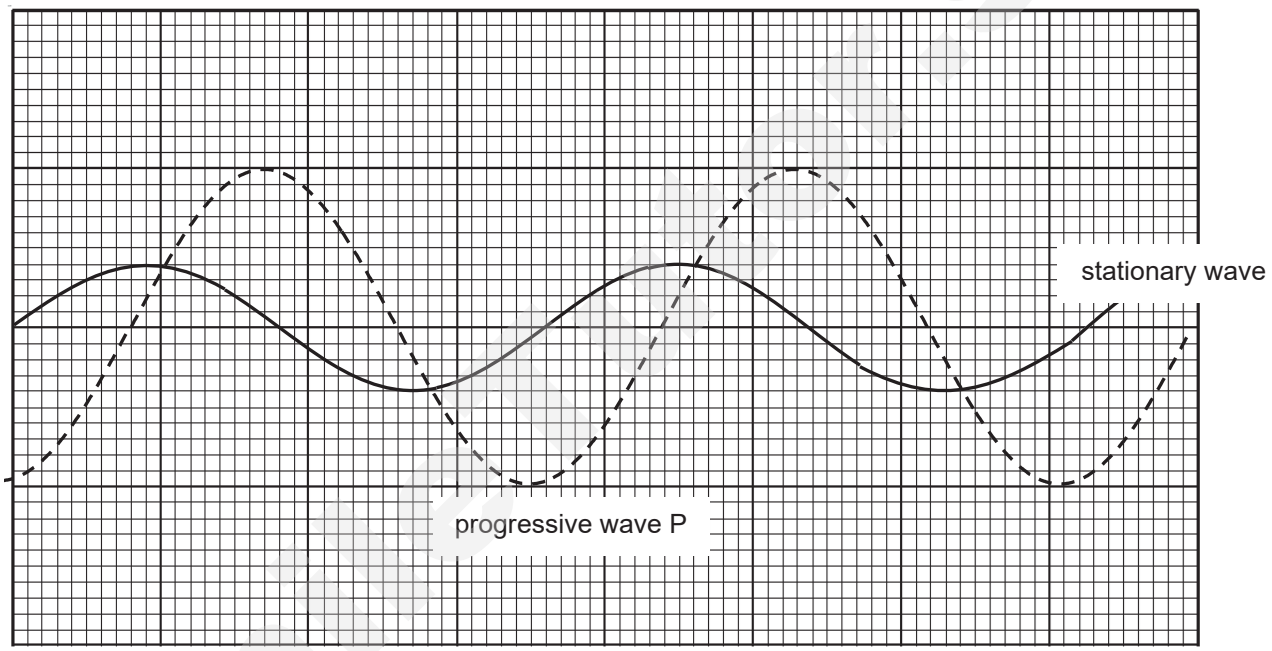


**Fig. 9.1**

Sketch on Fig. 9.1 progressive wave Q that superposes with progressive wave P to produce the stationary wave shown. You should include at least one complete wavelength in your sketch. [2]

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**(c)** Fig. 9.2 shows an experiment with sound waves.

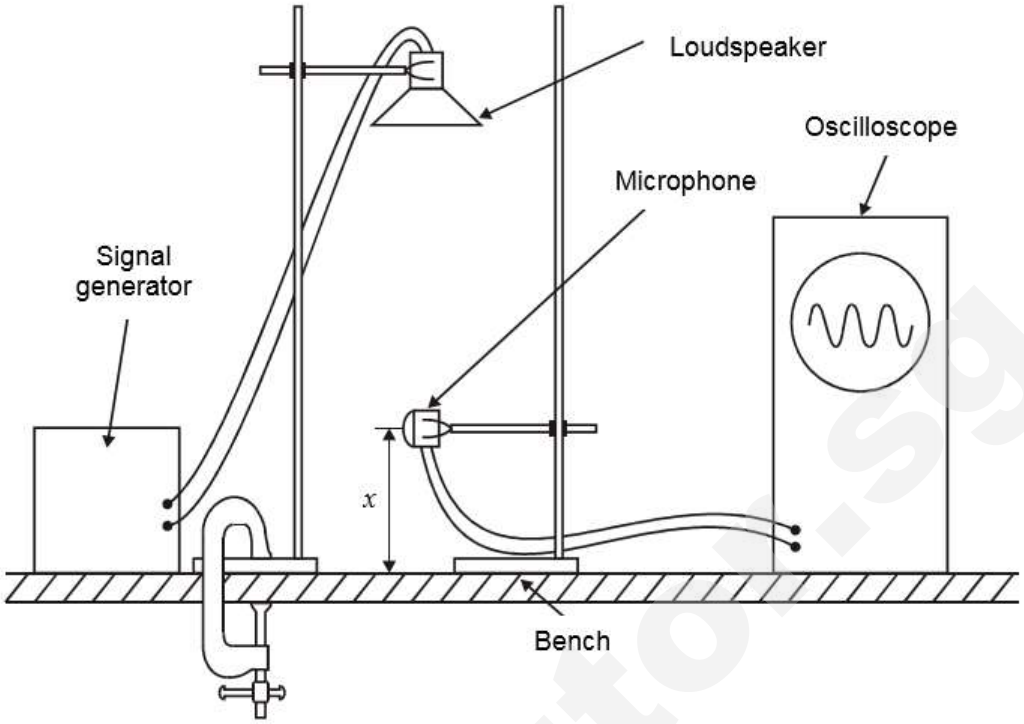


**Fig. 9.2**

The loudspeaker connected to a signal generator is mounted, pointing towards the bench. The sound is detected by a microphone connected to an oscilloscope. The height of the trace on the oscilloscope is proportional to the amplitude of the sound waves at the microphone.

When the vertical distance *x* between the microphone and the bench is varied, the amplitude of the sound waves is found to vary as shown in Fig. 9.3.

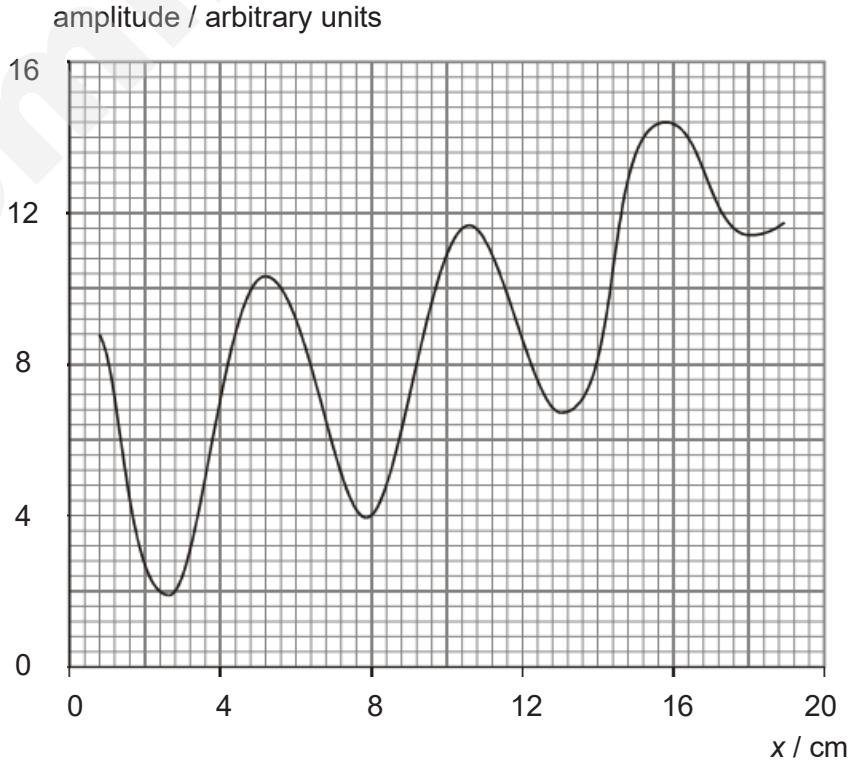


**Fig 9.3**

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**(i)** Explain the formation of alternating maxima and minima.

……..

……..

……..

……..

…….. [3]

**(ii)** Explain why the intensity of the minima increases with *x*.

……..

……..

……..

…….. [2]

**(iii)** The speed of sound is 340 m $s^{-1}$. Use Fig. 9.3 to calculate the frequency of the waves emitted by the loudspeaker.

frequency = …… Hz [3]

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**(d)** Light of wavelength 650 nm is incident normally on a double slit such that the waves emerge from X and Y in phase, and reach a screen 1.5 m away, as shown in Fig. 9.4.

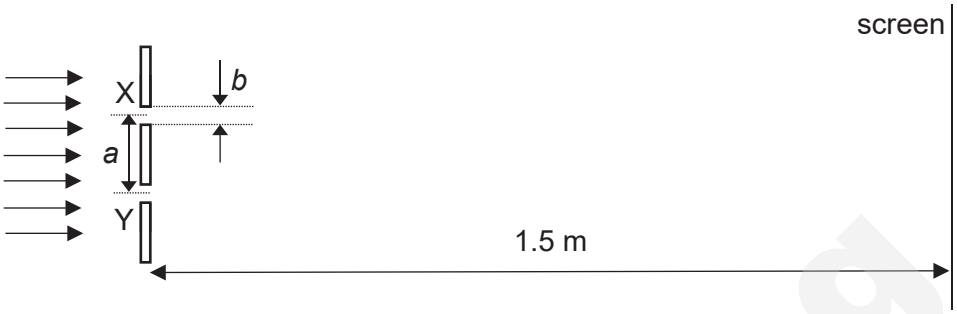


**Fig. 9.4**

The variation of intensity with distance along the screen is shown in Fig. 9.5.

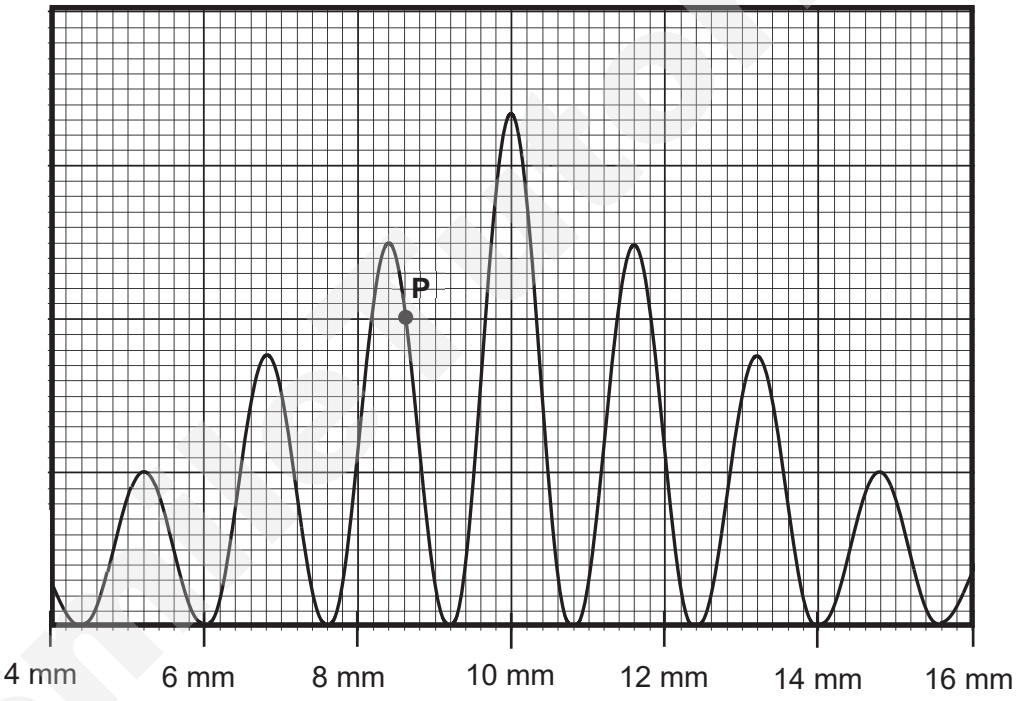


**Fig. 9.5**

**(i)** Explain how it can be deduced from Fig. 9.5 that the waves from the two slits are coherent.

…….. [1]

**(ii)** Determine the phase angle between the waves from the slits when the waves meet to produce the intensity at point **P** on the pattern of Fig. 9.5.

phase angle = ……. rad [2]

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**(iii)** Calculate the separation $a$, between the slits.

$a$ = ..... mm [2]

**(iv)** Given that the 6$^{th}$ order bright fringe is the first missing order due to the diffraction envelope, calculate the width $b$, of each slit.

$b$ = ..... mm [3]

**END OF PAPER**

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**HWA CHONG INSTITUTION**
**C2 Preliminary Examination**
**Higher 2**

**A**

| CANDIDATE NAME | | CT GROUP | **18S** |
|---|---|---|---|
| CENTRE NUMBER | | INDEX NUMBER | |

## PHYSICS

**9749/04**

Paper 4 Practical

**30 August 2019**

**2 hours 30 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

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

Answer **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

At the end of the examination, submit sets A, B and C separately.
The number of marks is given in brackets [ ] at the end of each question or part question.

| **Shift** |
|---|
| |
| **Laboratory** |
| |

| **For Examiner's Use** | |
|---|---|
| **1** | **/ 13** |
| **2** | **/ 8** |
| **3** | **/ 22** |
| **4** | **/ 12** |
| **Total** | **/ 55** |

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**1** In this experiment, you will investigate the behaviour of a system in static equilibrium.

**(a) (i)** Use the weighing balance to determine the mass of one paper clip.

mass of one paper clip = ..... [2]

**(ii)** Connect two mass hangers with a short string and place them on both sides of a pulley as shown in Fig. 1.1. The mass hangers should balance each other's weight and hang in equilibrium.

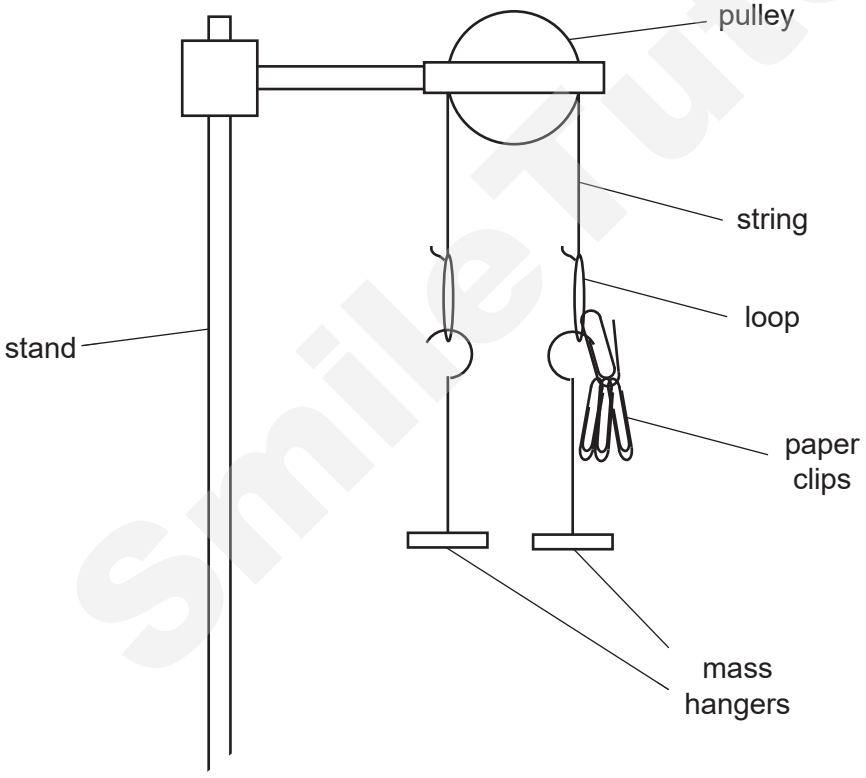


**Fig 1.1**

Now add paper clips, one by one, to one side until the pulley starts to rotate. Record the maximum number of paper clips that is added before the equilibrium is broken.

number of paper clips = ..... [1]

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**(b)** Set up the apparatus as shown in Fig. 1.2. Mass $m$ and $M$ are provided by a 50 g mass hanger and a pendulum bob, respectively.

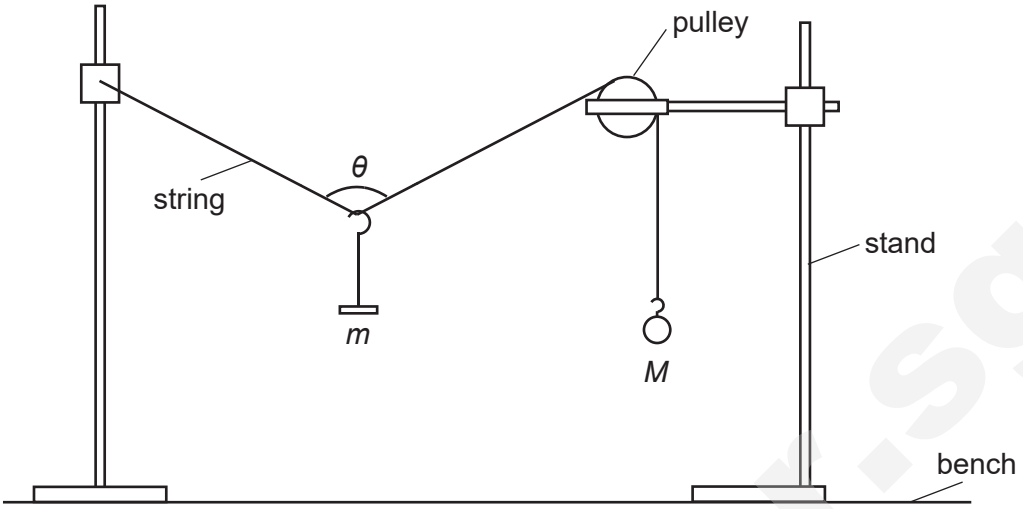


**Fig 1.2**

**(i)** Adjust the position of $m$ along the string until the angle $\theta$ is symmetrical about the vertical axis.

Measure and record $\theta$.

$\theta$ = ……° [1]

**(ii)** Estimate the uncertainty in your value of $\theta$.

uncertainty in $\theta$ = …… [1]

**(c)** Theory suggests that

$$2M\cos\frac{\theta}{2} = m$$

**(i)** Calculate the value of $M$.

$M$ = …… [1]

**(ii)** Using your values in **(a)(ii)** and **(b)(ii)**, estimate the maximum value of $M$.

maximum $M$ = …… [1]

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**(d) (i)** Repeat **(b)(i)** for $m$ = 100 g.

$\theta$ = ..... [1]

**(ii)** If you were to repeat this experiment with more masses, describe the graph that you would plot to determine $M$.

.....

.....

.....

.....[2]

**(e) (i)** Suggest two significant sources of error in the measurement of $\theta$.

1.....

.....

.....

.....

2.....

.....

.....

.....[2]

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

.....

.....

.....

.....[1]

[Total: 13]

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**2** In this experiment, you are provided with an LED (light emitting diode) that produces light of wavelength 640 nm.

**(a)** Connect the circuit as shown in Fig. 2.1. You should be able to turn the LED on and off by adjusting the potentiometer. You are reminded that an LED allows current to pass in one direction, but not the other.

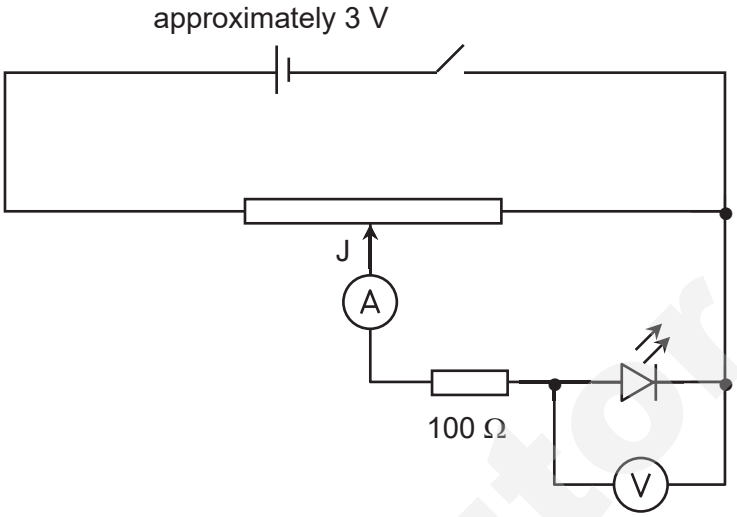


**Fig 2.1**

Close the switch.

**(i)** Adjust the potentiometer J until the ammeter reading is 5.0 mA. Record the voltmeter reading $V$ to the nearest 0.001 V.

$V$ = ..... [1]

**(ii)** Calculate the resistance of the LED when it is operated at a current of 5.0 mA.

resistance = ..... [1]

**(b)** The turn-on voltage $V_F$ is defined as the potential difference across the LED that produces a current of 0.10 mA through the LED.

**(i)** Adjust the potentiometer J to determine the turn-on voltage of the LED you're provided.

$V_F$ = ..... [1]

**(ii)** Estimate the percentage uncertainty in your value of $V_F$.

percentage uncertainty in $V_F$ = ..... [1]

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**(iii)** It is suggested that the turn-on voltage $V_F$ of an LED is inversely proportional to the wavelength $\lambda$ of the light produced by the LED.

You are told that the turn-on voltage of another LED producing green light of wavelength 565 nm is 1.800 V.

State whether this information and your values from **(b)(i)** support the suggested relationship. Justify your conclusion by referring to your values in **(b)(ii)**.

.....

.....

.....

.....[2]

**(c)** Fig. 2.2 shows another circuit that may be used to control the current through the LED.

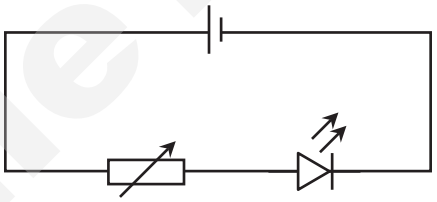

**Fig 2.2**

Draw lines in Fig. 2.3 to show how the components can be connected to achieve the circuit shown in Fig. 2.2.

[2]




**Fig 2.3**

[Total: 8]

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NAME _____ CLASS 18S ( ) SCORE _____ **B**

**3** In this experiment, you will investigate the behaviour of an oscillating system.

**(a)** Measure and record the width *w* and thickness *d* of the half metre ruler, as shown in Fig. 3.1.

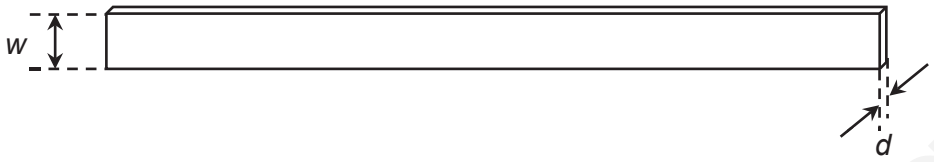


**Fig 3.1**

*w* = ..... [1]

*d* = ..... [1]

**(b)** Use rubber bands to attach two 50-g masses separately to about 5 cm away on either side from the centre of a half metre ruler.

Use a bulldog clip to attach the centre of the half metre ruler to the spring and set up the apparatus as shown in Fig. 3.2.

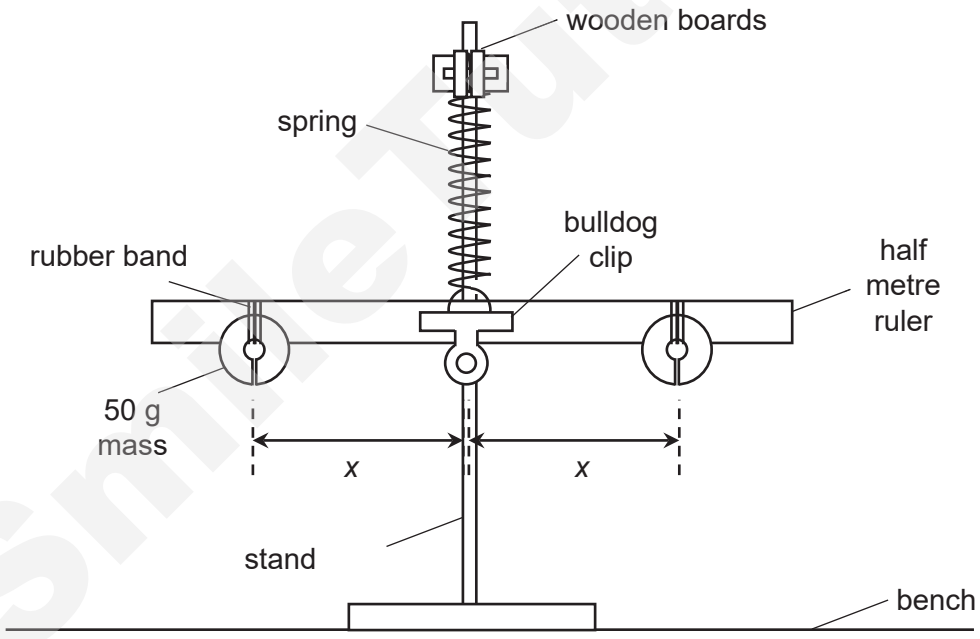


**Fig 3.2**

**(i)** Measure and record the distance *x* between the centre of the ruler and the centre of each of the two masses.

*x* = .....

**(ii)** Turn the ruler through approximately 45° about a vertical axis. Release the ruler.
The ruler will oscillate about a vertical axis. Determine the period *T* of these oscillations.

*T* = ..... [2]

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**(c)** Vary $x$ and repeat **(b)(i)** and **(b)(ii)** for each new distance $x$. Tabulate all results including previous ones.

[6]

**(d)** $T$ and $x$ are related by the expression

$$T^2 = P + Qx^2$$

where $P$ and $Q$ are constants.

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

$P$ = .....

$Q$ = .....

[6]

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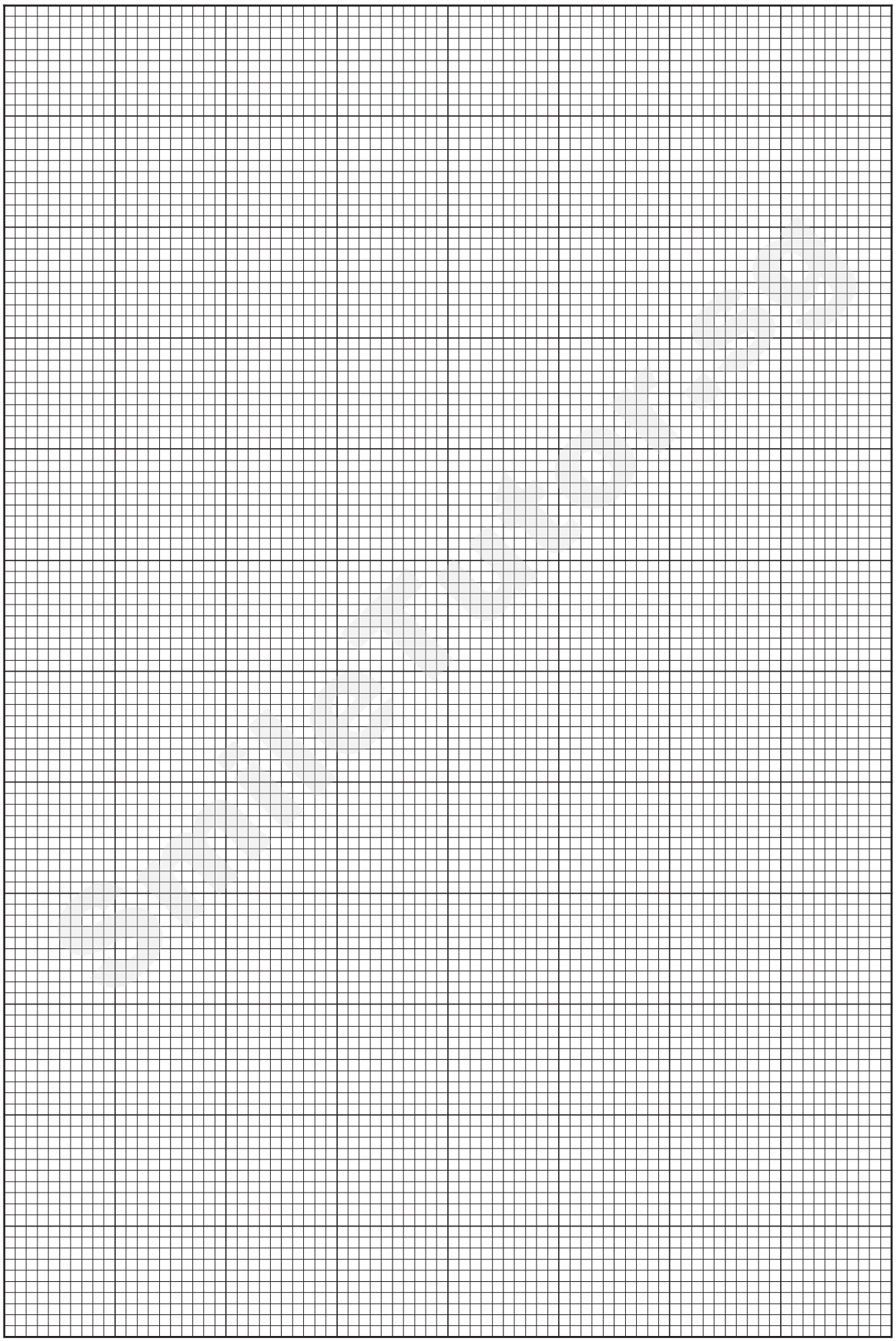

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**(e)** The relationship between $T$ and $x$ are given in more detail by the expression

$$T^2 = \frac{4\pi^2}{k}\left(\frac{1}{12}ML^2 + 2mx^2\right)$$

where $k$ is a constant related to the elasticity of the spring, $M$ and $L$ are the mass and length of the ruler respectively, and $m$ is the mass of each of the 50-gram mass attached to the ruler.

Calculate $M$.

$M$ = ..... [2]

**(f)** Calculate the density of the ruler.

density = ..... [2]

**(g)** Draw another line to show the graph that would be obtained if the ruler is made of material half the density as the one used.

[2]

[Total: 22]

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NAME _____ CLASS 18S ( ) SCORE _____ C

**4** The attenuation of a beam of beta radiation is the reduction in its intensity due to its passage through a material. One way to investigate the attenuation is to measure the half-value thickness $\tau$, the thickness of material that reduces the intensity of the beta radiation to half its original value.

In addition to apparatus which may be commonly found in a school laboratory, you are also provided with the following:

Beta-source
Geiger-Muller tube
Ratemeter
A number of aluminium plates of different thicknesses
A uniform magnetic field of exactly 0.500 mT
Variable high-voltage DC power supply
A pair of parallel metal plates

Design a laboratory experiment to obtain the relationship between the half-value thickness $\tau$ for aluminium and the speed of the beta-particles. 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 speed of the beta particles can be determined or chosen, (You do NOT have to provide any detail on how to generate or monitor the 0.500 mT magnetic field. You are to ignore any relativistic effect)
**(c)** how the beta radiation would be detected and the measurements that would be made,
**(d)** how a suggested relationship may be validated,
**(e)** the safety precautions that you would take,
**(f)** any precautions that you would take to improve the accuracy of the experiment.

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**Diagram**

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……

……

……

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Q1

Weighing balance (shared)

2 retort stands

2 1.5-metre strings

2 50-g mass hanger

2 50-g slotted mass

1 pendulum bob (big, about 68 g)

1 pulley

1 scissors

1 protractor (1 degree precision)

30 paper clips (each about 3 g)

2 bricks

Q2

DMM set to 200 mA

DMM set to 2 V

Dry cells (2 in holders)

Switch

LED

100 Ω resistor

Rheostat

5 connecting wires

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Q3

Half-metre ruler

Spring

2 wooden clamp boards

Bulldog clip

2 50-g mass

2 rubber bands

Stopwatch

Retort stand

30 cm rule

Vernier Callipers

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**2019 HCI H2 PHYSICS Prelim P1 Suggested Solutions**

**1 D** Transposing the equation: $k = \frac{H}{A\left|\frac{\Delta T}{l}\right|}$

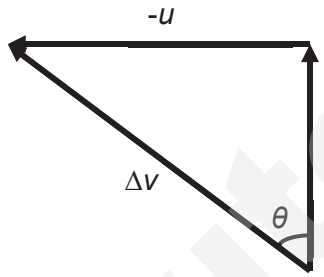
Hence, the units of *k* are $\frac{J\,s^{-1}}{m^2\,K\,m^{-1}} = \frac{N\,m\,s^{-1}}{m\,K} = \frac{kg\,m\,s^{-2}\,s^{-1}}{K} = \frac{kg\,m\,s^{-3}}{K} = kg\,m\,s^{-3}\,K^{-1}$

[

"Rate of" is considered as "per unit time," so the units of 'rate of energy transfer' are J $s^{-1}$.]

[Note: answers A and B have the unit 'W,' which is not a base unit; these answers do not have to be considered.

**2 D** Initial velocity, $u$ = 4.0 m $s^{-1}$ due east.
Final velocity, $v$ = 3.0 m $s^{-1}$ due north.
Change in velocity $\Delta v = v - u = v + (-u)$, where $(-u)$ = 4.0 m $s^{-1}$ due west.
Doing a vector addition:




$|\Delta v| = \sqrt{(-u)^2 + v^2} = \sqrt{4^2 + 3^2} = 5$
$\theta = \tan^{-1}(4/3) = 53°$
Hence, the change in velocity is 53° west of north.

**3 D** As the object is released, the speed will increase until it reaches a constant value.
As speed is given by the gradient of the graph, the gradient will increase until a constant value.

**4 A** The mass slowed down at an increasing rate from $t$ = 0.25 s to $t$ = 0.50 s.

**5 C** $(\Sigma P_i = \Sigma P_f)_y \uparrow +$

$0 = (h/\lambda_f)\sin 75° - p\sin\alpha$

$(6.63 \times 10^{-34}/966.8 \times 10^{-12})\sin 75° - (8.362 \times 10^{-25})\sin\alpha$

$\sin\alpha = 0.7922$

$\alpha = 52.4°$

**6 A** Clockwise moment by weight of M = anticlockwise moment by tension in string

$Mg(1.200) = 300\sin 30^{O}(0.805)$

$M = 10.3$ kg

**7 C** Net force
= Upthrust by air – Weight of helium – Weight of balloon skin & instrument.
= Weight of air displaced – $\rho_{He}Vg - Mg$
= $\rho_{air}Vg - \rho_{He}Vg - Mg$
= $(\rho_{air} - \rho_{He})Vg - Mg$

**8 C** Option A: Student thought that force and extension were reversed.
Option B: Student confused the net work done with work done by the force *F*.
**Option C: Correct.**
Option D: Student thought that there is no deformation in the wire.

**9 B** By drawing the free body diagram of the car for each bridge, realise that for convex bridges,

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Weight of car – Normal contact force on car by road = $mv^2/r$

Normal contact force on car by road = Weight of car – $mv^2/r$ (smaller than weight)

The convex bridge which has the shorter radius will exert the least normal contact force on the car.

By Newton's 3rd Law, force exerted by car has same magnitude as the normal contact force

**10 B** $g = \frac{GM}{R^2}$

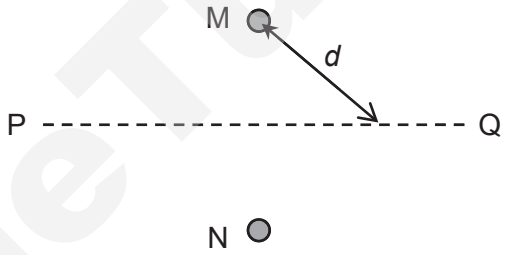
Work done = increase in GPE $= -\frac{GMm}{3R} - \frac{GMm}{R}$

$$= \frac{2}{3}\frac{GMm}{R}$$

$$= \frac{2}{3}\frac{GMm}{R^2}R$$

$$= \frac{2}{3}mgR$$

**11 B**




Gravitational potential $\phi$ is a **scalar** quantity. It is always negative and for point masses follow the formula $\phi = -\frac{GM}{r}$. So in this case, the resultant potential is $-2\frac{GM}{d}$ . As such it is most negative (but not infinitely negative) at the midpoint, where it is nearest to both the stars, and less negative along either side as they move further away from the stars.
(modified from 2014 P1 Q13)

**12 B** $pV = nRT$

$(1.2\times10^5)V_1 = (50+273)$

$(6.0\times10^5)V_2 = (200+273)$

$$5\frac{V_2}{V_1} = \frac{473}{323}$$

$$\frac{V_2}{V_1} = 0.29$$

**13 B**
A At higher temperature, the average KE of molecules are higher. Evaporation occur at a faster rate for this reason.
B S has negative potential energy while G has negligible.
C Water contracts both when melting and condensing, so the atmospheric pressure does positive work.
D The specific latent heat of fusion is a lot less than the specific latent heat of vaporization

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**14 D** Damping force on the forced oscillation increases. Amplitude with added friction is always lower for all frequencies. The resonant frequency at which maximum amplitude occurs would be also be lower.

**15 A** Wavelength is 8.00 cm.

The wave profile travelled by 3.20 cm in 0.20 seconds, the speed is 0.032/0.2 = 0.16 m $s^{-1}$.

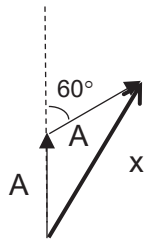
Distance between A and B is 2 cm. Hence, the phase difference must be

$$\frac{\Delta x}{\lambda} = \frac{\Delta \phi}{2\pi} \rightarrow \frac{2.00 \text{ cm}}{8.00 \text{ cm}} = \frac{\Delta \phi}{2\pi} \rightarrow \Delta \phi = \pi / 2$$

**16 A**

The wavelength of the electromagnetic wave is $c = \lambda f \rightarrow \lambda = \frac{3 \times 10^8}{10^{13}} = 30\ \mu\text{m}$, which is longer than the visible light. Hence, the answer is infra-red waves.

**17 C**




Resultant amplitude x = $\sqrt{(2A^2 - 2A^2 \cos 120°)} = \sqrt{3}\,A$

**18 D**

$$d \sin\left(\frac{\theta}{2}\right) = 2\lambda$$

$$d = \frac{2\lambda}{\sin\left(\frac{\theta}{2}\right)}$$

**19 A**

$$\tau = qE \times d = (2 \times 1.6 \times 10^{-19})\left(\frac{2.0 \times 10^2}{0.001}\right)(4.0 \times 10^{-12} \sin 30^0)$$

$$= 1.3 \times 10^{-25} \text{N m}$$

**20 D** An $\alpha$-particle has mass 4*u* and carries charge +2e.

Within the plates, constant *E* = *V*/*x*

By PCOE,

Loss in KE = Gain EPE

½ (4*u*)($v_i^2 - v_f^2$) = *qV*

½ (4*u*)($v_i^2 - v_f^2$) = 2*eEx*

$v_f^2 = v^2 - eEx/u$

$v_f = \sqrt{(v^2 - eEx/u)}$

**21 D**

$R_{eff} = R_{\square} + R_K = \frac{\rho 2x}{\frac{x}{2}t} + \frac{\rho x}{xt}$, where $\rho$ is resistivity and *t* is thickness

$R_{eff} = R + 4R = 8.0 + 4(8.0) = 40\ \Omega$

Option A: Student thought that J and K are connected in parallel.
Option B: Student thought that the resistance of K is also 8.0 Ω
Option C: Student forgot to add the resistance of J.

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**22 A**

R at ***1 V*** | R at **6 *V***

When $I$ is at 2.0 A, V < 2.0 V

$V/I < 2.0 / 2.0$ | $V/I = 6.0 /3.5$

$V/I < 1.0\ \Omega$ | $= 1.7\ \Omega$

**23 B** Option A: Student thought that no current flows through hence potential drop must be zero across all the bulbs in the circuit.
**Option B: Correct.**
Option C: Student did not consider the potential difference across A and thought that the potentials across bulb D is the same.
Option D: Student did not consider the potential difference across A.

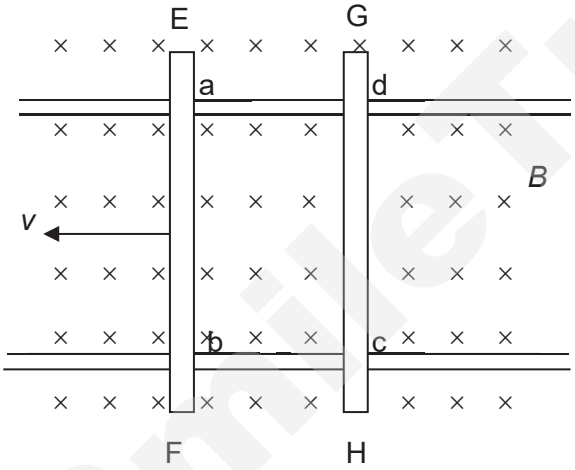
**24 D** Excess weight in one arm over the other = $mg$

$= \rho Ahg$

$= 960 \times 4.0 \times 10^{-4} \times 0.020 \times 9.81 = 0.07534$ N

Magnetic force = $BIL$ = 0.07534
0.07534 = $B$(60)(0.020)
$B$ = 0.063 T

**25 B**




When EF is moved to the left, by FRHR, induced current flow in the direction ab and thus abcd in the closed circuit. By FLHR, induced current in rod GH experiences a magnetic force to the left, causing it to accelerate to the left, while rod EF will experience a magnetic force to the right that slows it down. When both rods achieve the same velocity, there will be no flux change, and no induced current, both rods will continue to move at this constant speed.

**26 B**

$$\langle E \rangle = \left| -\frac{\Delta\Phi}{\Delta t} \right| = \frac{NBA - (-NBA)}{0.20} = \frac{2(800)(4.0 \times 10^{-5})(0.050)}{0.20} = 0.016\,V$$

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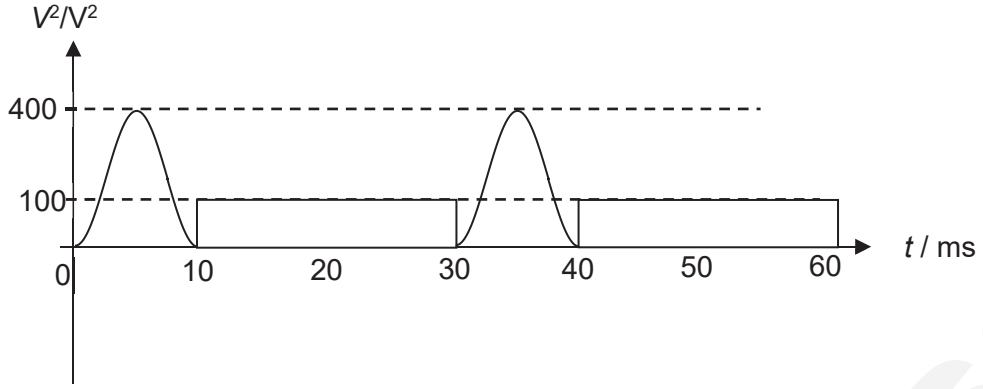
**27 B** Calculate r.m.s. voltage across the resistor. Then use P = $\frac{V_{rms}^2}{R}$ to find the mean power.




Mean of $V^2$ = $\frac{(200\times10)+(100\times20)}{30}$ = 4000/30 volts$^2$

Mean power = $\frac{V_{rms}^2}{R} = \frac{4000/30}{5.0} = 26.7$ W

**28 B** Originally, $eV_s = hf - \Phi$ , $V_s = (hf - \Phi)/e$
Intensity $L$ = power/area = $nhf/At$
Frequency $2f$ implies energy of photon is doubled. Same metal surface used implies work function, $\Phi$ remains the same. Thus maximum KE of electron or its PE gained, $eV'_s = (2hf - \Phi)$.
Thus new stopping potential $V'_s = (2hf - \Phi)/e > 2(hf - \Phi)/e$ or $2V_s$

Intensity remains the same, but since frequency of light is now $2f$, number of photons incident on the metal surface is halved.
Thus the number of photoelectrons emitted per unit time will be less; maximum photocurrent will be less than $I$.

**29 D** the parent nucleus is less stable and has a smaller binding energy per nucleon than the daughter nucleus.

**30 A** From the first 2 sets of reading, Corrected count rate, $C_0$ = 40 s$^{-1}$, C = 10 s$^{-1}$.

$$\frac{C}{C_0} = \left(\frac{1}{2}\right)^{\frac{20}{T}}$$

$$\frac{10}{40} = \left(\frac{1}{2}\right)^{\frac{20}{T}} \Rightarrow \left(\frac{1}{2}\right)^2 = \left(\frac{1}{2}\right)^{\frac{20}{T}}$$

By comparison, T = 10 days.

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**HCI H2 PHYSICS Prelim P2 Suggested Solutions**

| | | | | |
|---|---|---|---|---|
| **1** | **(a)** | **(i)** | The tension force must be greater than the weight so that the resultant force provides a **centripetal force** for the ball to moving along the **arc of a circle**. | [1] |
| | **(a)** | **(ii)** | From Fig 1.2, velocity of the ball just before it hits the wall, v = 2.6 m $s^{-1}$<br>By Newton's 2nd Law, $F_{net} = ma_c$<br>Tension force – weight = $mv^2/r$<br>Tension force = $mv^2/r + mg$ = 350 ($2.6^2$ / 5.8 + 9.81)<br>Tension force = 3840 = 3800 N (2 or 3 s.f.) | [1]<br>[1] |
| | **(b)** | From the graph, the average force exerted by the wall on the ball<br>$\langle F \rangle = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{\Delta t} = \frac{350 \times (0.000 - 2.600)}{(1.35 - 1.20)}$<br>$= -6070$ N<br><br>By Newton's Third Law,<br>(average force by ball on the wall) = - (average force by wall on the ball)<br>= 6070 = 6100 N (2 or 3 s.f.) | [1]<br><br>[1] |
| | **(c)** | The principle of conservation of linear momentum states that the total momentum remains constant provided there is no **net** external force acting on the system.<br><br>In this case, external force is acting on the wall as the wall is held by the ground, thus the principle does not apply.<br><br>OR<br><br>Considering the system as the ball, the wall and the Earth, the total momentum is constant: momentum loss of ball = momentum gain of wall and Earth. | [1]<br><br>[1] |
| | **(d)** | Thermal energy of ball = 12% of initial KE of ball<br>$mc\Delta T$ = 0.12(½ $mv^2$)<br>$\Delta T$ = 0.12 (½ $v^2$)/c<br>= 0.12 (½ x $2.6^2$) / 450<br>= 9.0 x $10^{-4}$ K or °C | [1]<br><br>[1] |



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| **2** | **(a)** | | (Net) upward force by a fluid on an object (partially or fully) immersed in the fluid. | 1 |
| | **(b)** | **(i)** | $M = \rho V = \rho \times 4/3\ (\pi r^3)$<br><br>$= 1.21 \times 4/3\ (\pi)\ (11.0 \times 10^{-2})^3$<br><br>$= 0.00675$ kg $= 6.75$ g | <br><br>1<br><br>1 |
| | | **(ii)** |  <br>Upthrust, U $= 6.74 \times 10^{-3}\ g$<br>Force by scale on balloon, $N = 1.55 \times 10^{-3}\ g$<br>Wt of balloon and air, $W = 1.30 \times 10^{-3}\ g + m_{air}g$<br><br>Net force = 0<br>Thus $1.30 \times 10^{-3}\ g + m_{air}g = 6.74 \times 10^{-3}\ g + 1.55 \times 10^{-3}\ g$<br><br>Mass of air in balloon, $m_{air} = 6.99$ g | <br><br><br><br><br>1<br><br>1 |
| | | **(iii)** | The air is being compressed by the elastic balloon material so is at a higher pressure and hence denser. | 1 |
| | **(c)** | **(i)** | At start assume velocity is momentarily zero so drag is zero<br><br>Upthrust $= 6.75 \times 10^{-3}$ g<br>  <br>$2.10 \times 10^{-3}$ g<br>Wt of balloon and air $= 8.30 \times 10^{-3}$ g<br><br>$a = F_{net}/m$<br>$= [(8.30 + 2.10 - 6.75) \times 10^{-3} \times 9.81\}/ [(7.00 + 1.30 + 2.10) \times 10^{-3}]$<br>$= 3.44$ m s$^{-2}$ | <br><br><br><br><br><br><br><br>1<br><br>1 |
| | | **(ii)** | As speed increases, drag force (upward) increases.<br><br>Acceleration becomes zero when upthrust + drag force = weight of balloon, air and nut. | 1<br><br>1 |



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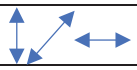
**3 (a)** The direction of vibration of *electric field* is restricted to one direction in a plane that is normal to the direction of energy transfer (propagation). [1]

**(b) (i)** When polariser X is oriented such that its direction of polarisation is not perpendicular to A, a component of the polarised light along the direction of polarization of X passes through X. [1]

The light component passing through X has a component along the direction of polarization of A that can pass through A. Thus the intensity of the transmitted light is not zero. [1]

**1.**

| $\theta$ | **Intensity of light tranmitted by polariser A (in terms of $I_o$ )** |
|---|---|
| 0° | 0 |
| 45° |  $(\cos^2 45°)^2 I_o = I_o / 4 = 0.25\, I_o$ |
| 60° | $(\cos^2 60°)(\cos^2 30°) I_o = 3I_o / 16 = 0.1875\, I_o$ |

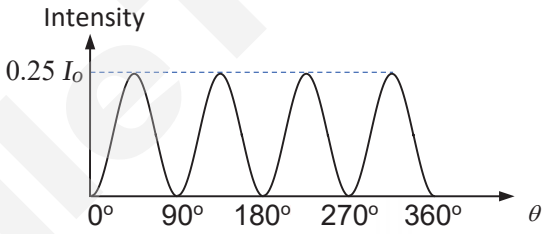
[1]

[1]

**2.** - min intensities are correct at 0°, 90°, 180°, 270° and 360°. [1]

Max intensities (0.25 $I_o$) at 45°, (90°+ 45°), (180°+ 45°), and (270°+ 45°) [1]

- correct shape




**(c) (i)** Let $P_s$ = Power emitted by source uniformly in all directions
$I_{78}$ = Intensity at 78.0 m away
$I_{300}$ = Intensity at 300 m away

Power = Intensity x area

$$Ps = (I_{78})(4\pi \times 78.0^2) = (I_{300})(4\pi \times 300.0^2)$$ [1]

$$I_{300} = (0.026)\left(\frac{4\pi \times 78.0^2}{4\pi \times 300.0^2}\right) = 0.00176\ \text{W m}^{-2}$$ [1]

**(ii)** Let $P_r$ = power received by the microphone diaphragm

$$P_r = (I_{300})(\textit{area of microphone})$$

$$P_r = (0.00176)(3.2 \times 10^{-4}) = 5.63 \times 10^{-7}\ \text{W}$$ [1]



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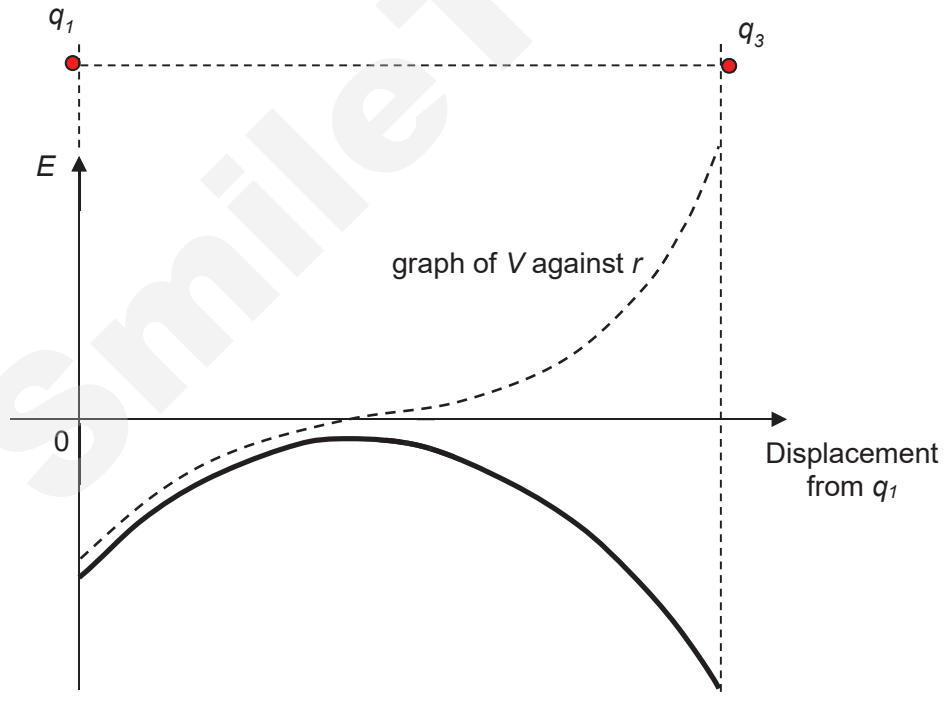
| **4** | **(a)** | **(i)** | Electric potential is the <u>work done **per unit positive charge** by an external force</u> in <u>bringing a test charge from infinity to that point</u> without a change in kinetic energy. | 2 |
| | | **(ii)** | Electric field strength at a point in the electric field is numerically equal to the potential gradient at that point, and directed towards lower potential. (no marks if direction not stated).<br>or $E = -\frac{dV}{dr}$ (where E is the electric field strength at the point, V is the potential and r is the distance from a particular reference point) | 1 |
| | **(b)** | | $q_1$, $q_2$ are negative. Potential around them is negative and increases (ie less negative) with distance from either charge.<br><br>$q_3$ is positive. The potential around it is positive and decreases (ie less positive) with distance from the charge. | 1<br><br>1 |
| | **(c)** | **(i)** | Direction of field strength is perpendicular to P, radially towards $q_2$. | 1 |
| | | **(ii)** | $\|E\| = \Delta V / \Delta r$ = [ –1 – (– 3)] / (1.5 x $10^{-2}$) = 130 V $m^{-1}$ (2 sf) | 1 |
| | **(d)** | | Work done by external agent<br>= $q\,(V_f - V_i)$ = $q\,(V_R - V_P)$<br>= $(-1.60 \times 10^{-19})[(+3.0) - (-2.0)]$<br>= $-8.0 \times 10^{-19}$ J | 1<br><br>1 |
| | **(e)** | |  <br>• 1 mark for correct shape (having the turning point vs the inflexion point)<br>• 1 mark for negative and not touching the x-axis<br>• 1 mark for a larger magnitude of $E$ at $q_3$ than at $q_1$ | 3 |



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| | | | |
|---|---|---|---|
| | | *Comments*<br>1. Students should first draw the potential *V*-curve, then use $E = -\frac{dV}{dr}$ to help sketch the *E*-curve. *E* is simply the negative of the potential gradient.<br>2. The potential gradient near $q_3$ is steeper and thus the magnitude of *E* at $q_3$ should be larger than that at $q_1$. | |

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|---|---|---|---|---|
| **5** | **(a)** | | The current in the copper and tungsten filament wires is the same because both wires are connected in series. | [1] |
| | **(b)** | | *Resistivity,* $\rho = \dfrac{AR}{L}$<br>$= \dfrac{\pi(0.020\times10^{-3})^2\times300}{4(1.5)} = 6.28 \times10^{-8}\ \Omega$ m | [1]<br>[1] |
| | **(c)** | **(i)** | Since current is the same in both wires,<br>using $I = neAv$<br>where $I$: current, $n$:number density, $A$: cross-sectional area, $v$: drift velocity of electrons<br>Hence $neAv$ for tungsten = $neAv$ for copper<br>$v_{tungsten} = \dfrac{n_{Cu}A_{Cu}v_{Cu}}{n_{tungsten}A_{tungsten}} = \dfrac{(8.49\times10^{28})(1.5)^2(0.021\times10^{-3})}{(3.4\times10^{28})(0.020)^2}$<br>$= 0.295$ m s$^{-1}$ OR 0.30 m s$^{-1}$ | [1]<br>[1]<br>[1] |
| | | **(ii)** | The electrons in the tungsten filament have a significantly higher drift velocity. This implies that they collide with the positive lattice ions at a much higher speed more frequently (more collisions per unit area). They impart more kinetic energy to the lattice ions at the same time, such that the ions vibrate more vigorously and obstruct the flow of electrons. Since the tungsten filament gains thermal energy at a significantly higher rate and subsequently heats up, the filament of the lamp gets hot but the copper leads stay relatively cold. | [1]<br>[1] |
| | | **(iii)** | If the diameter of the wire is doubled, the cross-sectional area of the wire will be quadrupled.<br>The resistance $\left(R = \dfrac{\rho l}{A}\right)$ is thus quartered. Current $\left(I = \dfrac{V}{R}\right)$ will be quadrupled.<br>Electron number density is the same for the same material, the drift velocity of electrons in the tungsten wire ($v = I/nqA$) is unchanged. | [1]<br>[1] |



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| **6** | **(a)** | **(i)** | Increasing $R$ increases the total resistance of the circuit, thus reducing the current in the circuit.<br><br>Thus the potential drop across the internal resistance is reduced.<br><br>Since the terminal p.d. is the e.m.f. of the battery minus the p.d. across the internal resistance, terminal p.d. increases with $R$.<br><br>OR<br><br>Increasing $R$ increases the external resistance.<br><br>This increases the ratio of the external resistance to the total resistance.<br><br>By the potential divider principle, the terminal p.d. increases with $R$. | [1]<br><br>[1]<br><br>[1]<br><br><br>[1]<br><br>[1]<br><br>[1] |
| | **(a)** | **(ii)** | $I = \dfrac{25.2}{2.00 + 4.00 + 40.0} = 0.548 \text{ A}$<br><br>$V_B = 25.2 - 0.548(2.00)$<br>$= 24.1 \text{ V}$<br><br>OR<br><br>$V_B = \dfrac{4.00 + 40.0}{2.00 + 4.00 + 40.0} \times 25.2$<br>$= 24.1 \text{V}$ | <br><br>[1]<br>[1]<br><br><br>[1]<br>[1] |
| | **(b)** | **(i)** | $V_R = (1.60 \times 10^{-3})(1.50 \times 10^{3}) = 2.40 \text{ V}$<br><br>$V_{thermistor} = 6.00 - 2.40 = 3.60 \text{ V}$ and $R_{thermistor} = \dfrac{3.60}{1.60 \times 10^{-3}} = 2250\,\Omega$<br><br>From the graph, $t = 14°\text{C}$ | [1]<br><br>[1]<br><br>[1] |
| | **(b)** | **(ii)** | From the graph, $R_{thermistor} = 3100\ \Omega$ at $t = 5°\text{C}$<br><br>Based on potential divider principle, potential difference across the fixed resistor<br><br>$V_R = \left(\dfrac{1500}{1500 + 3100}\right) 6.00 = 1.96$ V | [1]<br><br><br>[1] |

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| **7** | **(a)** | A photon is a discrete packet of electromagnetic energy. [1] | | | [1] |
| | **(b)** | **(i)** | 1. | $E_i = E_s + ½ mv^2$ | [1] |
| | | **(i)** | 2. | $p_i = p_s \cos \theta + mv \cos \alpha$ | [1] |
| | | **(ii)** | Energy of photon, E = hf.<br>As the scattered photon energy $E_s$ is less than the incident photon energy $E_i$, the frequency of the scattered photon is smaller than that of incident photon. [1]<br>As the wavelength is inversely proportional to its frequency, the scattered photon will have a wavelength greater than that of the incident photon. [1] | | [2] |
| | **(c)** | | Actual value, $\cos 75^o = 0.2588$<br><br>Check that $\cos 80^o = 0.1736$, $\cos 70^o = 0.3420$<br><br>Using $\Delta R = (R_{max} – R_{min}) / 2$<br>$\Delta(\cos \theta) = (\cos 70^o – \cos 80^o) / 2 = 0.08$ (1 s.f.)<br><br>Therefore $\cos \theta = 0.26 \pm 0.08$ | | [2] |
| | **(d)** | **(i)** | Calculate cos θ<br>Correctly plot the two data points to within half smallest square | | [1]<br>[2] |
| | | **(ii)** | Correct best fit line | | [1] |
| | | **(iii)** | $\Delta\lambda = k – k \cos \theta$<br><br>Method 1: gradient of graph gives negative k [1]<br><br>Method 2: y-intercept of graph gives k [1] | | [2] |
| | | **(iv)** | Correct values for k based on graphs. [1]<br>Correct unit for k. [1] | | [2] |



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| | **(e)** | **(i)** | Energy of Incident beam 19.0 keV<br>$E = \frac{hc}{\lambda}$<br>Wavelength, $\lambda = \frac{hc}{E} = \frac{\left(6.63\times10^{-34}\right)\left(3\times10^{8}\right)}{\left(19.0\times10^{3}\right)\left(1.6\times10^{-19}\right)} = 6.53\times10^{-11}\ m$<br><br>Using $\lambda' = \lambda + \frac{h}{mc}\left(1-\cos\theta\right)$, $\lambda' = 6.56\times10^{-11}\ m$<br>Alternatively, accept $\Delta\lambda$ = k – k cos $\theta$ and using the value of k obtained in (d)(iv). | [1]<br><br>[1] |
| | | **(ii)** | As the binding energy of an electron of a carbon atom is negligible compared with the energy of the incident photons (19 keV).<br><br>Therefore it is justified to assume that the electrons are free. | [1]<br><br>[1] |

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**2019 HCI H2 PHYSICS Prelim P3 Suggested Solutions**

| | | | | |
|---|---|---|---|---|
| **1** | **(a)** | **(i)** | The gas molecules rebound off the incoming piston at speed higher than before the collisions.<br>The increase in average KE corresponds to an increase in temperature. | B1 |
| | | **(ii)** | The frequency of collisions increases.<br>The change in momentum per collision is higher. | B1<br>B1 |
| | **(b)** | **(i)** | For ideal gas,<br>total internal energy = total number of molecules x mean kinetic energy of a molecule of ideal gas<br>$U = \frac{3}{2}NkT$<br>$\Delta U = \frac{3}{2}Nk\Delta T$<br>$\Delta U = \frac{3}{2}\Delta(pV)$<br>$\Delta U = \frac{3}{2}(30\times 20 - 10\times 40)(10^5\times 10^{-6})$<br>$= 30\ \text{J}$ | M1<br>A1 |
| | | **(ii)** | During the change B $\rightarrow$ C $\rightarrow$ A,<br>By First Law of Thermodynamics,<br>$W = 0 + (-p\Delta V)$<br>$= -(10)(40-20)(10^5\times 10^{-6})$<br>$= -20\,\text{J}$<br>$\Delta U = Q + W_{on}$<br>$-30 = Q + (-20)$<br>$Q = -10\,\text{J}$ | M1<br>M1<br>A1 |

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| **2** | **(a)** | | At equilibrium, the net force is zero hence weight = spring force<br>$mg = kx$<br>$0.850(9.81) = k(0.220)$ [1]<br>$k = \frac{0.850(9.81)}{(0.2200)} = 37.9$ N m$^{-1}$ | |
| | **(b)** | **(i)** | $F_{net}$ = spring force – weight<br>$= ke - mg$<br>$= 37.9(0.110 + 0.220) - 0.850(9.81)$<br>= 4.17 N<br>$F_{net} = ma$<br>$a = \frac{Fnet}{m} = \frac{37.9(0.330) - 0.850(9.81)}{0.850}$ [1]<br>$a$ = 4.91 m s$^{-2}$ [1] | |
| | | **(ii)** | $a_0 = \omega^2 x_0$<br>4.91 = $\omega^2$ (0.110)<br>$\omega^2 = \frac{4.91}{0.110}$<br>$\omega = 2\pi f$<br>$f = \frac{\omega}{2\pi} = \frac{\sqrt{\frac{4.91}{0.110}}}{2\pi}$ [1]<br>$f = 1.06$ Hz [1] | |

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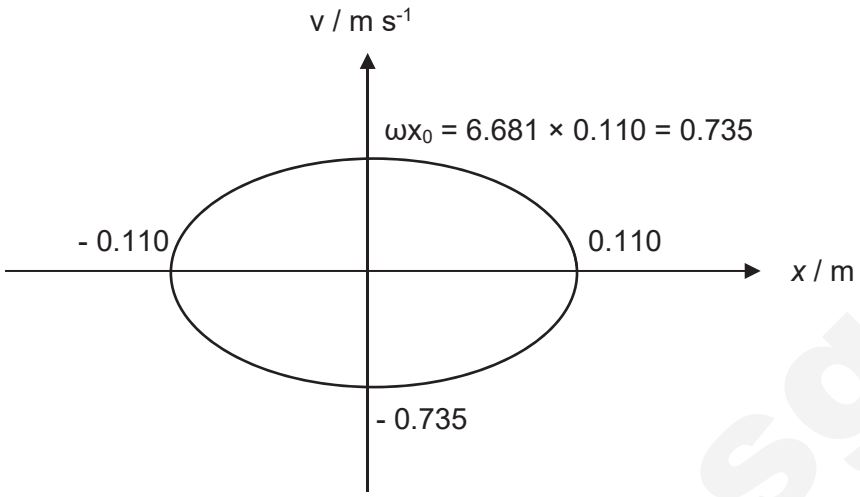
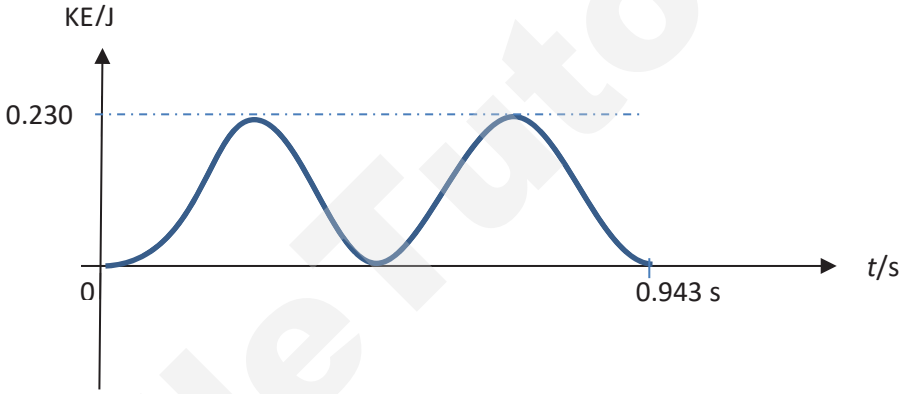
**(iii)**



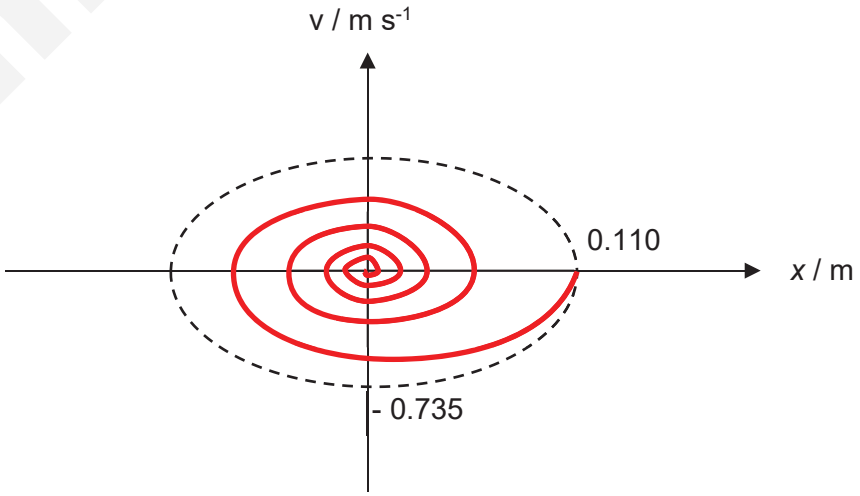

[1] shape must be an ellipse
[1] correct values of x-intercepts and y-intercepts of ellipse.

**(iv)**




[1] Sine-squared wave in one period
[1] Labels: $KE_{max} = \frac{1}{2} m\omega^2 x_0^2 = 0.5(0.850)(44.636)(0.110)^2 = 0.230$ J
and period = 1/f = 1/1.06 = 0.941 s or 0.943 s.

**(v)**




[1] Spiral clockwise inwards starting from at $x_0$ = + 0.110 m.
[1] Exponentially decreasing amplitude of oscillation (spacing between x-intercepts become smaller), at least 3 complete spiral rounds

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| | | | |
|---|---|---|---|
| **3** | **(a)** | By conservation of energy,<br>Gain in kinetic energy = Loss in electric potential energy<br>$\frac{1}{2}mv^2 - 0 = qV$<br>$v = \sqrt{\frac{2qV}{m}}$ | 1 |
| | **(b)** | The moving ion, upon entering the magnetic field, will experience a constant magnetic force perpendicular to the direction of velocity. This constant magnetic force provides the centripetal acceleration, causes the velocity to change its direction but not the speed (its magnitude). As a result, the ion moves in a uniform circular motion in the magnetic field. | 1<br>1 |
| | **(c)** | Magnetic force on ion provides the centripetal force.<br>Bqv = $mv^2/r \rightarrow r = mv/Bq = \sqrt{\frac{2mV}{B^2q}}$<br>$r_{14} = \sqrt{\frac{2\times14\times1.66\times10^{-27}\times4000}{0.50^2(1.60\times10^{-19})}} = 0.068176$ m<br>$r_{12} = \sqrt{\frac{2\times12\times1.66\times10^{-27}\times4000}{0.50^2(1.60\times10^{-19})}} = 0.063119$ m<br>Hence $\Delta x = 2(0.068176 - 0.063119) = 0.0101$ m | 1<br>1<br>1 |
| | **(d)** | If an electron were to be introduced into the magnetic field, it would be deflected to the left because electron is negatively-charged. The electron will move towards the left in a semicircle in an anticlockwise manner.<br>In addition, the diameter of its semi-circular path would be much smaller since the mass of electrons is only much smaller at 9.11 x $10^{-31}$ kg. | 1<br>1 |

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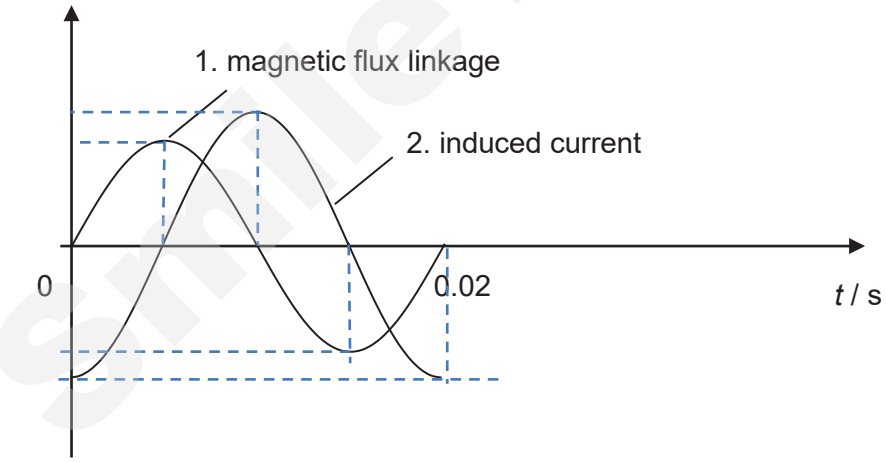
| | | | |
|---|---|---|---|
| **4** | **(a)** | Period or time for 1 full cycle = 1/f<br><br>time to rotate 1° = $\frac{1}{360}\left(\frac{1}{f}\right) = \frac{1}{360}\left(\frac{1}{50}\right) = 5.56 \times 10^{-5}$ s<br><br>OR<br><br>since it rotates 50 x 360 = 18000° in 1 s, time taken to rotate 1° = 1/18000 = 5.6 x $10^{-5}$ s | 1 |
| | **(b)** | Change in flux linkage = $\Delta\Phi$<br>= $\Delta$(NBA) = NA$\Delta B_{\perp}$<br>= 38 (0.29)(2.0)(1.2) sin 1.0° - 0<br>= 0.46 Wb turns | 1<br>1 |
| | **(c)** | e.m.f. = $\Delta\Phi/\Delta t$ = 0.46 / 5.6 x $10^{-5}$<br>= 8200 V = 8.2 k V | 1 |
| | **(d)** | The direction of the current induced in side AD is **A to D.**<br><br>As the coil starts turning, induced emf in the coil is proportional to the rate of increase in flux linkage, by Faraday's Law.<br><br>**By Lenz's Law, induced current in the coil will be in the direction A to D to produce a leftward magnetic field to oppose the increase of flux linkage to the right.**<br>(The direction of current is predicted using right hand grip rule.) | 1<br><br>1 |
| | **(e)** |  <br><br>-1 mark for wrong shape of graph or not labelling the period. | 1<br><br>1 |

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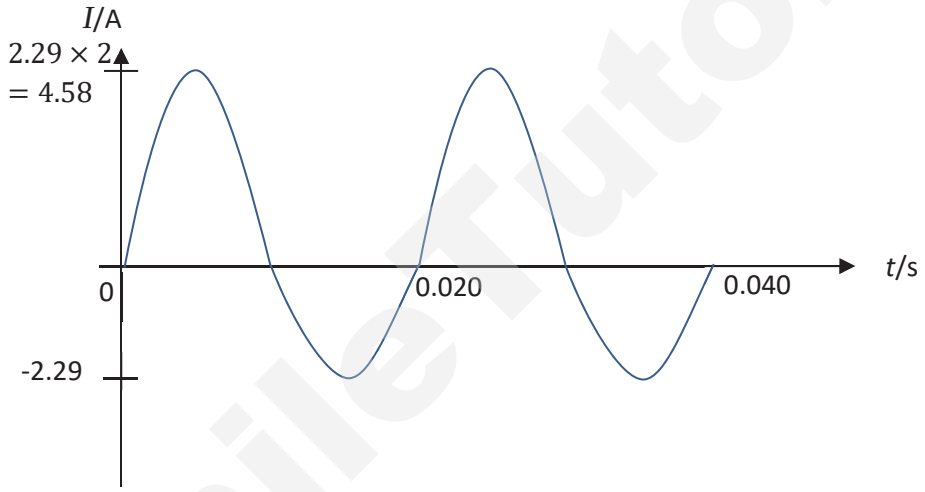
| | | | | |
|---|---|---|---|---|
| **5** | **(a)** | **(i)** | $V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{170}{\sqrt{2}}$ = 120 V | 1 |
| | | **(ii)** | $\omega = 2\pi/T = 314$<br>$T = 0.0200$ s | 1 |
| | **(b)** | **(i)** | $\frac{V_S}{V_P} = \frac{N_S}{N_P}$<br>$\frac{V_S}{170} = \frac{3500}{2000}$<br>$V_S$ = 298 V | 1<br>1 |
| | | **(ii)** | $V_S = I_S R$<br>$298 = I_S(130)$<br>$I_S = 2.288$ A<br>$\frac{I_P}{I_S} = \frac{N_S}{N_P} = \frac{3500}{2000}$<br>For correct working above:<br>$I_P$ = 4.00 A | 1<br>1 |
| | **(b)** | |  <br>Shape of graph: 1 mark.<br>Correct labels: 1 mark | |

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| | | | |
|---|---|---|---|
| **6** | **(a)** | $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$<br><br>$\lambda = \frac{6.63\times10^{-34}}{\sqrt{2\times9.11\times10^{-31}\times7.50\times1.60\times10^{-19}}} = 4.48\times10^{-10}\,\text{m}$ | 1<br><br>1 |
| | **(b)** | Enough energy to excite atom to -1.43 eV.<br><br>Hence recoil speeds are 0.25 eV (excited to -1.43 eV), 4.55 eV (excited to -5.73 eV). | <br><br>1 |
| | **(c)** | 6 transitions shown. | 1 |
| | **(d)** | $\Delta E = \frac{hc}{\lambda}$<br><br>$\lambda = \frac{\left(6.63\times10^{-34}\right)\left(3\times10^{8}\right)}{\left(-1.43-\left(-8.68\right)\right)\left(1.6\times10^{-19}\right)} = 1.71\times10^{-7}\ m = 171\ nm$<br><br>UV region. | 1<br><br>1<br><br>1 |
| | **(e)** | Work function is smaller.<br>Liberated electron not bound to a specific nucleus/atom | 1<br>1 |

| | | | | |
|---|---|---|---|---|
| **7** | **(a)** | | If it were the only particle produced besides the daughter nucleus, then, **by the principle of conservation of linear momentum, the beta particle and the daughter nucleus would always have the same speed ratio**.<br><br>Since the energy released in each decay is fixed, **by the principle of conservation of energy, all the beta particles would** (receive the same fraction of the released energy and therefore) **have the same energy**.<br><br>Note: Accept any variation that shows *proper understanding* of COLM and COE *in the context*. Do not accept the statement that, if there were no other particle, the energy of the beta-particle would have to be equal to 0.546 MeV without further elaboration. | 1<br><br>1 |
| | **(b)** | **(i)** | The half-life of a radioactive nuclide is the **average** time taken for half of the original number of nuclei in **a sample of the radioactive nuclide** to decay.<br><br>OR<br><br>The half-life of a radioactive nuclide is the **average** time taken for the activity of **a sample of radioactive nuclide** to halve. | 1 |
| | | **(ii)** | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{28.0\times365\times24\times60\times60} = 7.85\times10^{-10}\ \text{s}^{-1}$ | 1<br><br>1 |
| | | **(iii)** | $A = \lambda N$<br><br>number of nuclei $N = \frac{A}{\lambda} = \frac{6.40\times10^{9}}{7.85\times10^{-10}} = 8.15\times10^{18}$<br><br>mass of strontium-90 in the sample = $N$ x 90 / $N_A$ | 1<br><br>1 |

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| | | | | |
|---|---|---|---|---|
| | | | $= \left( \frac{6.40 \times 10^{9}}{7.85 \times 10^{-10}} \right) \times 90 \times \frac{1}{6.02 \times 10^{23}}$<br><br>OR<br>mass of strontium-90 in the sample = $N$ x 90 x $u$<br>$= \left( \frac{6.40 \times 10^{9}}{7.85 \times 10^{-10}} \right) \times 90 \times \left( 1.66 \times 10^{-27} \right)$<br>= 1.22 x $10^{-6}$ kg<br><br>= 1.22 x $10^{-3}$ g | 1 |

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**8 (a)** The force of attraction between two point masses is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

0 mark for nonsensical definition.
1 mark for mostly correct definition.
2 marks for faultless definition.

**(b) (i)** Gravitational pull provides the required centripetal force.

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

$$\frac{1}{2}\frac{GM}{r} = \frac{1}{2}mv^2$$

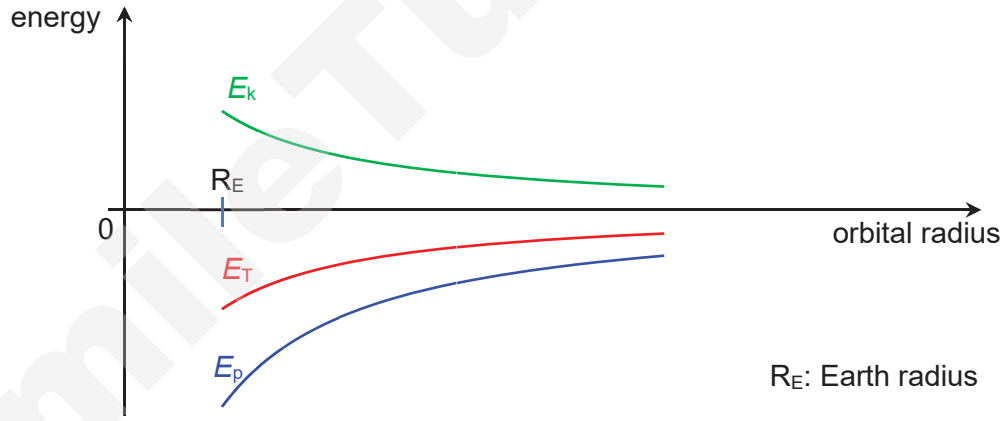
$$-\frac{1}{2}\left(-\frac{GM}{r}\right) = \frac{1}{2}mv^2$$

$$-\frac{1}{2}E_p = E_k$$

$$E_p = -2E_k$$

1 mark for correct GPE or KE.
2 marks for full derivation.

**(ii)**




1 mark if a least 1 graph is correct.
2 marks for all correct.

**(c) (i)**

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

$$\frac{GM}{r} = v^2$$

$$\frac{(6.67\times10^{-11})(5.98\times10^{24})}{6.7\times10^{6}} = v^2$$

$$v = 7716 \text{ m s}^{-1}$$

$$= 27800 \text{ km h}^{-1}$$

M1 at correct substitutions.
A1 at correct numerical answer.

**(ii)** At this altitude, the centripetal force provided by the Earth is larger than the required centripetal force (for circular motion at geostationary speed). **B1**

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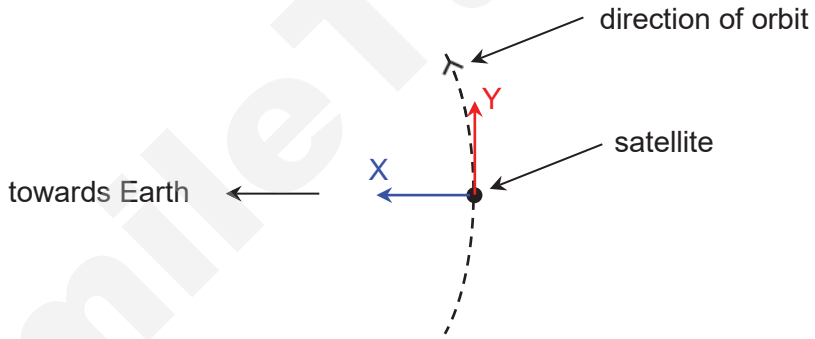
| | | | | |
|---|---|---|---|---|
| | **(d)** | **(i)** | GPE is converted into KE and heat.<br>1 mark if KE or heat is omitted. | |
| | | **(ii)** | $\frac{\Delta TE}{TE} = \frac{\Delta r}{r}$<br>$= 0.2\%$ | B1 |
| | | **(iii)** | $\Delta TE = -\frac{0.2}{100} \times (\frac{1}{2}\frac{GMm}{r})$<br>$= -\frac{0.2}{100} \times \frac{1}{2}\frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})(1.80 \times 10^{3})}{6.70 \times 10^{6}}$<br>$= -\frac{0.2}{100} \times 5.3579 \times 10^{10}$<br>$= 1.072 \times 10^{8}$ J<br><br>Rate of loss of energy $= \frac{1.072 \times 10^{8}}{7 \times 24 \times 3600} = 177$ J s$^{-1}$<br>$(P = Fv)$<br>$177 = f(7716)$<br>$f = 0.0230$ N | M1<br><br>M1<br><br>M1 |
| | **(e)** | **(i)** |  | B2 |
| | | **(ii)** | $F = u$□<br>$0.0230 = 2.00 \times 10^{3}$ □<br>□$= 1.148 \times 10^{-5}$ kg s$^{-1}$<br><br>Fuel needed $= 24 \times 3600 \times 1.148 \times 10^{-5} = 0.992$ kg | M1<br><br>A1 |

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| | | | | |
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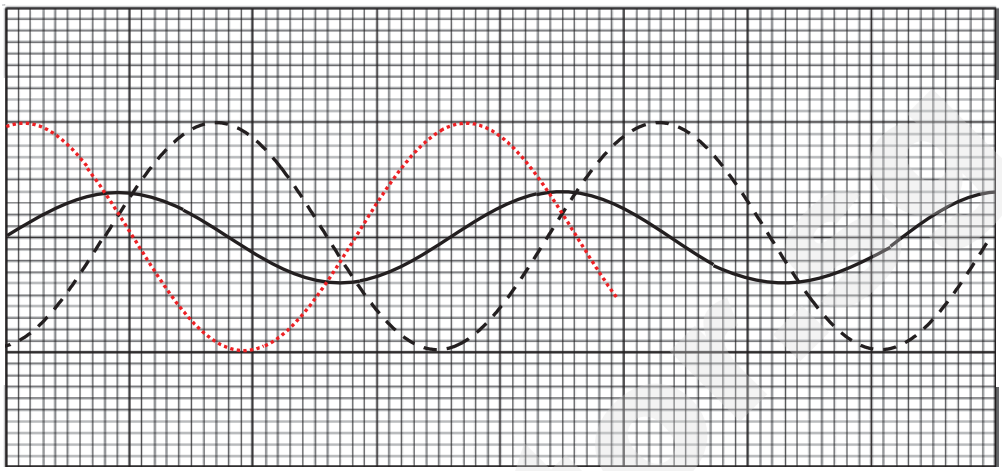
| 9 | (a) | | When two or more waves meet at a point at the same time, the resultant displacement is the vector sum of the individual displacements at that point at that time.<br>[2 marks for flawless definition.<br>1 mark for somewhat correct definition.] | [2] |
| | (b) | |  | [2] |
| | (c) | (i) | The sound wave reflects off the bench.<br>The incident and reflected waves superpose/interfere with each other.<br>Maximum amplitude where the waves interfere constructively; minimum amplitude where they interfere destructively. | [1]<br>[1]<br>[1] |
| | | (ii) | As x increases, the incident wave is stronger and the reflected wave weaker.<br>There is more complete cancellation of the incident and reflected waves at small values of x and less complete cancellation at larger values of x. | [1]<br>[1] |
| | | (iii) | Distance between 2 consecutive nodes = λ/2 = (18.0 – 2.6)/3 = 5.13 cm<br>λ = 10.26 cm<br>f = 340/0.1026 = 3310 Hz | [1]<br>[1]<br>[1] |
| | (d) | (i) | An interference pattern is seen on the screen. | [1] |
| | | (ii) | $\Delta\phi = \frac{1.4}{1.6} \times 2\pi$<br>$= 5.5$ rad | [1]<br>[1] |
| | | (iii) | $x = \frac{14.8 \quad 5.2}{6} = 1.6$ mm<br>$a = \frac{\lambda D}{x} = \frac{650 \times 10^{-9} \times 1.5}{1.6 \times 10^{-3}} = 0.61$ mm | [1]<br>[1] |
| | | (iv) | Distance of 6th order from principal axis = 1.6 × 6 = 9.6 mm<br>$\theta = \tan^{-1}\left(\frac{0.0096}{1.5}\right) = 0.0064$ rad | [1]<br>[1] |

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| | | | | |
|---|---|---|---|---|
| | | | $b = \frac{1\lambda}{\sin\theta} = \frac{650 \times 10^{-9}}{\sin(0.0064 \text{ rad})} = 0.102 \text{ mm}$ | [1] |

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**2019 HCI H2 PHYSICS Prelim P4 Mark Schemes & Suggested Solutions**

| | | |
|---|---|---|
| **1 a) i)** | Value of mass in the range 0.10 to 0.50 gram (inclusive)<br>Students should weigh the total mass of at least ten paperclips, with working<br><br>Mass is recorded with unit and to the correct precision<br>Precision is based on raw data and calculation | **[1]**<br><br><br>**[1]** |
| **1 a) ii)** | Number of paperclips in the range 5 to 20 (inclusive) | **[1]** |
| **1 b) i)** | Value of $\theta$ in the range 125° to 155° (inclusive)<br>$\theta$ is recorded to the correct precision (nearest degree) | **[1]** |
| **1 b) ii)** | Absolute uncertainty in the range 2° to 5° (inclusive)<br>1 s.f.<br>Degree symbol has to be present | **[1]** |
| **1 c) i)** | Value of $M$ is calculated correctly with appropriate s.f. and units (2 or 3 s.f.) | **[1]** |
| **1 c) ii)** | Clear explanation or method on how the maximum value of $M$ can be obtained<br>Maximum value of $M$ correctly calculated<br><br>Students have to explicitly use the values of (a) (ii) and (b) (ii)<br>Their calculation must be carried out correctly | **[1]** |
| **1 d) i)** | Value of $\theta$ should be smaller than that in (b) (i)<br>$\theta$ is recorded with unit and to the correct precision (nearest degree)<br>Check with (b) (i) and do not double penalise incorrect precision | **[1]** |
| **1 d) ii)** | Plot $m$ versus cos ($\theta$/2) or another appropriate graph<br>Log-log graphs are accepted, as long as the mathematics is fine<br><br>$M$ will be half the gradient *or* 2$M$ is the gradient<br>For other graphs, check that the method to obtain $M$ is correct | **[1]**<br><br><br>**[1]** |

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**1 e) i)** [2]

Two reasonable sources of error should be given.

| ***Accepted sources of error*** | ***Improvement*** |
|---|---|
| Difficult to measure $\theta$ accurately, using a protractor held in one's hand, because of **shaky hands** | **Clamp the protractor** with a retort stand, so that it is stable |
| **Friction** present in the ball bearings of the **pulley** causes the setup to be stable over a range of $\theta$ | **Lubricate** the axle of the **pulley** |
| The **hook of the hanger** makes it impossible to place the protractor close to the setup | Tie the hanger to a **piece of string** |
| Difficult to gauge where the **vertical axis** is | Use a **plumb line** to indicate the vertical axis |
| The **hook of the hanger** is too thick, making the origin of the angle difficult to judge | Tie the hanger to a **piece of string** |
| ***Not accepted sources of error*** | |
| Parallax error | |
| Wind (due to fans) | |
| Thickness of string | |

**1 e) ii)** [1]

Improvement should address one of the sources of error indicated in (e)(i).

**2 a) i)** [1]

Voltage in the range 1.600 to 1.800 volts (inclusive)

Voltage is recorded with unit and to the correct precision

**2 a) ii)** [1]

Value of resistance calculated correctly and presented with appropriate s.f. and units (2 or 3 s.f.)

**2 b) i)** [1]

Voltage in the range 1.480 to 1.560 volts (inclusive)

Voltage is recorded with unit and to the correct precision

**2 b) ii)** [1]

Percentage uncertainty in $V_F$ is **based on an absolute uncertainty of 0.002 to 0.008 V and correctly calculated**

Accept 1, 2 and 3 s.f.

% symbol has to be present

**2 b) iii)** [1]

Values of proportionality constant $k$ are calculated correctly

Percentage difference between values of $k$ is calculated correctly

[1]

Percentage difference is explicitly compared to the value obtained in (b)(ii)

Conclusion is consistent with data obtained

**2 c)** [1]

Three wires drawn

Rheostat correctly connected

[1]

LED correctly connected, with short leg connected to negative pole of battery

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## Question 3 Suggested Marking Scheme

| | | | |
|---|---|---|---|
| **(a)** | Value of *w* in range of 2.50 to 3.00 cm measured by VC to the correct precision with unit. Value of *w* in range of 2.5 to 3.0 cm measured by 30-cm ruler to the correct precision with unit.<br><br>Value of *d* in range of 0.35 to 0.75 cm measured ONLY by VC to the correct precision with unit.<br>*Student should indicate zero error for VC (annotate). | | [1]<br><br>[1] |
| **(b)** | **(i)** | Value of x should be around 5 cm. Mark cross and annotate if student did not follow instruction but no mark is deducted. | |
| | **(ii)** | Correct mode of oscillation, i.e. $T > 3$ s for x around 5 cm (check table if x in b(i) is not 5 cm).<br>Evidence that appropriate number of oscillations (N) has been taken for $t \geq 15$ s (check table if x in b(i) is not 5 cm). Correct calculation of *T* with correct unit given. *$T$ has already been clearly defined in the question as period of oscillations, hence we only give credit to correct usage of this symbol. We do not interpret for student that N =1 in the absence of evidence of *t* and N in the working or in (c). | [1]<br><br>[1] |
| **(c)** | Data collection<br>Candidate is expected to collect 6 or more sets of data (*x*, *t*).<br>- Deduct one mark for collection of 5 sets of data (*x*, *t*).<br>- Deduct one mark for not including data in b(ii).<br>- Deduct one mark for no evidence of repeat readings (for time for N oscillations).<br>- Deduct one mark for insufficient range of x values (min. $5 \leq x \leq 20$ cm) or include x = 25 cm.<br><br>- Layout: Column headings:<br>The unit must conform to accepted scientific convention e.g. $T^2$ / $s^2$ and $x^2$/ $m^2$.<br>Annotate if student does not have N column in table or state N clearly.<br>Deduct one mark if N cannot be deduced directly from b(ii) or table.<br><br>- All raw values of x and *t* must be given to the correct precision. Credit will be awarded only if both x and *t* are tabulated.<br><br>- For each calculated value of e.g. *T*, $x^2$ or $T^2$, the number of s.f. should be the same or one more than the number of s.f. in the raw data.<br><br>- Correctly calculated values of calculated quantity (max. 1 slip allowed). | | [2]<br><br>[1]<br><br>[1]<br><br>[1] |
| **(d)** | - Linearizing equation correctly and suitable graph plotted.<br>- Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed.<br>- Scales must be chosen so that plotted points occupy at least half the graph grid in both *x* and *y* directions.<br>- Axes must be labelled with the quantity which is being plotted.<br><br>- All observations must be plotted. Work to an accuracy of half a small square.<br><br>- Straight line of best fit – judged by scatter of points about the candidate's line.<br>There must be a fair scatter of points on either side of the line.<br>Deduct this mark if student identified anomaly due to wrong judgement.<br><br>- Y-intercept must be read off to the nearest half small square or determined from $y = mx + c$ using a point on the line.<br><br>- Gradient – the hypotenuse of the triangle must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square.<br><br>- P and Q values are consistent with values of y-intercept and gradient calculated respectively with correct units.<br>**Unit** of P: $s^2$ **Units** of Q: $s^2\ m^{-2}$ or $s^2\ cm^{-2}$. Check that experimental P & Q values are within range. Accept: $15 \leq P \leq 30\ s^2$ & $1700 \leq Q \leq 3000\ m^{-2}\ s^2$ or $0.17 \leq Q \leq 0.30\ cm^{-2}\ s^2$. | | [1]<br><br>[1]<br><br>[1]<br><br>[1]<br><br>[1]<br><br>[1] |
| **(e)** | Correct method and working for calculation of M. E.c.f. allowed.<br><br>Final value of M given to the correct s.f. with appropriate unit. | | [1]<br><br>[1] |
| **(f)** | Correct method and working for calculation of density. E.c.f. allowed.<br><br>Final value of density given to the correct s.f. with appropriate unit. | | [1]<br><br>[1] |
| **(g)** | Line must have same gradient.<br><br>Y-intercept value is halved or all y values moved down by half of y-intercept value.<br>Deduct one mark if student has reasoned out the above 2 points but did not draw new line. | | [1]<br><br>[1] |


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**Q4 Mark Scheme**

| | Marks | Marking Points | Remarks |
|---|---|---|---|
| **D**iagram | 2 | Clear labeled diagram showing<br>• Correct setup (D1)<br>• Correct polarity of E-field and B-field of the velocity selector (D2) | D1: Apparatus must include a small slit that allows a straight beam of beta particles to pass through<br><br>D2: Polarity of the E-field and B-field must be such that the forces acting on the beta particles are in the opposite directions |
| **V**ariables | 5 | • Measurement of the thickness of the aluminium using a micrometer screw gauge or vernier caliper (V1).<br>• Measurement of count rate using GM tube connected to counter/any appropriate detector (V2)<br>• Vary thickness to obtain $\tau$ (V3)<br>• Method to vary $v$ for 10 sets of readings (V4)<br>• Correct formula to calculate $v$ $\left(= \frac{E}{B} = \frac{V}{dB}\right)$(V5) | If wrong method is used (eg varying v with a constant thickness of aluminum), marks for V3 and V4 will not be awarded.<br><br>V2: Rate-meter connected to the GM tube is shown in the diagram or stated in the write-up is acceptable.<br><br>V4: At least 8 sets of readings is acceptable<br><br>V5: B not substituted with the given value of 0.500 mT is acceptable |
| **A**nalysis | 2 | • Propose power law relationship: $\tau = kv^n$ (A1)<br>• Correct linearization, suggest an appropriate graph to plot and comment on how the data will suggest whether the relationship is valid (A2) | A1: Only accepts power law relationship. Either $\tau = kv^n$ or $v = k\tau^n$ is acceptable.<br><br>A2: Linearisation based on an inappropriate relationship can be accepted provided if all the criteria for A2 are met |
| **R**eliability | max. 2 | Suggested methods to ensure reliability:<br>• Taking into account background radiation (R1)<br>• Use the count rate vs thickness graph to obtain half-value thickness (R2)<br>• Repeating count rate measurement because of random nature of radioactive decay (R3)<br>• Preliminary trial to identify range of potential difference $V$ corresponding to the range of speed $v$ of the beta source (R4)<br>• Keep distance between the apparatus constant (R5) | R1: Description of how background radiation is taken into account (ie subtract background radiation from measured count-rate) is required<br><br>R5: Need to state explicitly distance is kept constant or suggest a specific distance.<br><br>Not acceptable:<br>• Measure thickness at different locations and take average (trivial)<br>• Using a source with a long half life (the source is provided) |
| **s**afety | max. 1 | Relevant safety precaution relating to handling of radioactive source, such as:<br>• Store source in lead lined box when not in use | Reject ridiculous suggestions such as wear lead suits/ lead lined rooms/ lead gloves etc |


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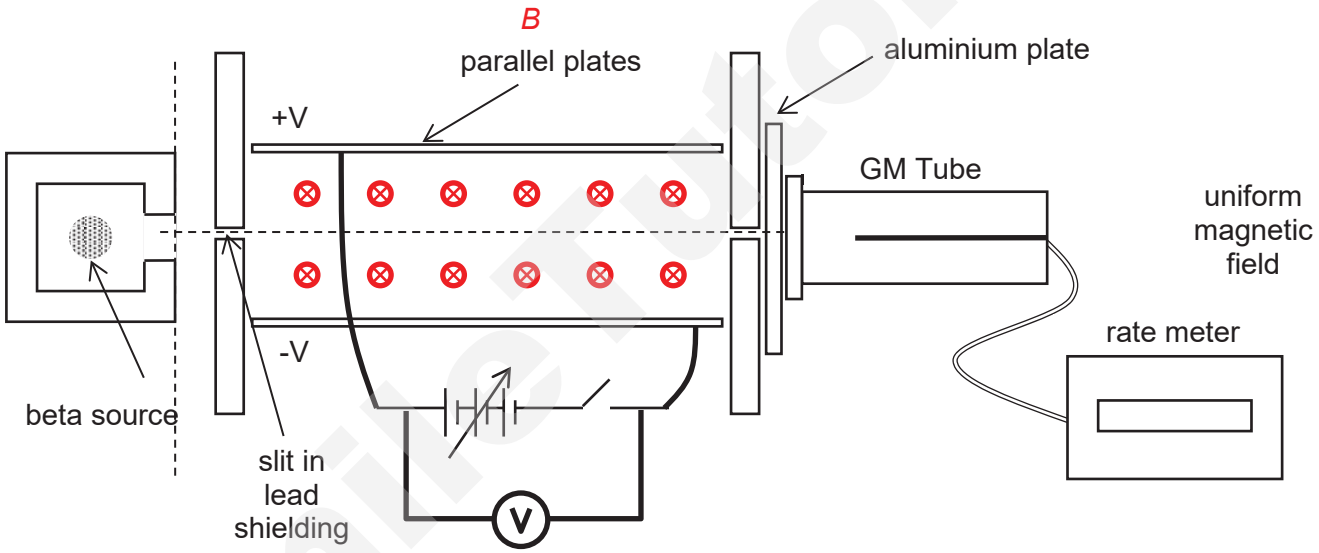
| | | | |
|---|---|---|---|
| | | • use tongs to handle source.<br><br>Relevant safety precaution relating to the high voltage power supply, such as:<br>• Wear rubber gloves and boots to avoid accidental electric shock. | |

**max 12 marks**

**Q4 Suggested Solutions**

**Diagram**

**Setup**




**Procedures**

1. Set up the apparatus as shown, except the beta source and aluminium plates, as shown.
2. Measure the background count rate, $C_b$, using the Geiger-Muller counter
3. Put the beta source in position, measure the un-attenuated count rate $C_0$. .
4. Use a micrometer screw gauge to measure the thickness $D$ of the aluminium plate (near the centre of the plate which will be positioned at the slit where the beta radiation will hit).
5. Insert the aluminium plate between the velocity selector and the GM Tube. Measure and obtain the count rate $C$.
6. Repeat steps 4 to 5, using a different aluminium plate each time for 20 sets of data.
7. Plot a graph of $C - C_b$ against $D$.
8. Draw the best-fit-curve. The half-value thickness $\tau$ is obtained by reading the value of $D$ at which $C = 0.5(C_0 - C_b)$ on the best-fit-curve.
9. Read the voltmeter reading $V$.
10. Measure the distance between the parallel plates using a metre rule.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11. Calculate the speed of the beta particles $v = \frac{E}{B} = \frac{V}{d(0.05)}$.
12. Repeat steps 4 to 11, each time adjusting the variable DC power supply to a different voltage *V*, to obtain 10 sets of data of $\tau$ and *v*.
13. Propose the relationship $\tau = kv^n$, where $\tau$ and *n* are constant.
14. $\lg \tau = n \lg v + \lg k$
15. Plot a graph of lg $\tau$ against lg *v*. A linear trend would validate the relationship.

**Reliability Measures**

16. A preliminary trial should be done to find the range of values of *V* that result in significantly above background count rate. This is so that the experiment is conducted with the range of speed of beta particles provided by the particular beta source.
17. Once set up, tapes can be used to mark the positions of each apparatus to ensure the distances between the source, the velocity selector and the GM tube and their orientations remain unchanged.

**Safety Precautions**

- Use tongs to handle the radioactive source to avoid direct physical contact.
- Put the source back in its lead box immediately after use.
- Wear rubber gloves and boots to avoid accidental electric shock.

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# JURONG PIONEER JUNIOR COLLEGE

## JC2 Preliminary Examination 2019

**PHYSICS** **9749/01**
**Higher 2** **27 September 2019**

Paper 1 Multiple Choice **1 hour**

Additional Material: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and index number on the Answer Sheet in the spaces provided.

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

**Read the instructions on the Answer Sheet very carefully.**

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

This document consists of **17** printed pages.

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**Data**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on/by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -\frac{Gm}{r}$ |
| temperature | $T\,/\,\mathrm{K} = T\,/\,^\circ\mathrm{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t$<br>$= \pm\omega\sqrt{(x_0^2 - x^2)}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** A cyclist changes his velocity from 5 m $s^{-1}$ due east to 7 m $s^{-1}$ due south.

What is his change in velocity?

**A** 2 m $s^{-1}$ at a direction of 36° east of south

**B** 2 m $s^{-1}$ at a direction of 36° west of south

**C** 9 m $s^{-1}$ at a direction of 36° east of south

**D** 9 m $s^{-1}$ at a direction of 36° west of south

**2** A racing driver enters the home straight at 50 m $s^{-1}$. He then accelerates uniformly until he passes the finish line 432 m away with a speed of 70 m $s^{-1}$.

Which statement is correct?

**A** The acceleration is 20 m $s^{-2}$.

**B** The time taken to reach the finish line is 6.2 s.

**C** When the driver's speed is 55 m $s^{-1}$, he is 5.8 s from the finish line.

**D** When the driver's speed is 60 m $s^{-1}$, he is 234 m from the finish line.

**3** Steel pellets, each of mass 0.80 g, fall vertically onto a horizontal plate at a rate of 100 pellets per minute. They strike the plate with a velocity of 5.0 m $s^{-1}$ and rebound with a velocity of 4.0 m $s^{-1}$.

What is the average force exerted on the plate by the pellets?

**A** 0.0013 N

**B** 0.0072 N

**C** 0.012 N

**D** 0.72 N

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**4** An elastic collision occurs between two bodies P and Q. The mass of body P is $m$ and the mass of body Q is $4m$. Body P travels at speed $v$ before the collision and speed $\frac{3v}{5}$ in the opposite direction after the collision. Body Q is stationary before the collision.




What is the kinetic energy of body Q after the collision?

**A** $\frac{1}{5}mv^2$

**B** $\frac{8}{25}mv^2$

**C** $\frac{17}{25}mv^2$

**D** $\frac{4}{5}mv^2$

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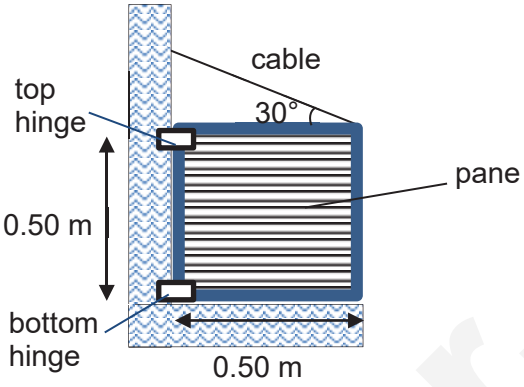
**5** A door is made up of a uniform pane of mass 20 kg. The pane is 0.50 m wide and 0.50 m high and is freely hinged at the top and bottom as shown. A cable attached to the top right corner of the pane makes an angle of 30° with the top of the pane and has a tension of 150 N.




What is the magnitude and direction of the horizontal force exerted by the top hinge on the pane?

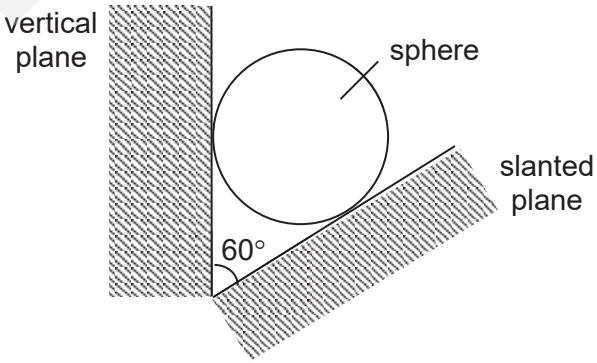
**A** 110 N to the left

**B** 300 N to the left

**C** 110 N to the right

**D** 300 N to the right

**6** 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** 0 N **B** 7.5 N **C** 8.7 N **D** 26 N

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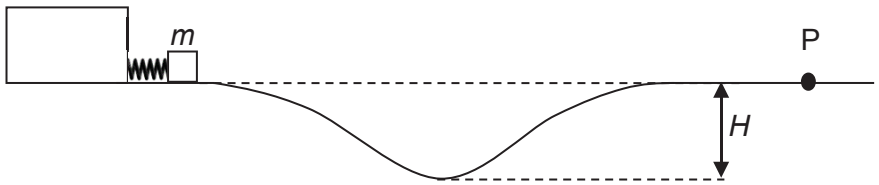
**7** A small object of mass $m$ is launched by a spring and travels along a rough track to a point P. The spring constant is $k$ and the initial compression of the spring is $x$. As it travels to P it goes through a dip of depth $H$. The object experiences a constant force of friction $f$ for the entire distance of $d$.




What is the kinetic energy of the object at point P?

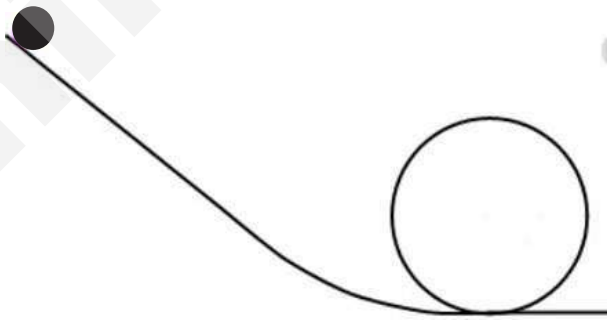
**A** $\frac{1}{2}kx^2 - fd$

**B** $\frac{1}{2}kx^2 + fd$

**C** $\frac{1}{2}kx^2 + fd + mgH$

**D** $\frac{1}{2}kx^2 - fd - mgH$

**8** A ball rolls down a frictionless circular ramp as shown below.



Which statement is incorrect?

**A** The force that the ramp exerts on the ball is always perpendicular to the velocity of the ball.

**B** The force that the ramp exerts on the ball is greater than its weight when it is at the bottom of the ramp.

**C** The speed of the ball when it goes around the circular ramp is not constant.

**D** The acceleration of the ball is always directed towards the centre of the circular ramp.

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**9** The gravitational potential energy of an object of mass 2.0 kg at the surface of the Earth is $-1.3 \times 10^8$ J.

The radius of the Earth is $6.4 \times 10^6$ m.

What is the gravitational field strength 9000 km above the Earth's surface?

**A** 1.8 N kg$^{-1}$

**B** 3.6 N kg$^{-1}$

**C** 5.1 N kg$^{-1}$

**D** 9.8 N kg$^{-1}$

**10** What is the speed of a geostationary satellite orbiting Earth?

The mass of the Earth is $6.0 \times 10^{24}$ kg.

**A** $4.65 \times 10^2$ m s$^{-1}$

**B** $3.08 \times 10^3$ m s$^{-1}$

**C** $4.71 \times 10^4$ m s$^{-1}$

**D** $4.23 \times 10^7$ m s$^{-1}$

**11** A solid copper metal of mass 5.0 kg at an initial temperature $T$ is placed with ice of mass 3.0 kg at 250 K. The copper and ice are in an insulated container of negligible mass. After thermal equilibrium is reached, the container has 2.2 kg of ice and 0.8 kg of liquid water.

Specific heat capacity of copper is 390 J kg$^{-1}$ K$^{-1}$.
Specific heat capacity of water is 4200 J kg$^{-1}$ K$^{-1}$.
Specific latent heat of fusion of ice is 340000 J kg$^{-1}$.
Specific heat capacity of ice is 2100 J kg$^{-1}$ K$^{-1}$.

What is the initial temperature $T$ of the copper metal?

**A** 210 K

**B** 470 K

**C** 490 K

**D** 560 K

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**12** The temperature of one mole of oxygen gas is the same as that of one mole of nitrogen gas.

Which statement is correct?

**A** The gas molecules have the same root mean square speed.

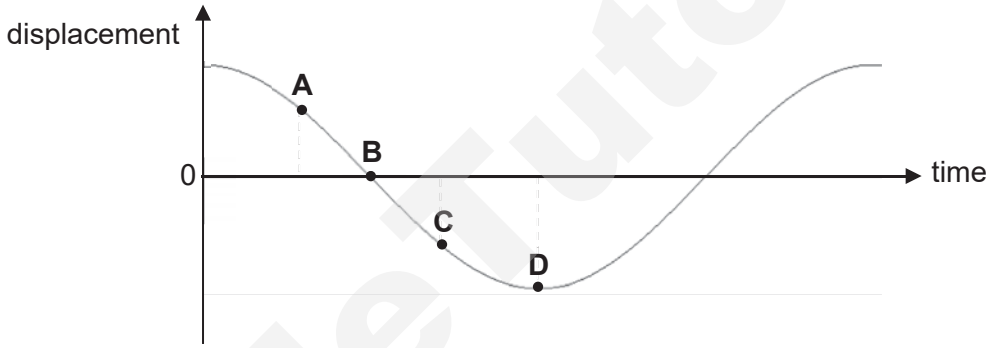
**B** The gas molecules have different mean translational kinetic energies.

**C** The total translational kinetic energy of both gases are the same.

**D** The values of the product of volume and pressure of both gases are different.

**13** The oscillations of a mass suspended on a spring are simple harmonic. The variation with time of the displacement of the mass is shown.

At which point is the mass travelling and accelerating in the same direction?




**14** A particle oscillates with simple harmonic motion along a line with maximum kinetic energy *E*.

What is its potential energy when its displacement from the equilibrium position is a quarter of the amplitude?

**A** $\frac{1}{16}E$

**B** $\frac{1}{4}E$

**C** $\frac{3}{4}E$

**D** $\frac{15}{16}E$

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**15** A beam of plane-polarised light of intensity $I$ falls normally on a thin sheet of polaroid.

If the transmitted beam has an intensity of $\frac{I}{4}$, what is the angle between the plane of incident polarisation and the polarising direction of the polaroid?

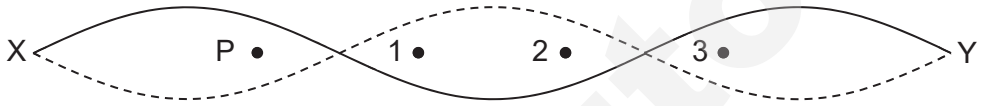
**A** 30°

**B** 60°

**C** 76°

**D** 86°

**16** A standing wave is set up on a stretched string XY as shown.




At which point(s) will the oscillation be in phase with that at P?

**A** 1 and 2 only

**B** 2 and 3 only

**C** 2 only

**D** 3 only

**17** Fringes of separation *y* are observed in a plane 1.0 m from a Young's double slit arrangement illuminated by light of wavelength 600 nm.

At what distance from the slits would fringes of the same separation *y* be observed when using light of wavelength 450 nm?

**A** 0.38 m

**B** 0.67 m

**C** 0.75 m

**D** 1.3 m

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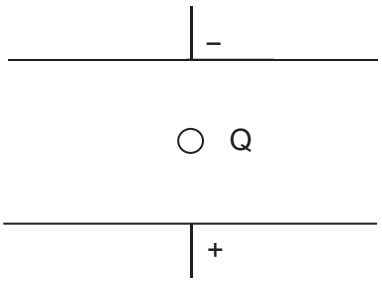
**18** A tiny charged mass Q is suspended at rest by the electric field between two horizontal, charged metallic plates as shown. The lower plate has a positive charge and the upper plate has a negative charge.




Which statement is true?

**A** Q is negatively charged.

**B** If some electrons are removed from Q, it will accelerate upwards.

**C** If the perpendicular distance the two plates is increased, Q will accelerate upwards.

**D** Decreasing the potential difference between the plates will cause Q to accelerate upwards.

**19** The electric potentials $V$ are measured at distances $x$ from P along a line PQ.

The results are:

| $V$ / V | 18.0 | 15.0 | 14.5 | 14.0 | 13.0 |
|---|---|---|---|---|---|
| $x$ / m | 0.020 | 0.030 | 0.040 | 0.050 | 0.060 |

The component along PQ of the electric field for $x$ = 0.040 m is approximately

**A** 50 V m$^{-1}$ towards P.

**B** 50 V m$^{-1}$ towards Q.

**C** 360 V m$^{-1}$ towards Q.

**D** 360 V m$^{-1}$ towards P.

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**20** Charge carriers, each of charge $q$, move along a wire of fixed length. The number density of the charge carriers in the wire is $n$.

What is also required for this wire to determine the average drift velocity of the charge carriers in terms $n$ and $q$?

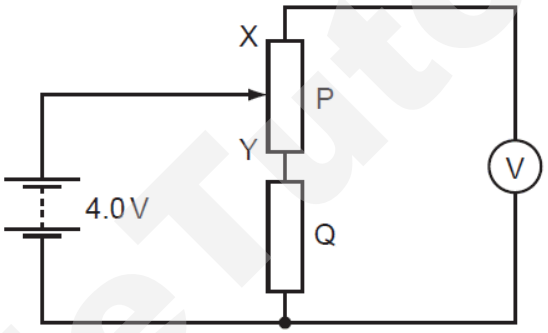
**A** resistivity and cross-sectional area

**B** current per unit of cross-sectional area

**C** resistance per unit of cross-sectional area

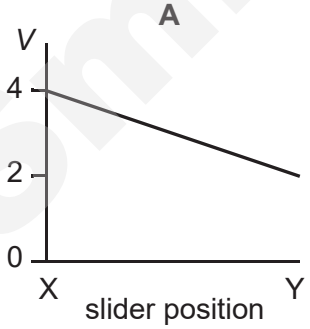
**D** potential difference and cross-sectional area

**21** In the circuit below, P is a potentiometer of total resistance 10 Ω and Q is a fixed resistor of resistance 10 Ω. The battery has an e.m.f. of 4.0 V and negligible internal resistance. The voltmeter has a very high resistance.

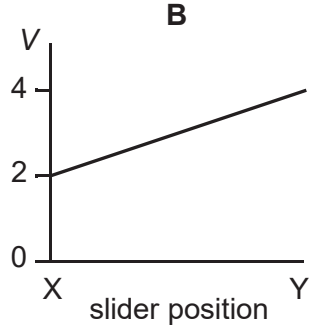



What graph shows the variation with slider position of the voltmeter reading $V$ as the slider on the potentiometer is moved from X to Y?

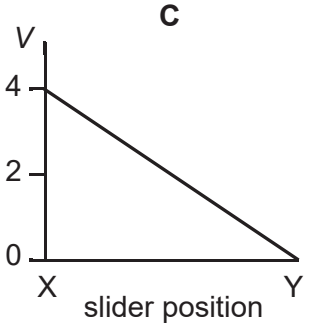
**A**



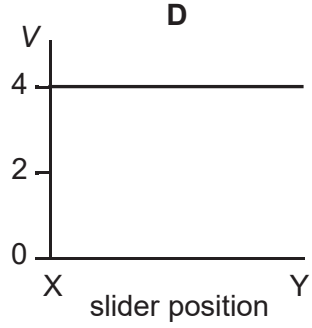

**B**




**C**




**D**

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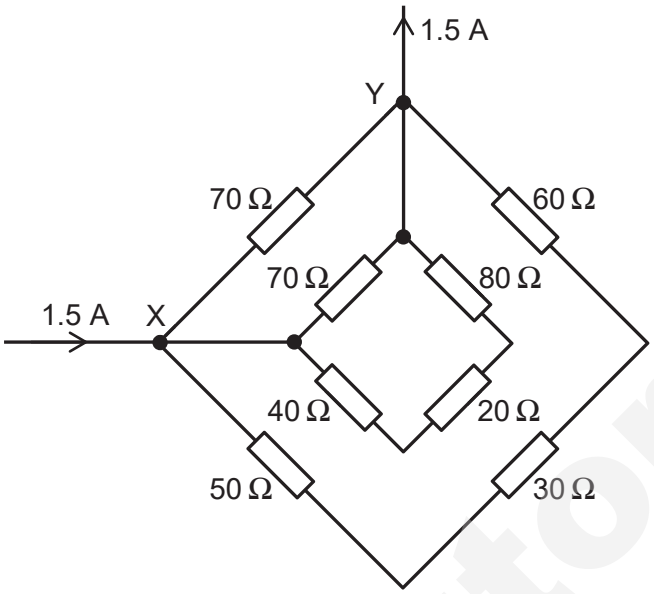
**22** Eight resistors are arranged as shown.

A current of 1.5 A enters the network at junction X and leaves through junction Y.




What is the current in the resistor of resistance 30 Ω?

**A** 0.25 A

**B** 0.50 A

**C** 0.75 A

**D** 1.0 A

**23** Differently charged ions are all fired at the same speed into a region where there is a uniform magnetic field at right angles to their initial path.

Which ion travels in a circular path of the smallest radius?

**A** singly charged ion with mass 6*m*

**B** doubly charged ion with mass 6*m*

**C** doubly charged ion with mass 12*m*

**D** singly charged ion with mass 16*m*

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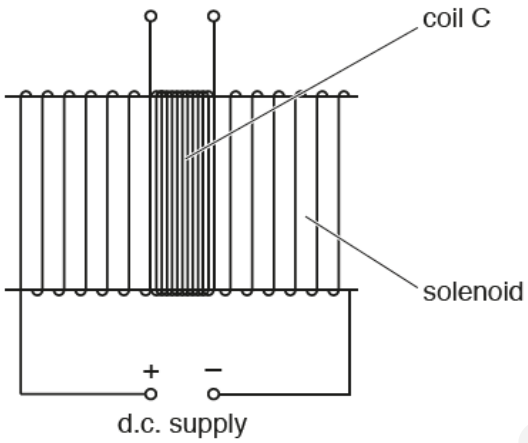
**24** A solenoid has a coil C of wire wound tightly about its centre as shown.




Coil C has 96 turns.

The uniform magnetic flux $\phi$ (in weber) in the solenoid is given by the expression

$$\phi = 6.8 \times 10^{-6} \times I$$

where $I$ is the current (in amperes) in the solenoid.

What is the average e.m.f. induced in coil C when a current of 3.3 A is reversed in the solenoid in a time of 2.4 ms?

**A** 0.0094 V

**B** 0.019 V

**C** 0.90 V

**D** 1.8 V

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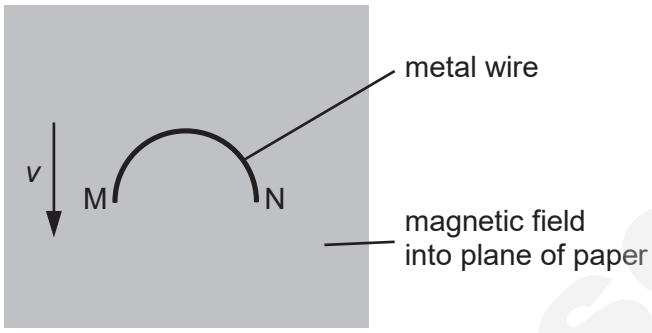
**25** The diagram shows a thin semicircular metal wire MN of radius *r* falling through a region of uniform magnetic field of magnetic flux density *B*.

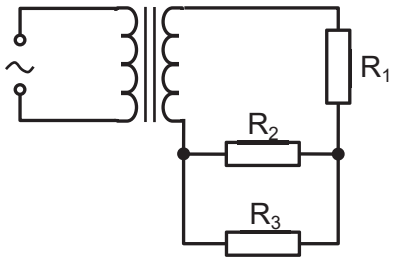



The wire is falling with speed *v* and the plane of the wire is normal to the direction of the field.

What is the magnitude of the induced e.m.f. in MN and which end will be at a higher potential?

| | magnitude of induced e.m.f. | end at higher potential |
|---|---|---|
| **A** | $2Brv$ | M |
| **B** | $\pi Brv$ | M |
| **C** | $2Brv$ | N |
| **D** | $\pi Brv$ | N |

**26** The secondary coil of a 2:1 step-down transformer is connected to three identical resistors $R_1$, $R_2$ and $R_3$ each of resistance 80 Ω as shown.




The alternating supply to the primary coil delivers a peak voltage of 180 V.

What is the value of the average power dissipated in $R_1$?

**A** 11 W

**B** 23 W

**C** 45 W

**D** 90 W

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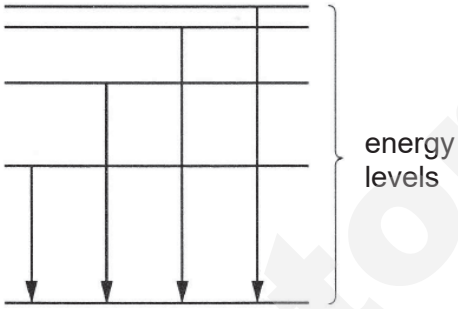
**27** Electrons are accelerated from rest through a potential difference $V$.

What is the relationship between the de Broglie wavelength $\lambda$ of the electrons and $V$?

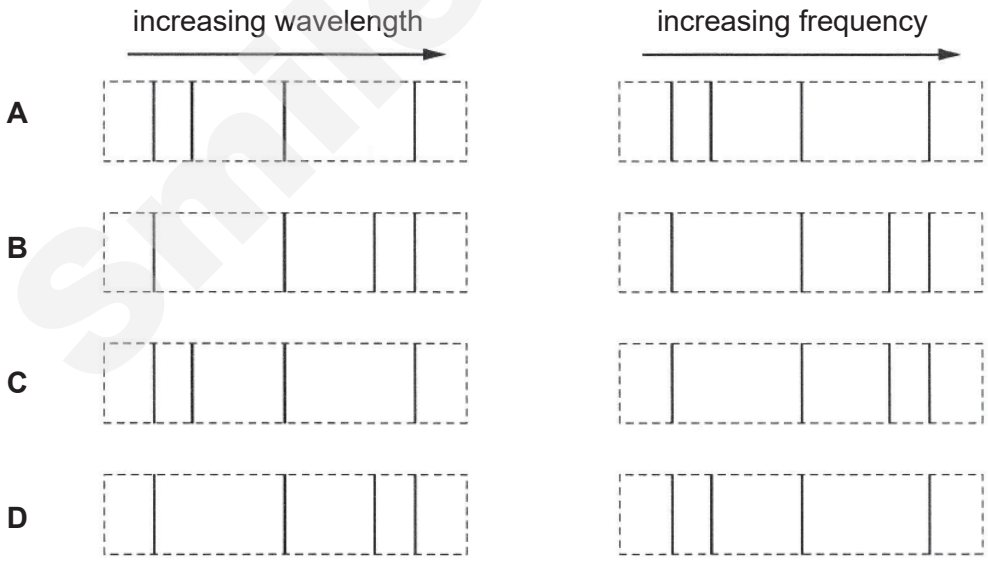
**A** $\lambda \propto \frac{1}{\sqrt{V}}$ **B** $\lambda \propto \sqrt{V}$ **C** $\lambda \propto \frac{1}{V}$ **D** $\lambda \propto V$

**28** The diagram shows five electron energy levels in an atom and some transitions between them.




The line spectrum produced can be represented on a wavelength scale or a frequency scale.

Which diagrams best represent the electromagnetic radiation emitted by the transitions shown above?

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**29** It was once thought that the mass of an atom is spread uniformly through the volume of the atom. When α-particles are directed at a piece of gold foil, the results led scientists to believe instead that nearly all the mass of the gold atom is concentrated at a point inside the atom.

Which effect is possible only if nearly all the mass of the gold atom is concentrated at a point?

**A** A few α-particles bounce back.

**B** Most α-particles are only slightly deflected.

**C** Some α-particles pass through without any deflection.

**D** Some α-particles are absorbed.

**30** The isotope $^{222}_{86}Rn$ decays in a sequence of emissions to form the isotope $^{214}_{84}Po$. At each stage of the decay sequence, it emits either an α-particle or a β-particle.

What is the number of stages in the decay sequence?

**A** 3

**B** 4

**C** 5

**D** 6

**End of paper**

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Name: _____ Class: _____

# JURONG PIONEER JUNIOR COLLEGE

## JC2 Preliminary Examination

**PHYSICS** **9749/02**

**Higher 2** **20 September 2019**

Paper 2 Structured Questions **2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

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

Answer **all** questions.

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

| For Examiner's Use | |
|---|---|
| **1** | / 10 |
| **2** | / 11 |
| **3** | / 10 |
| **4** | / 8 |
| **5** | / 8 |
| **6** | / 11 |
| **7** | / 22 |
| **Total** | / 80 |



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**Data**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on/by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -\frac{GM}{r}$ |
| temperature | $T\,/\,\mathrm{K} = T\,/\,^{\circ}\mathrm{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t$<br>$= \pm\omega\sqrt{{x_0}^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + ...$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + ...$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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Answer **all** questions in the spaces provided

**1** An aeroplane is at rest on a runway. It accelerates in a straight line along the runway and takes off after 55.0 s.

Fig. 1.1 shows the variation with time of the resultant force acting on the aeroplane while it is in contact with the runway.

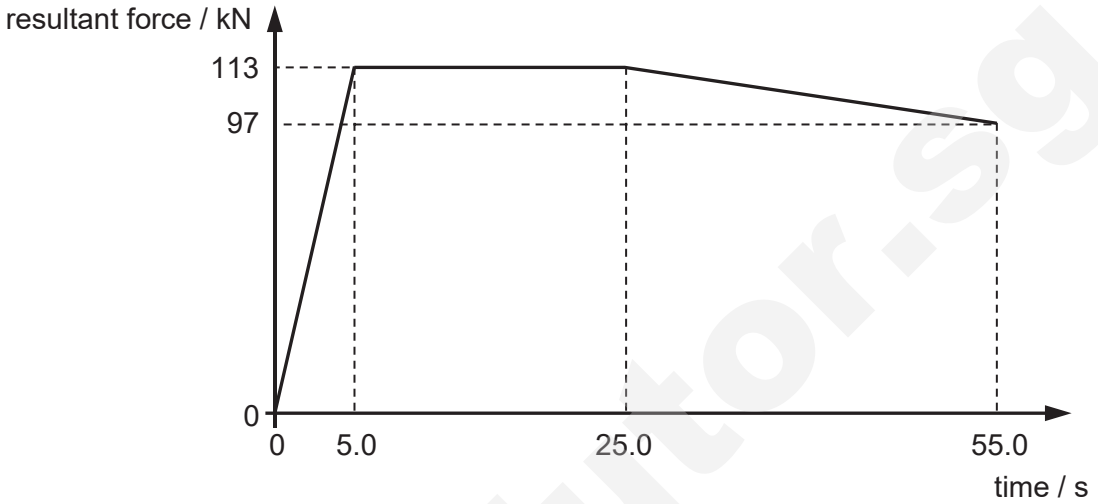


**Fig. 1.1**

**(a)** State two reasons why the resultant force on the aeroplane is not constant as it travels along the runway.

1. .....

.....

2. .....

..... [2]

**(b)** Calculate the momentum of the aeroplane at take-off.

momentum = ..... N s [3]



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**(c)** The total mass of the aeroplane is $7.45 \times 10^4$ kg.

Calculate the velocity $v_{max}$ of the aeroplane at take-off.

$v_{max}$ = ……..……..…..... m $s^{-1}$ [1]

**(d)** On Fig. 1.2, sketch a graph to show the variation with time of the velocity of the aeroplane as it travels along the runway. (Numerical values for the velocity are not required.)

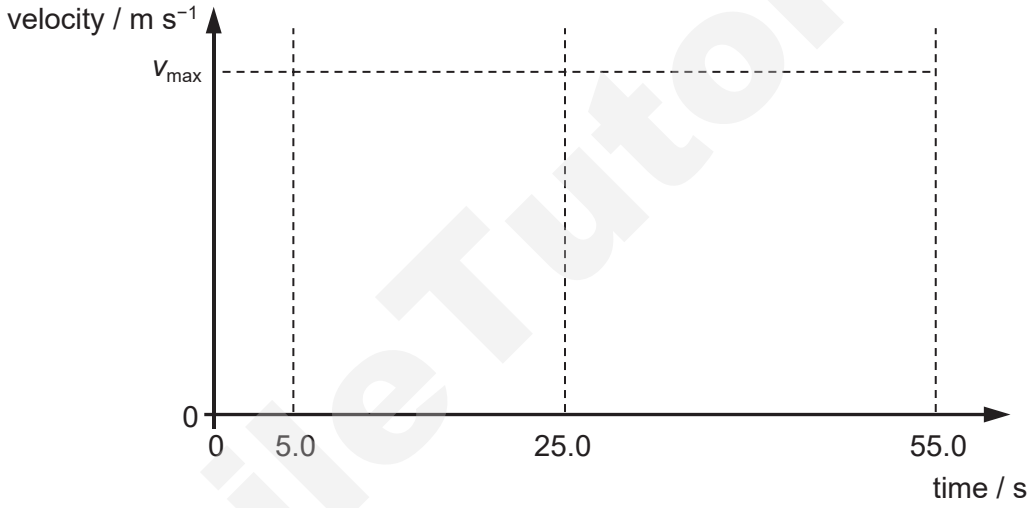


**Fig. 1.2**

[2]

**(e)** Estimate the distance the aeroplane travels along the runway.

distance = ……..……..…..... m [2]

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**2** A roller coaster car of mass 380 kg slides down a smooth slope and executes a loop of diameter *d*. After the loop, it experiences friction only in the area denoted as zone A, as shown in Fig. 2.1.

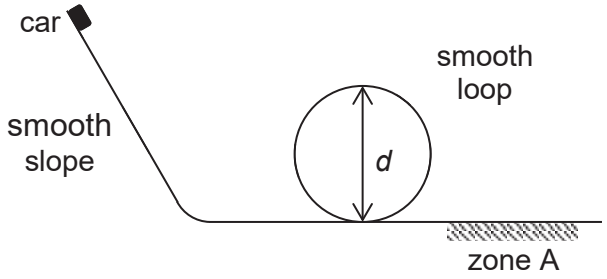


**Fig. 2.1**

The variations of gravitational potential energy and kinetic energy of the car with time *t* are shown in Fig. 2.2.

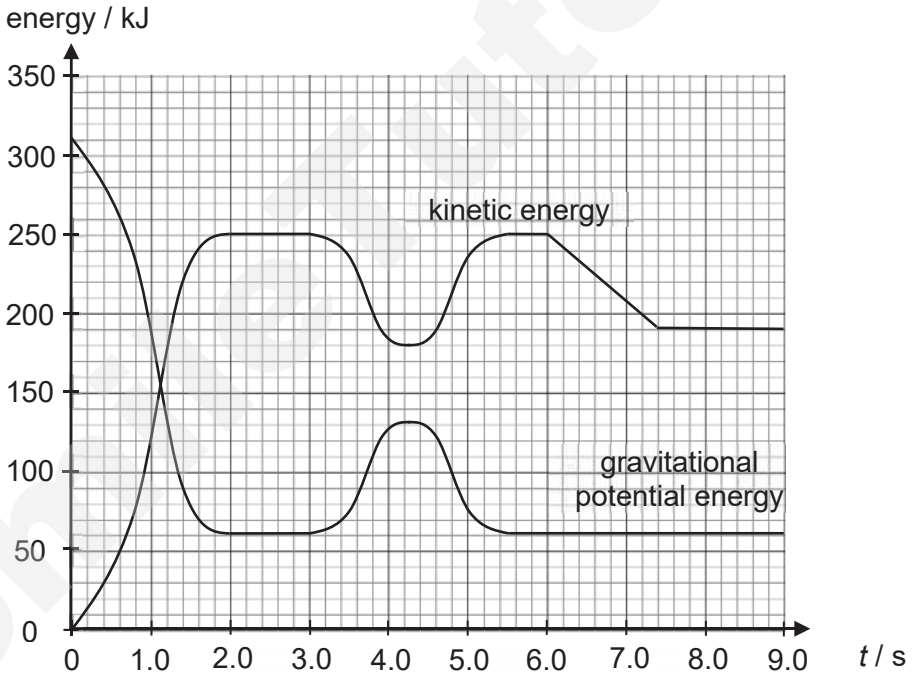


**Fig. 2.2**

**(a)** On Fig. 2.2, sketch the variation of total mechanical energy with time of the car, from $t = 0$ s to $t = 9.0$ s. [2]



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**(b)** Between $t$ = 3.0 s and $t$ = 5.4 s, the car executes the loop.

Using Fig. 2.2, calculate $d$.

$d$ = ……..……..…..... m [2]

**(c) (i)** State the start and end times at which the car is within zone A.

start time = ……..……..……..…..... s

end time = ……..……..…..... s [1]

**(ii)** Calculate the rate at which the car loses kinetic energy in zone A.

rate = ……..……..…..... W [2]

**(iii)** Calculate the speed of the car when it first enters zone A.

speed = ……..……..…..... m $s^{-1}$ [2]

**(iv)** Hence, calculate the magnitude of the frictional force acting on the car when it first enters zone A.

force = ……..……..…..... N [2]

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**3** **(a)** Explain what is meant by *internal energy* of a gas.

.....

.....

..... [1]

**(b)** The pressure $p$ of an ideal gas of density $\rho$ is related to the mean-square speed of its molecules by the expression

$$p = \frac{1}{3}\rho\langle c^2 \rangle$$

Show that the average kinetic energy of a molecule of an ideal gas is proportional to its thermodynamic temperature $T$.

[2]

**(c)** An engine operates by using 0.024 mol of an ideal gas. The gas undergoes a cycle of changes as shown in Fig. 3.1.

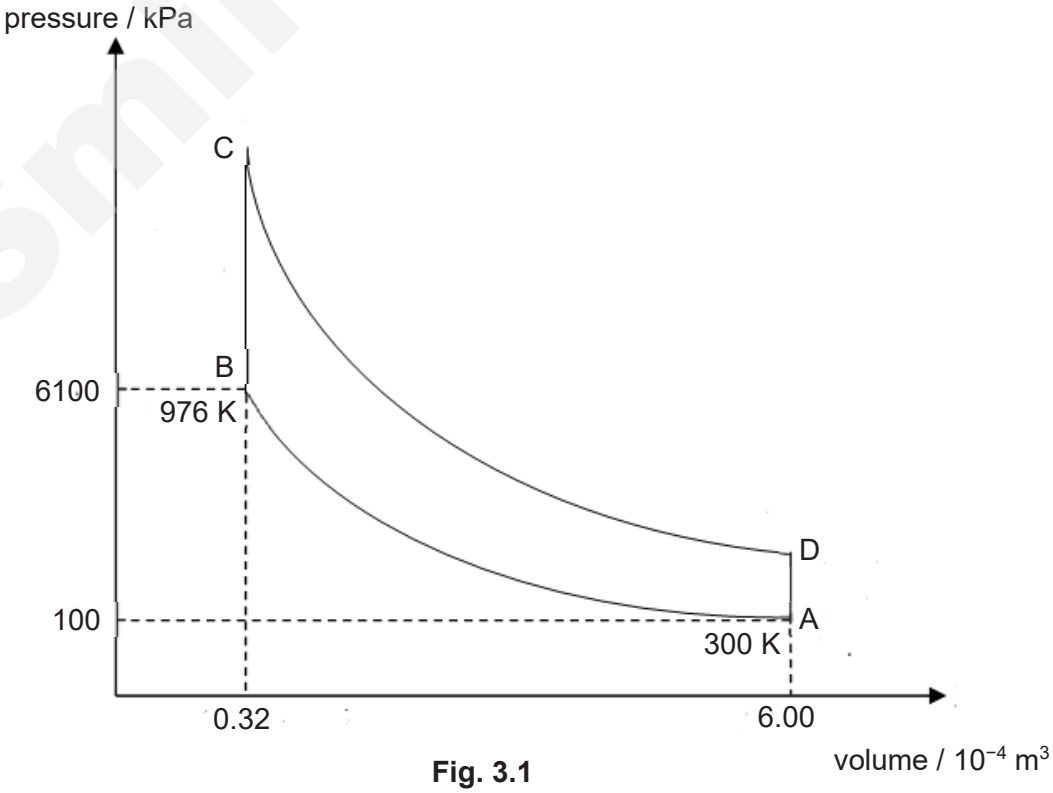


**Fig. 3.1**



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The temperature of the gas at A and B are 300 K and 976 K respectively.

**(i)** Given that the gas gains 250 J of heat during a heating process at constant volume from B to C, determine

**1.** the temperature at C,

temperature = ..... K [3]

**2.** the pressure at C.

pressure = ..... Pa [1]

**(ii)** Fig. 3.2 shows some of the values of changes in Fig. 3.1.

Complete Fig. 3.2.

| change | heat supplied to gas / J | work done by gas / J | increase in internal energy / J |
|---|---|---|---|
| A to B | 0 | −200 | |
| B to C | 250 | | |
| C to D | 0 | | |
| D to A | −100 | | |

**Fig. 3.2**

[3]

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**4** Fig. 4.1 shows two identical solenoids with their axes aligned and the two opposite faces at a distance of 0.20 m apart.

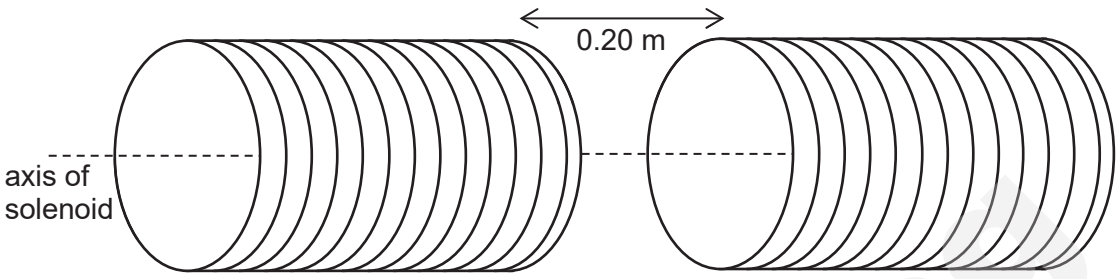


**Fig. 4.1**

The space between the solenoids is a vacuum with a uniform magnetic flux density of $1.2 \times 10^{-3}$ T.

An electron moving with speed $5.0 \times 10^{7}$ m s$^{-1}$ normal to the magnetic field between the solenoids traces an arc of a circular path.

**(a) (i)** Determine the radius of the circular path.

radius = ……..……..…..... m [2]

**(ii)** State and explain whether the electron will collide with any of the solenoids.

……

……

…… [2]



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**(b)** In another similar experiment described above, the electron is found to spiral inwards with decreasing radius even though the magnetic field remains constant.

With reference to the speed of the electron, suggest a reason for this motion.

...

...

..... [2]

**(c)** A uniform electric field is applied in the region of the magnetic field so that the electron continues undeflected through the two fields.

Determine the magnitude of the electric field strength $E$.

$E$ = ..... N $C^{-1}$ [2]

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**5** **(a)** When monochromatic radiation is incident on a clean cadmium surface, electrons with a range of kinetic energies up to a maximum of $3.65 \times 10^{-20}$ J are released. The work function of cadmium is 4.07 eV.

**(i)** Explain what is meant by *work function*.

.....

..... [1]

**(ii)** Explain why the emitted electrons have a range of kinetic energies up to a maximum.

.....

.....

.....

..... [2]

**(iii)** Calculate the wavelength of the radiation.

wavelength = ..... m [2]

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**(b)** In the wave model of electromagnetic radiation, electrons near the surface of a metal absorb energy from the wave.

**(i)** The radiation incident on the cadmium surface in **(a)** delivers energy at a rate of $3.0 \times 10^{-22}$ J $s^{-1}$.

Calculate the minimum time it would take an electron to absorb sufficient amount of energy to be emitted from the metal surface.

time = ..... s [1]

**(ii)** In the actual experiment conducted, photoelectrons are observed to be emitted without any time lag.

Explain how this observation provides evidence for the particulate nature of electromagnetic radiation.

……

……

……

…… [2]

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**6** Tritium is an isotope of hydrogen and is represented by the symbol ${}^{3}_{1}\mathrm{H}$.

**(a)** Explain the term *isotope*.

.....

..... [1]

**(b)** Tritium has a binding energy per nucleon of 2.83 MeV.

**(i)** Explain what is meant by the *binding energy* of a nucleus.

.....

..... [1]

**(ii)** Given that the mass of a proton is 1.00783 *u* and the mass of a neutron is 1.00867 *u*, calculate, to five decimal places, the mass of a tritium nucleus.

mass = ..... *u* [3]

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**(c)** In a fusion power reactor, two deuterium nuclei fuse together to form a tritium nucleus.

**(i)** Complete the nuclear equation below for the fusion of deuterium.

$$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + \text{……..}$$

[1]

**(ii)** For the fusion of deuterium shown in **(i)**, 4.03 MeV of energy is released.

Calculate

**1.** the binding energy of a deuterium nucleus,

binding energy = ..... MeV [2]

**2.** the mass of deuterium required per unit time to produce $2.86 \times 10^{9}$ W of power.

mass = ..... kg [3]

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**7** The decay of radioactive materials is a random process. On average, nuclides which decay rapidly exist for a shorter time than nuclides which decay slowly. It is common practice when making calculations on decay to make use of the half-life of a nuclide. One difficulty that arises with these calculations is when the radioactive material is a mixture of two or more nuclides.

This question considers the case when a mixture of two radioactive nuclides is present. In decommissioning a nuclear power station, this difficulty is compounded by the presence of about a hundred different radioactive nuclides in significant quantities.

**(a)** Explain what is meant by a *random* process.

……..

.....

..... [2]

**(b)** Define *half-life*.

……..

.....

..... [1]

**(c)** $^{131}_{52}\mathrm{Te}$ decays by $\beta$ emission to $^{131}_{53}\mathrm{I}$. $^{131}_{53}\mathrm{I}$ is not stable, and decays by $\beta$ emission to the stable isotope Xe, but the half-life for this decay is very much longer than that for the decay of $^{131}_{52}\mathrm{Te}$. A sample of pure $^{131}_{52}\mathrm{Te}$ is prepared at time $t$ = 0, and Fig. 7.1 shows the variation with time of the activity $A$ of the whole sample. Background radiation can be ignored.

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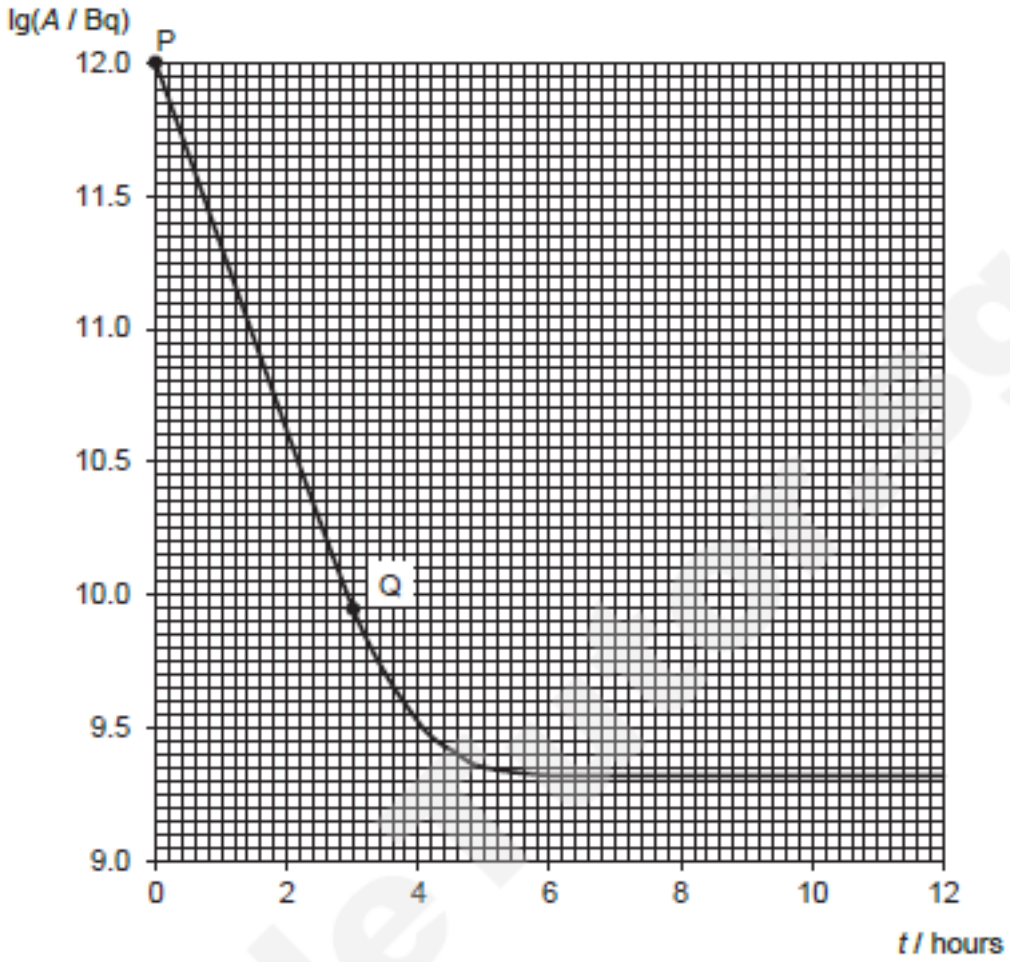


Fig. 7.1

(i) Write down the nuclear equation for the decay of $^{131}_{53}I$ to Xe, showing the mass number and atomic number of the isotope Xe clearly.

..... [2]

(ii) Explain why the part PQ on the graph corresponds mainly to the decay of $^{131}_{52}Te$.

.....

.....

..... [2]

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**(iii)** Determine the gradient of PQ.

gradient = ..... [2]

**(iv)** Hence, or otherwise,

**1.** show that the half-life of $^{131}_{52}Te$ is approximately 0.44 hours,

[3]

**2.** determine the initial number of $^{131}_{52}Te$ nuclides in the sample.

number of nuclides = ..... [2]

**(v)** Explain why the graph seems flat after a time of 6 hours.

.....

.....

..... [2]



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**(vi)** Hence, calculate the half-life of $^{131}_{53}\mathrm{I}$.

half-life = ..... hours [3]

**(d)** Suggest why background radiation can be ignored in this question.

.....

.....

..... [1]

**(e)** State and explain whether these two radioactive nuclides would pose any hazard if found when de-commissioning a nuclear reactor.

.....

.....

..... [2]

**End of paper**

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Name: _____ Class: _____

# JURONG PIONEER JUNIOR COLLEGE

## JC2 Preliminary Examination

**PHYSICS** **9749/03**
**Higher 2** **25 September 2019**

Paper 3 Longer Structured Questions **2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

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

**Section A**
Answer **all** questions.

**Section B**
Answer any **one** question only.

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

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

| For Examiner's Use | |
|---|---|
| **1** | / 8 |
| **2** | / 9 |
| **3** | / 8 |
| **4** | / 8 |
| **5** | / 10 |
| **6** | / 9 |
| **7** | / 8 |
| **8** | / 20 |
| **9** | / 20 |
| **Total** | / 80 |



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**Data**

| | |
|---|---|
| speed of light in free space | $c = 3.00 \times 10^{8}$ ms$^{-1}$ |
| permeability of free space | $\mu_0 = 4\pi \times 10^{-7}$ Hm$^{-1}$ |
| permittivity of free space | $\varepsilon_0 = 8.85 \times 10^{-12}$ Fm$^{-1}$ |
| | $= (1/(36\pi)) \times 10^{-9}$ Fm$^{-1}$ |
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| the Avogadro constant | $N_A = 6.02 \times 10^{23}$ mol$^{-1}$ |
| the Boltzmann constant | $k = 1.38 \times 10^{-23}$ JK$^{-1}$ |
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| acceleration of free fall | $g = 9.81$ ms$^{-2}$ |

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on/by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\varphi = -\frac{GM}{r}$ |
| temperature | $T\,/\,\mathrm{K} = T\,/\,^\circ\mathrm{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t$<br>$= \pm\omega\sqrt{{x_0}^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + ...$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + ...$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

**1** An experiment to determine the acceleration of free fall $g$ is conducted by projecting a stone with speed $u$ at an angle $\theta$ to the horizontal. The horizontal distance $R$ travelled by the stone when it returns to the level of projection is measured. Air resistance is negligible.

**(a)** In determining the speed of the stone, a student defines speed as "distance travelled per second".

Explain why this definition is physically incorrect.

.....

.....

..... [2]

**(b)** Show that $R$ is given by the expression

$$R = \frac{2u^2 \sin\theta \cos\theta}{g}.$$

[2]

**(c)** The above expression can be written as

$$R = \frac{u^2 \sin 2\theta}{g}.$$

The experiment is conducted to obtain the maximum range $R_0$.

Determine the value of $\theta$ to obtain $R_0$.

$\theta$ = ..... ° [1]

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**(d)** The values of $u$ and $R_0$ are 12.6 m $s^{-1}$ and 16.3 m, with associated percentage uncertainties of 3% and 4% respectively.

Calculate the value of $g$, and present the answer together with its uncertainty.

$g$ = .....±..... m $s^{-2}$ [3]

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**2** A light helical spring is suspended vertically from a fixed point, as shown in Fig. 2.1.

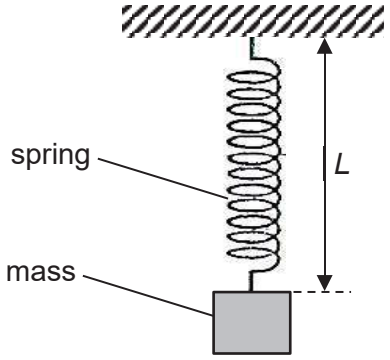


**Fig. 2.1**

Different masses are suspended from the spring. The weight $W$ of the mass and the length $L$ of the spring are recorded.

The variation with weight $W$ of the length $L$ is shown in Fig. 2.2.

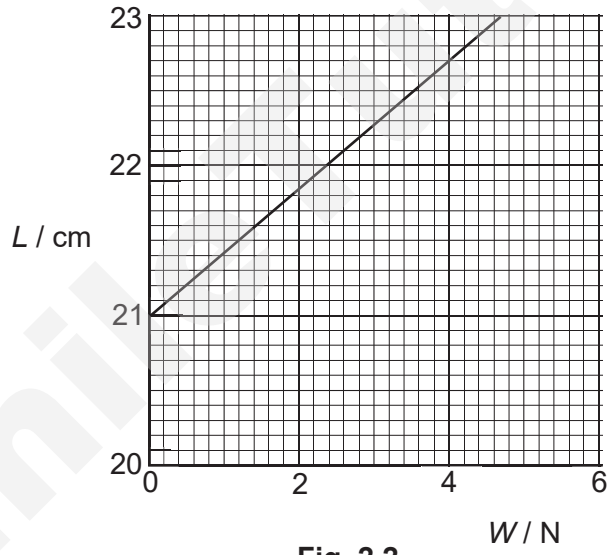


**Fig. 2.2**

**(a)** A mass of weight 2.6 N is suspended from the spring.

When the mass is stationary, it is then pulled downwards a distance of 0.60 cm and held stationary.

For the increase in extension of 0.60 cm, determine the magnitude of the change in

**(i)** the gravitational potential energy of the mass,

change = ..... J [1]

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**(ii)** the elastic potential energy of the spring.

change = ..... J [2]

**(b)** The mass in **(a)** is now released. The mass performs simple harmonic motion.

**(i)** Use your answers in **(a)** to show that the total energy of oscillation of the mass is 0.0042 J.

[1]

**(ii)** Calculate the angular frequency of the oscillation.

angular frequency = ..... rad $s^{-1}$ [2]

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**(c)** A light card is attached to the mass, as shown in Fig. 2.3. The mass is pulled downwards a distance of 0.60 cm, and released at $t = 0$.

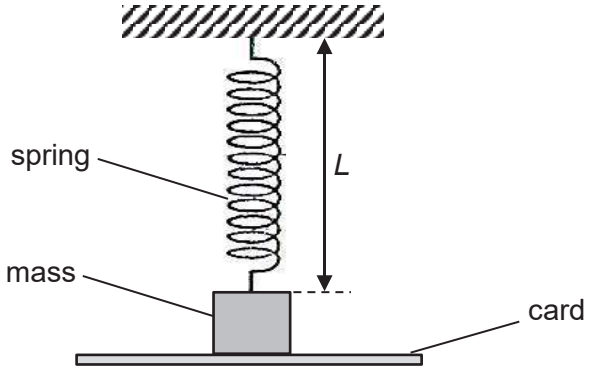


**Fig. 2.3**

The length of the spring is 21.7 cm after the first half of an oscillation.

Calculate the magnitude of the average force due to air resistance on the oscillating system.

force = ..... N [3]

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**3** Two sources of sound $S_1$ and $S_2$ emit waves of frequency 220 Hz in phase as shown in Fig. 3.1.

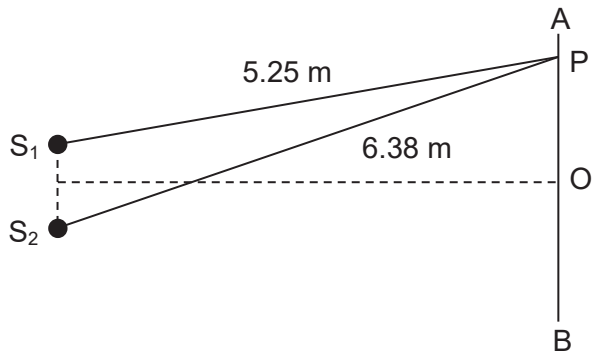


**Fig. 3.1**

**(a)** Sound wave is a longitudinal wave.

Explain what is meant by a longitudinal wave.

.....

.....

..... [1]

**(b)** At point P along the line AB, the waves are found to have a phase difference of $\frac{3}{2}\pi$ rad. $S_1$ and $S_2$ are 5.25 m and 6.38 m away from P respectively. For the sound waves emitted, determine

**(i)** the wavelength,

wavelength = ..... m [2]

**(ii)** the speed.

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

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**(c)** Point O is equidistant from $S_1$ and $S_2$. Sound waves from $S_1$ and $S_2$ arrive at O with intensities $I$ and $3I$ respectively.

Determine the resultant intensity at O in terms of $I$.

resultant intensity = ..... [3]

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**4** **(a)** Sound waves produced by a loudspeaker arrive at the microphone M via two different paths, LXM and LYM as shown in Fig.4.1. The left-tube is fixed in position, while the right-tube is a sliding-section.

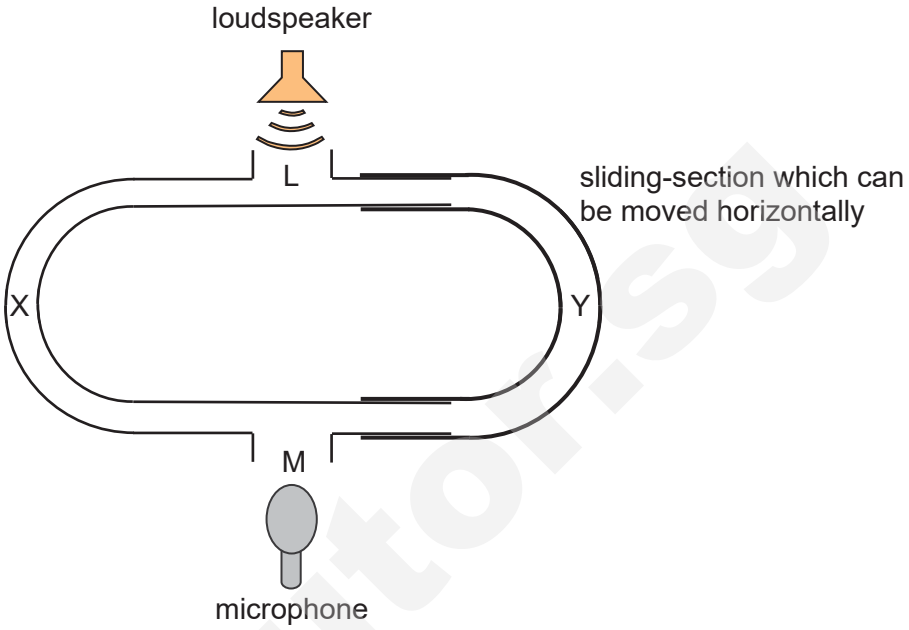


**Fig. 4.1**

Initially, the lengths of paths LXM and LYM are equal. The sliding-section is then pulled out horizontally to the right by a distance of 0.020 m, and the loudness detected at microphone M changes from a maximum to a minimum.

**(i)** Determine the wavelength of the sound waves.

wavelength = ..... m [2]

**(ii)** When the opening at M is subsequently sealed, explain why a stationary (standing) wave can be set up in the tube.

.....

.....

.....

..... [2]

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**(b)** Fig. 4.2 shows a monochromatic light of wavelength 600 nm passing through fine nylon threads. The threads act as a diffraction grating with lines in the horizontal direction. Part of the pattern of light showing the central bright fringe and its first two adjacent fringes on the screen is shown in Fig. 4.3.

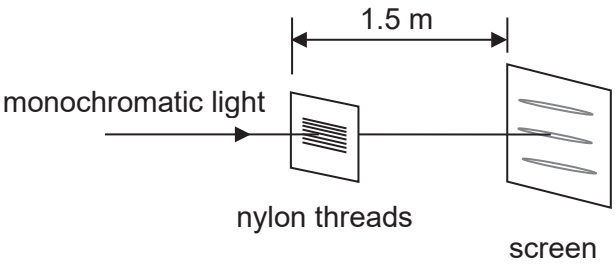


**Fig. 4.2**



**Fig. 4.3 (full size)**

**(i)** Calculate the angle between the two first orders of the diffracted light.

angle = ..... ° [2]

**(ii)** Using your answer to **(i)**, determine the number of nylon threads per millimetre.

number of threads per millimetre = ..... [2]

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**5** Four point charges, each of magnitude $q$, are placed at the corners of a square ABCD of side $a$ as shown in Fig. 5.1 below.

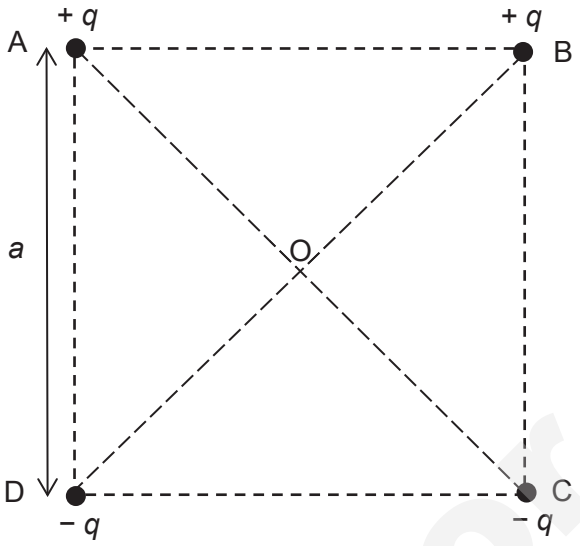


**Fig. 5.1**

Point O is the centre of the square.

**(a)** Define *electric field strength* at a point.

.....

.....

..... [1]

**(b) (i)** On Fig. 5.1, draw and label an arrow to show the resultant electric field strength $E$ at O.

[1]

**(ii)** Show that the electric field strength at O is $\frac{\sqrt{2}q}{\pi\varepsilon_o a^2}$.

[3]

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**(c)** A positively charged particle is projected into the square along a line that lies in the plane of the square as shown in Fig. 5.2. The line bisects the side AB.

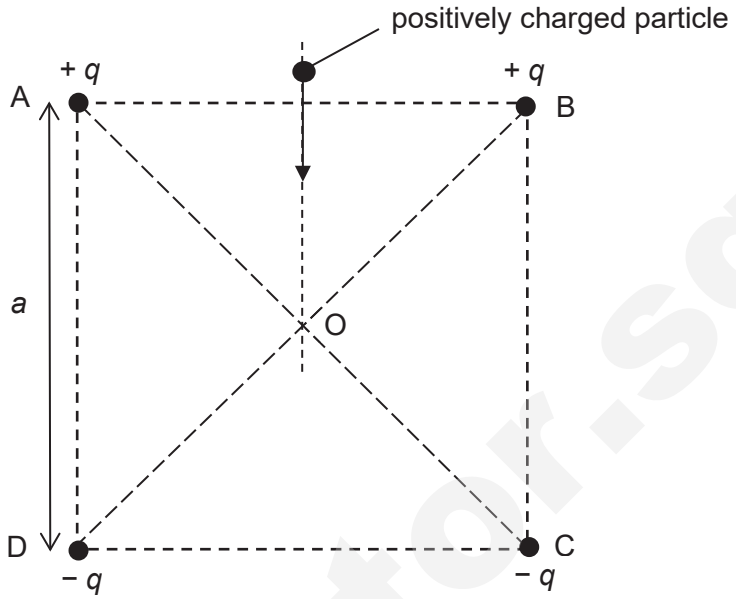


**Fig. 5.2**

Describe the motion of the particle after passing AB.

.....

.....

..... [2]

**(d)** Determine in terms of $q$, $a$ and $\varepsilon_o$, the minimum kinetic energy required for the charge at C to move to infinity.

minimum kinetic energy = ..... [3]

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**6** **(a)** A solenoid is connected to a variable d.c. supply as shown in Fig. 6.1.

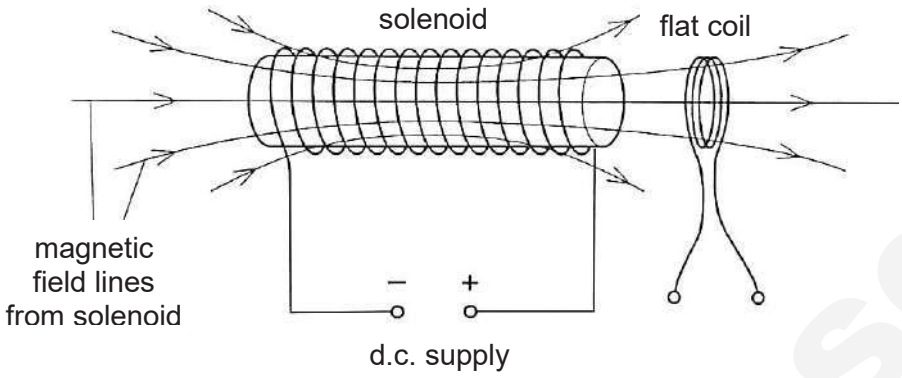


**Fig. 6.1**

A flat coil of diameter 6.4 cm and 180 turns is placed close to one end of the solenoid. The coil has a resistance of 1.5 Ω. The current in the solenoid is reduced. Fig. 6.2 shows the variation of the magnetic flux density $B$ at right angles to the plane of the coil with time $t$.

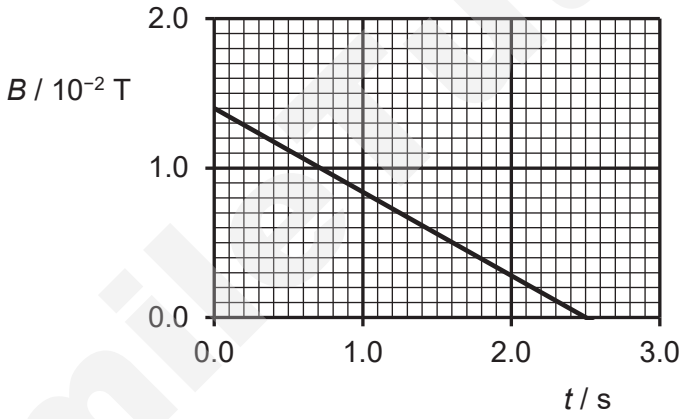


**Fig. 6.2**

**(i)** Use Fig. 6.2 to explain why the induced e.m.f. across the ends of the coil has a constant value from $t$ = 0 s to $t$ = 2.5 s.

.....

.....

.....

..... [2]

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**(ii)** Calculate the magnitude of the charge that flows through the coil from $t$ = 0 s to $t$ = 2.5 s.

charge = ……..……..…..... C [3]

**(b)** Fig. 6.3 shows a transformer circuit.

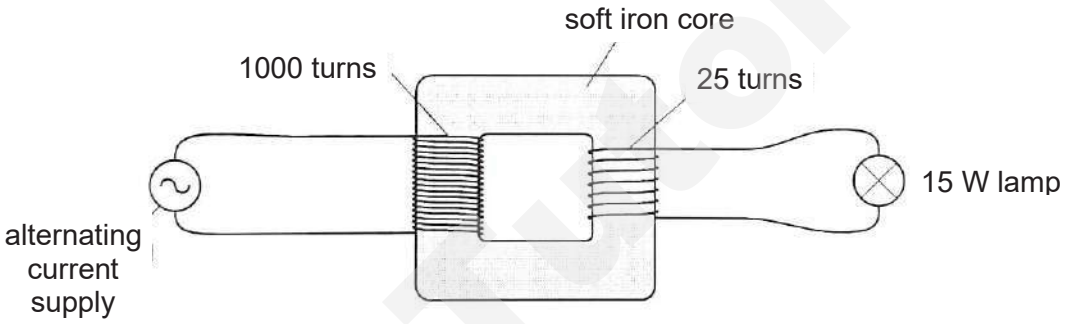


**Fig. 6.3**

The primary coil has 1000 turns and the secondary coil 25 turns. A lamp is connected to the output of the secondary coil. The potential difference across the lamp is 6.0 V and the lamp dissipates 15 W. The transformer has an efficiency of 100%.

**(i)** Calculate the current in the primary circuit.

current = ……..……..…..... A [2]

**(ii)** The alternating voltage supply is replaced by a battery.

Explain why the p.d. across the lamp increases but becomes zero some time after the battery is connected.

……

……

…….. [2]

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**7** **(a)** Some of the energy levels of a particular atom X are shown in Fig. 7.1.

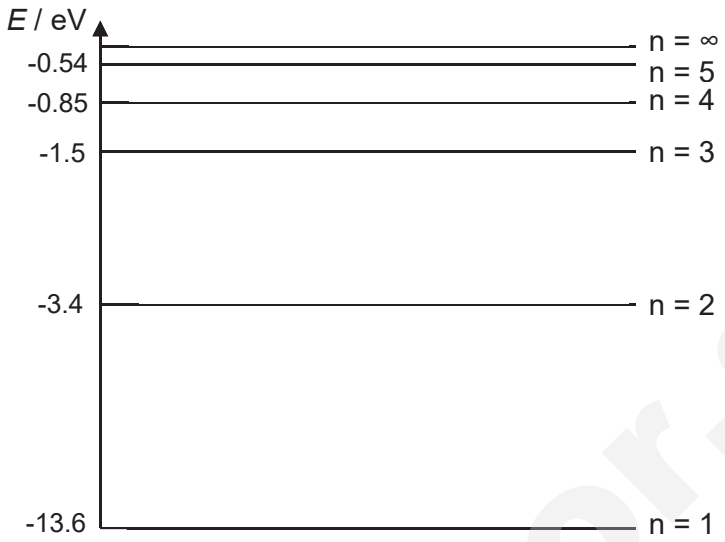


**Fig. 7.1**

**(i)** State the ionisation energy of atom X.

ionisation energy = ..... eV [1]

**(ii)** Cool vapour of X at low pressure is bombarded with electrons of kinetic energy $2.00 \times 10^{-18}$ J.

Determine the number of different wavelengths of radiation that will be emitted.

number of wavelengths = ..... [2]

**(iii)** The electrons in **(ii)** were replaced with photons of the same energy to bombard the cool vapour of X.

Suggest the number of different wavelengths of radiation that will be emitted. Explain your answer.

.....

.....

..... [2]

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**(b)** An X-ray spectrum is first produced by an X-ray tube with tungsten. Another X-ray spectrum is then produced using barium and both spectra are shown in Fig. 7.2.

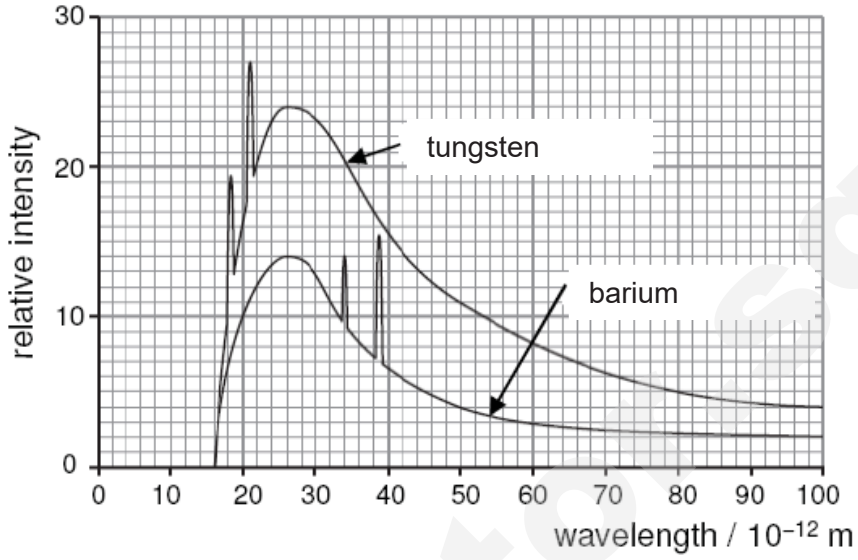


**Fig. 7.2**

**(i)** The accelerating potential used to produce the X-ray spectra using tungsten and barium are the same.

By reference to Fig. 7.2, state a feature how this can be deduced.

..... [1]

**(ii)** Hence, determine the accelerating potential.

accelerating potential = ..... V [2]

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## Section B

Answer **one** question from this section.

**8** **(a)** Explain why a body moving with uniform speed in a circle must experience a force towards the centre of the circle.

.....

.....

.....

..... [2]

**(b)** A small ball of mass *m* is moving in a horizontal circle on the inside surface of a frictionless hemispherical bowl. The normal reaction force *N* makes an angle $\theta$ to the horizontal and is directed along QO, which is the radius of the bowl. The radius of the bowl is 8.0 cm and $\theta$ is 22º.

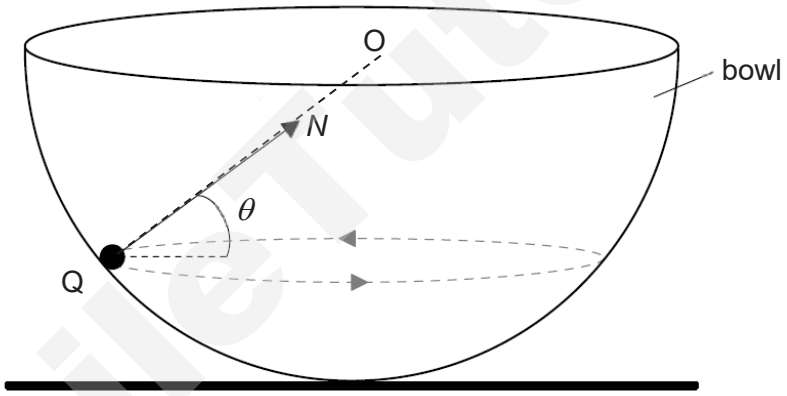


**Fig. 8.1**

**(i)** Determine the speed of the ball.

speed = ..... m $s^{-1}$ [4]

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**(ii)** Explain whether this ball can move on a horizontal circular path of radius equal to the radius of the bowl.

.....

.....

..... [1]

**(c)** A planet has radius $R$. At a distance $h$ above the surface of the planet, the gravitational field strength is $g$ and the gravitational potential is $\phi$.

**(i)** Define *gravitational potential* at a point.

.....

.....

.....

..... [2]

**(ii)** Show that $\phi = -g(R + h)$.

[2]

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**(iii)** A space probe moves past the planet with speed $u$ as shown in Fig. 8.2.

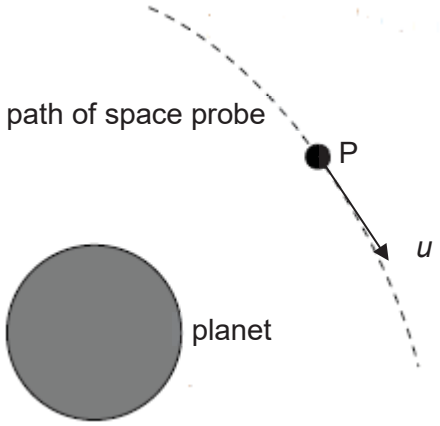


**Fig. 8.2**

The radius $R$ of the planet is $3.3 \times 10^6$ m. A point P, located at $1.4 \times 10^7$ m above the surface of the planet, has a gravitational field strength of 0.15 N kg$^{-1}$.

Determine the minimum value of $u$ such that the space probe at point P is just able to escape from the gravitational attraction of the planet.

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

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**(iv)** The variation with distance $r$ (in terms of radius $R$ of the planet) from the centre of the planet of the gravitational potential $\phi$ is as shown in Fig. 8.3.

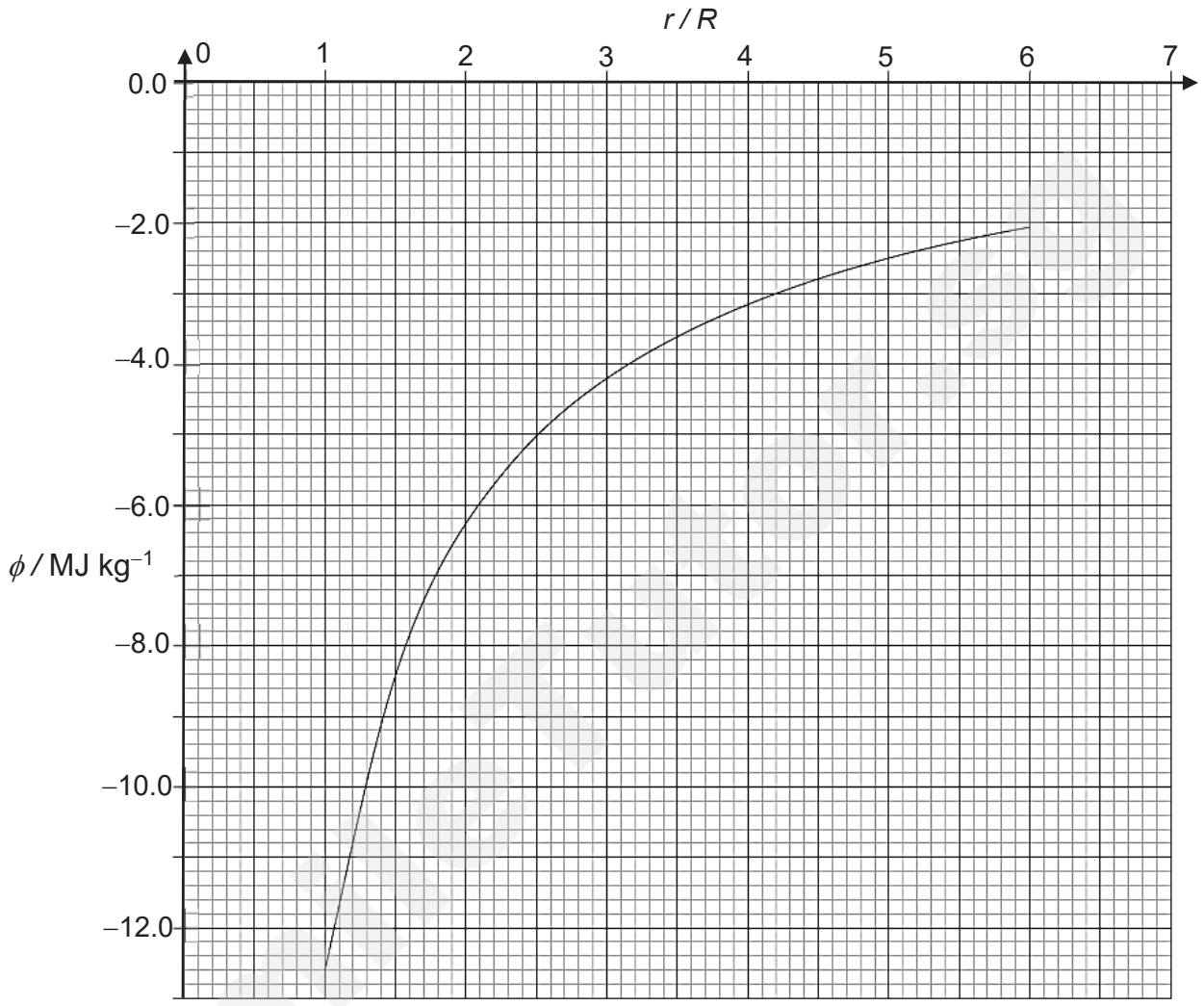


**Fig. 8.3**

A rocket of mass $1.2 \times 10^4$ kg lifts off from the surface of the planet.

**1.** Determine the change in gravitational potential energy of the rocket when it reaches a distance $4R$ from the centre of the planet.

change = ..... J [2]

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**2.** Determine the magnitude of the gravitational field strength at a distance $4R$ from the centre of the planet.

magnitude = ..... N kg$^{-1}$ [2]

**3.** Using the answer from **2.**, calculate the magnitude of the gravitational field strength at the surface of the planet.

magnitude = ..... N kg$^{-1}$ [2]

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**9** **(a)** Define the *volt*.

.....

..... [1]

**(b)** By reference to energy transfers, distinguish between e.m.f. and p.d.

e.m.f. .....

.....

p.d. .....

..... [2]

**(c)** The current flowing through a light bulb can be controlled by a potential divider as shown in Fig. 9.1.

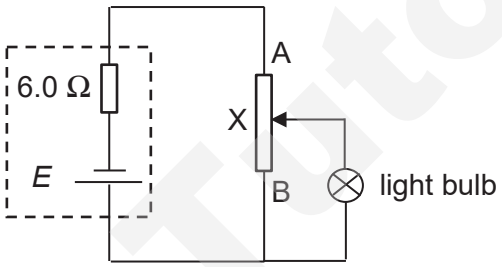


**Fig. 9.1**

AB is a potentiometer wire of uniform cross-sectional area with a total resistance of 16 Ω. It is connected to a battery of e.m.f. *E* and internal resistance 6.0 Ω and a light bulb. When the slider of the potentiometer wire is set at X, exactly mid-way along AB, the bulb has an operating power of 0.50 W and voltage of 2.0 V.

**(i)** Calculate the current through section XB of the potentiometer wire.

current = ..... A [2]

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**(ii)** Calculate the potential difference across section AX of the potentiometer wire.

potential difference = ..... V [3]

**(iii)** Determine the e.m.f. *E* of the battery.

*E* = ..... V [2]

**(d)** The current flowing through the light bulb can also be controlled using a variable resistor as shown in Fig. 9.2.

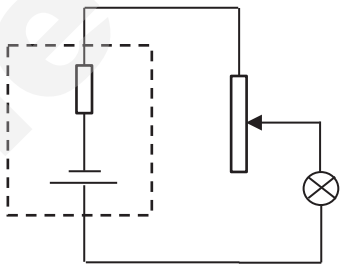

**Fig. 9.2**

State an advantage and disadvantage of using the variable resistor as compared to the potential divider in controlling the current through the light bulb.

……..

……..

……..

…… [2]

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**(e)** Fig. 9.3 shows two cells $E_1$ and $E_2$ of negligible internal resistances connected with a variable resistor R in a potentiometer circuit. AB is a uniform resistance wire.

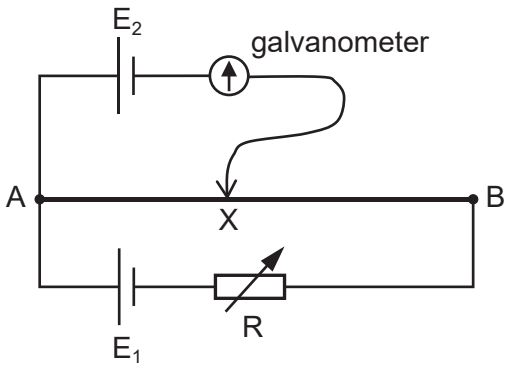


**Fig. 9.3**

**(i)** When the sliding contact is moved from A towards B, explain why a point X is found where the galvanometer gives zero deflection.

.....

.....

.....

..... [2]

**(ii)** If the e.m.f. of $E_1$ is much larger than that of $E_2$, explain why this circuit is not suitable for comparison of the e.m.f. of the cells.

.....

.....

.....

..... [2]

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**(f)** Fig. 9.4 shows a potentiometer circuit with two cells $E_1$ and $E_2$ of negligible internal resistances for measuring a small e.m.f. produced by a thermocouple. Wire CD is 1.0 m long with a resistance of 2.0 Ω. Cell $E_2$ has an e.m.f. of 1.1 V and resistor $R_1$ has a resistance of 110 Ω. Both galvanometers show no deflection.

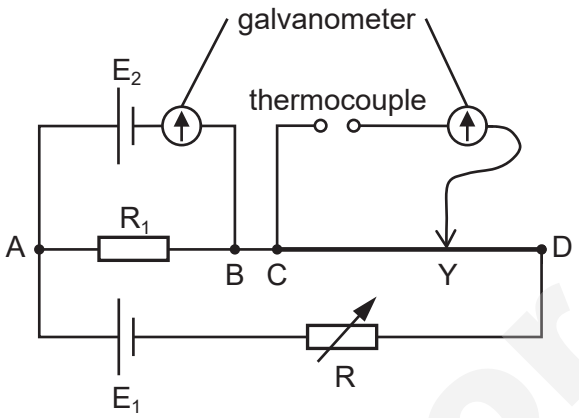


**Fig. 9.4**

**(i)** State the potential difference across AB.

potential difference = ..... V [1]

**(ii)** The balance length CY is 72.5 cm.

Determine the e.m.f. of the thermocouple.

e.m.f. = ..... V [3]

**End of paper**

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| Name | Class | Index Number |
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**JURONG PIONEER JUNIOR COLLEGE**
**JC2 Preliminary Examination**

**PHYSICS** **9749/04**
**Higher 2**

Paper 4 Practical

27 August 2019

**2 hours 30 minutes**

**READ THESE INSTRUCTIONS FIRST**

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

Answer **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| **1** | / 17 |
| **2** | / 5 |
| **3** | / 21 |
| **4** | / 12 |
| **Total** | / 55 |

This document consists of **19** printed pages.



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**1** In this experiment, you will investigate an electrical circuit.

**(a) (i)** You have been provided with a length of constantan wire attached to a metre rule, and a resistor Y of unknown resistance.

Connect the circuit as shown in Fig. 1.1.

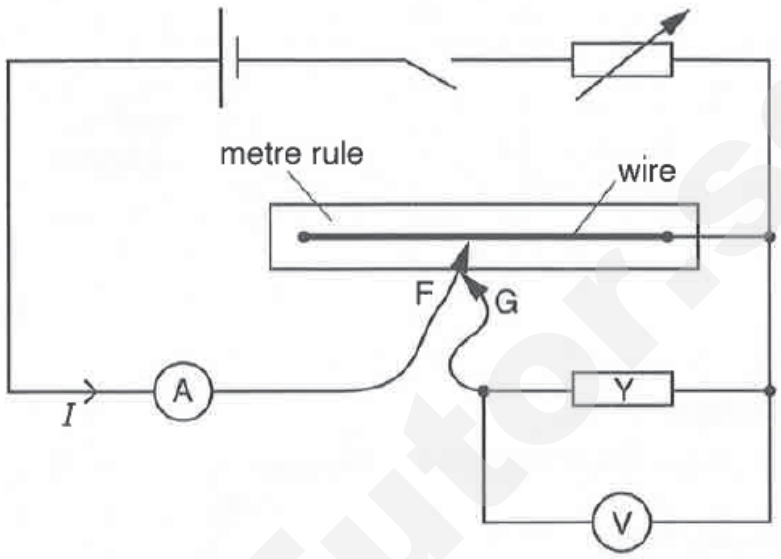


**Fig. 1.1**

F and G are crocodile clips.

**(ii)** Connect F to a point half-way along the wire. Connect G to F.

**(iii)** Place the slider of the rheostat at its mid-point.

**(iv)** Close the switch and record the voltmeter reading $V_0$ to the nearest 0.01 V.

$V_0$ = ..... [1]

**(v) 1** Adjust the slider of the rheostat until the voltmeter reading just changes to ($V_0$ + 0.01) V.

Record the ammeter reading.

ammeter reading = .....

**2** Adjust the slider of the rheostat until the voltmeter reading just changes to ($V_0$ – 0.01) V.

Record the ammeter reading.

ammeter reading = .....
[1]

**(vi)** Open the switch.


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**(b)** The distance *x* between the end of the wire and F is shown in Fig. 1.2.

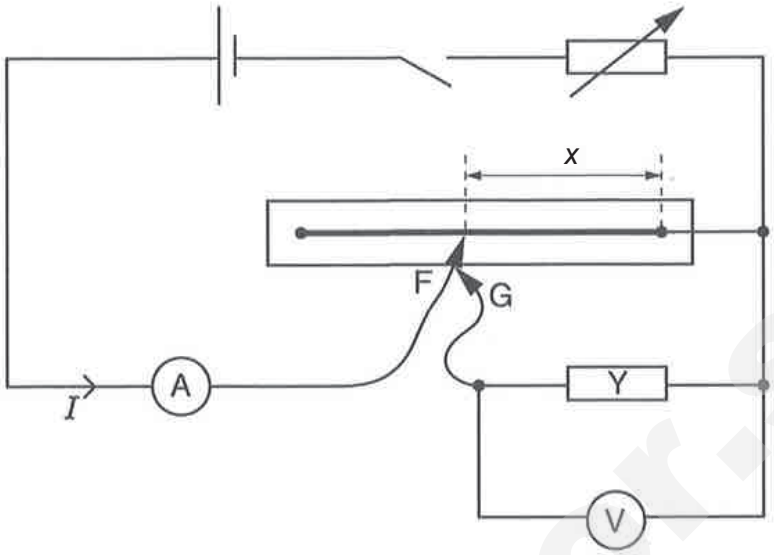


**Fig. 1.2**

**(i)** Move F so that *x* is approximately 30 cm.

**(ii)** Close the switch and adjust the slider of the rheostat until the voltmeter reading is equal to $V_0$.

**(iii)** Record *x* and the ammeter reading $I$.

*x* = .....

$I$ = .....
[1]

**(iv)** Open the switch.

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**(c)** Vary $x$ and repeat **(b)(ii)**, **(b)(iii)** and **(b)(iv)** keeping the voltmeter reading equal to $V_0$ throughout.

[5]

**(d)** $I$ and $x$ are related by the expression

$$I = \frac{P}{x} + Q$$

where $P$ and $Q$ are constants.

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

$P$ = .....

$Q$ = .....

[6]

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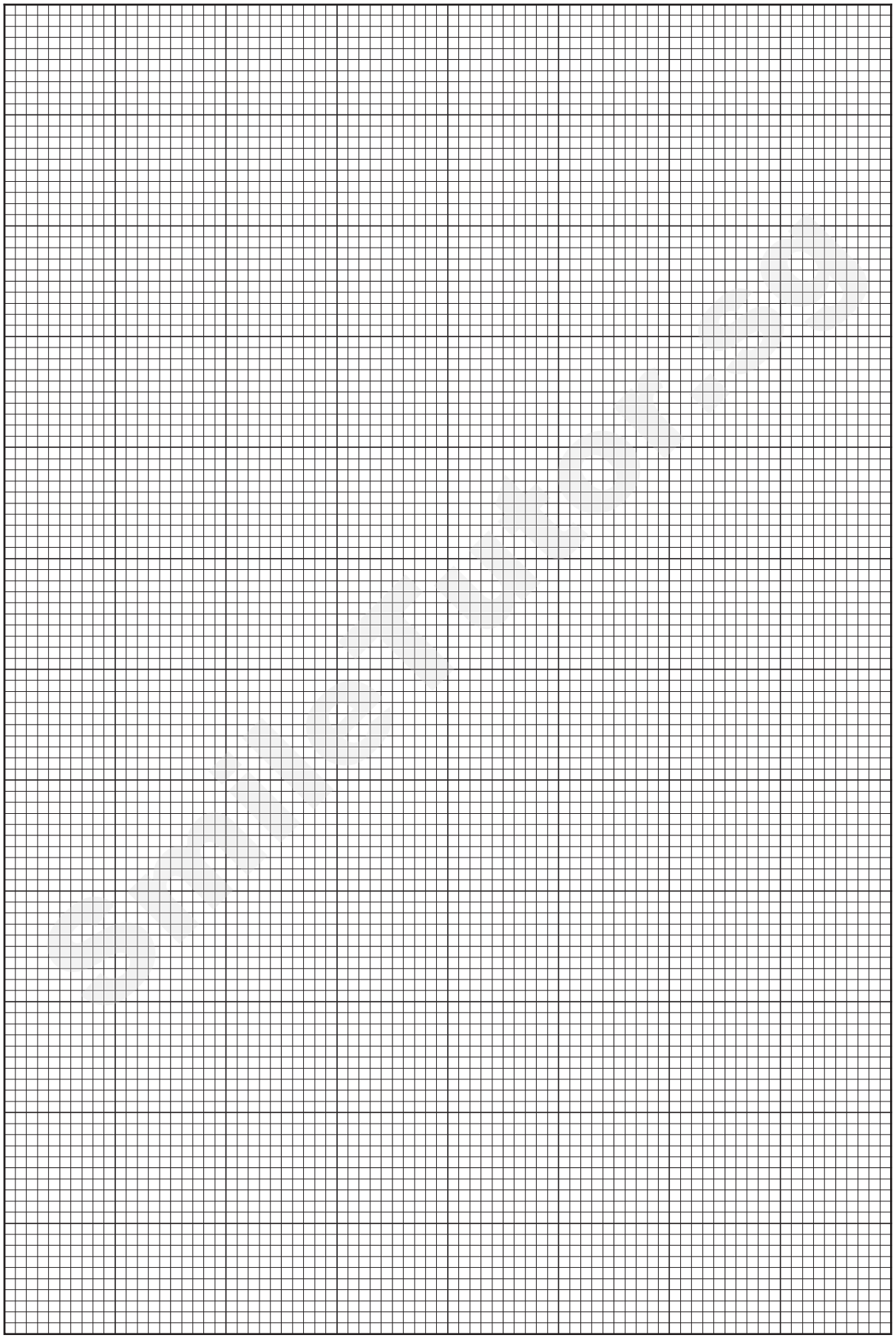

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**(e)** Theory suggests that

$$\frac{P}{Q} = L$$

where $L$ is the length of wire that has the same resistance as resistor Y.

Calculate $L$.

$L$ = ..... [1]

**(f)** **(i)** Remove Y from the circuit and replace it with a wire of length $L$ from the wire wound on the card. **Do not cut the wire**.

**(ii)** Connect F to a point half-way along the wire on the metre rule.

Repeat **(b)(ii)**, **(b)(iii)** and **(b)(iv)**.

$x$ = .....

$I$ = .....

**(iii)** Use your values in **(f)(ii)** to plot another point on your graph.

Label this point Z.

**(iv)** State whether this point agrees with the pattern of the other points on your graph.

Use your values in **(a)(v)** to justify your statement.

.....

.....

.....

.....

.....

..... [2]

**[Total: 17]**

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**2** In this experiment, you will determine the spring constant of a spring.

**(a)** You have been provided with three identical springs, attached to a ring.

The length of an unstretched spring is *S*, as shown in Fig. 2.1.

Without disconnecting the springs, measure and record *S* for **one** of the springs.

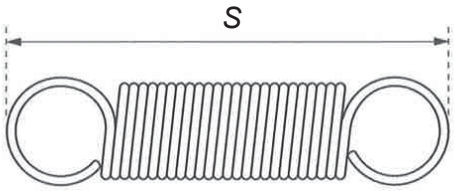


**Fig. 2.1**

*S* = .....

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**(b) (i)** Set up the apparatus as shown in Fig. 2.2.

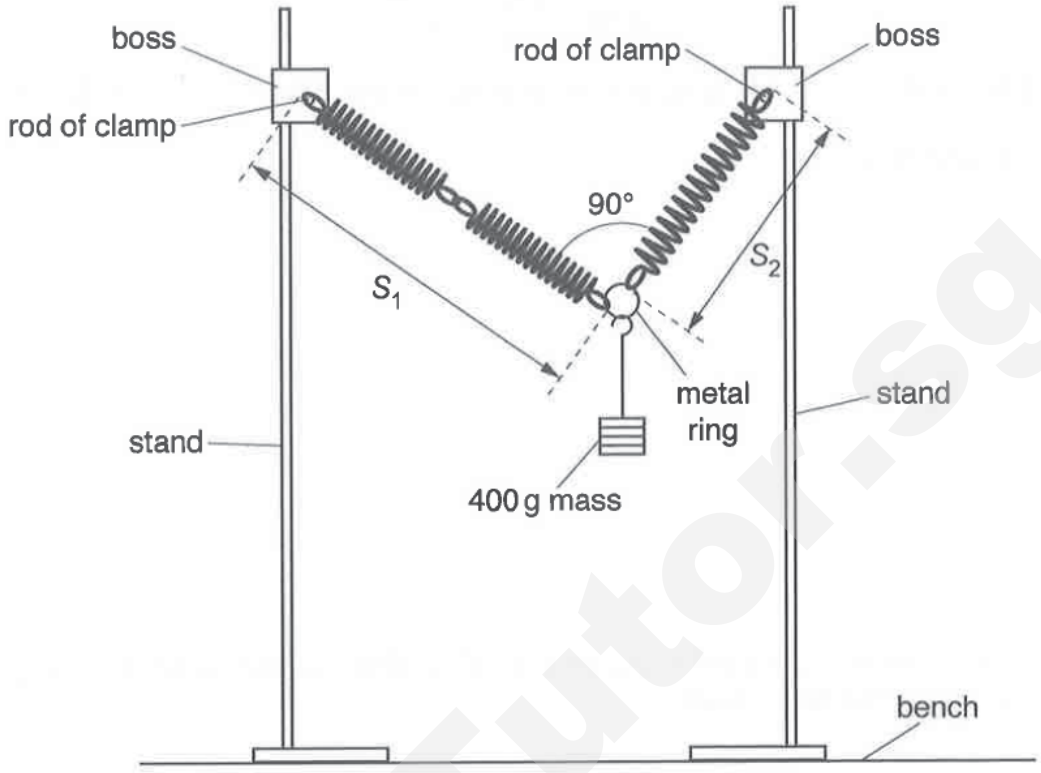


**Fig. 2.2**

Adjust the apparatus so that the angle between the springs is 90°.

The extended length of the double spring is $S_1$ and the extended length of the single spring is $S_2$.

Measure and record $S_1$ and $S_2$.

$S_1$ = .....

$S_2$ = .....
[1]

**(ii)** The extensions are $p$ and $q$ where

$$p = S_1 - 2S \text{ and } q = S_2 - S.$$

Calculate $p$ and $q$.

$p$ = .....

$q$ = .....
[1]


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**(c)** Theory suggests that

$$m^2g^2 = \frac{k^2p^2}{4} + k^2q^2$$

where $m$ = 400 g, $k$ is the spring constant of one of the springs and $g$ = 9.81 m s$^{-2}$.

**(i)** Calculate $k$.

$k$ = ..... N m$^{-1}$ [1]

**(ii)** If you were to repeat this experiment with other masses, describe the graph that you would plot to determine $k$.

.....

.....

.....

..... [2]

**[Total: 5]**

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**3** In this experiment, you will investigate the motion of an oscillating rule.

**(a) (i)** Balance the **metre rule** on the rod of the clamp, as shown in Fig. 3.1.

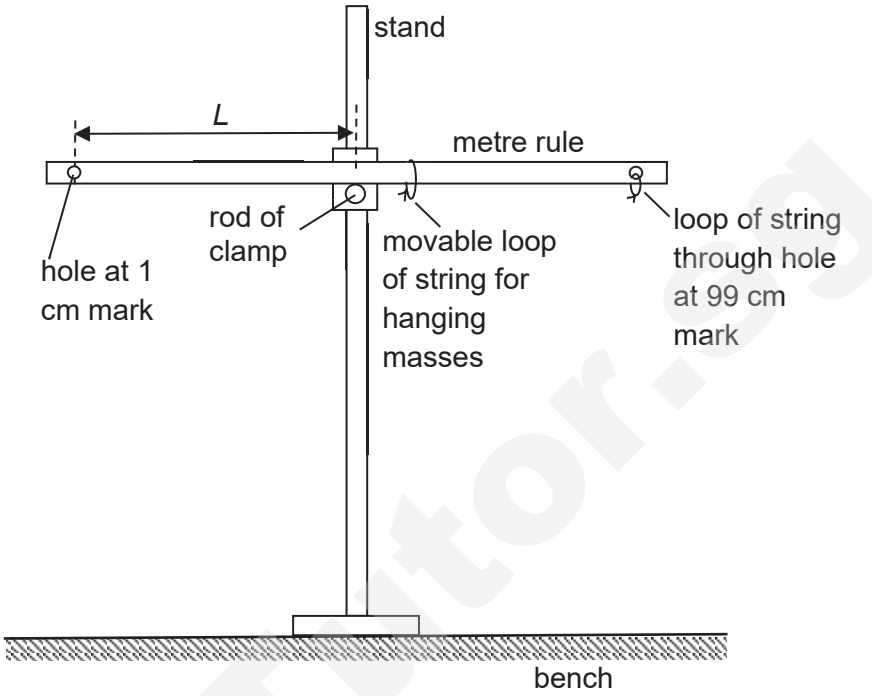


**Fig. 3.1**

**(ii)** Measure and record *L*, the distance from the hole at the 1 cm mark to the centre of gravity (c.g.) of the rule, as shown in Fig. 3.1.

*L* = ..... [1]

**(iii)** Estimate the percentage uncertainty in your value of *L*.

percentage uncertainty in *L* = ..... [1]

**(iv)** Measure and record *M*, the mass of the rule.

*M* = ..... [1]



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**(b)** Fig. 3.2 shows a spring attached to a loop of string with a paper clip at one end.

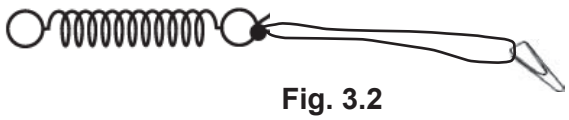

**Fig. 3.2**

**(i)** Set up the apparatus as shown in Fig. 3.3.

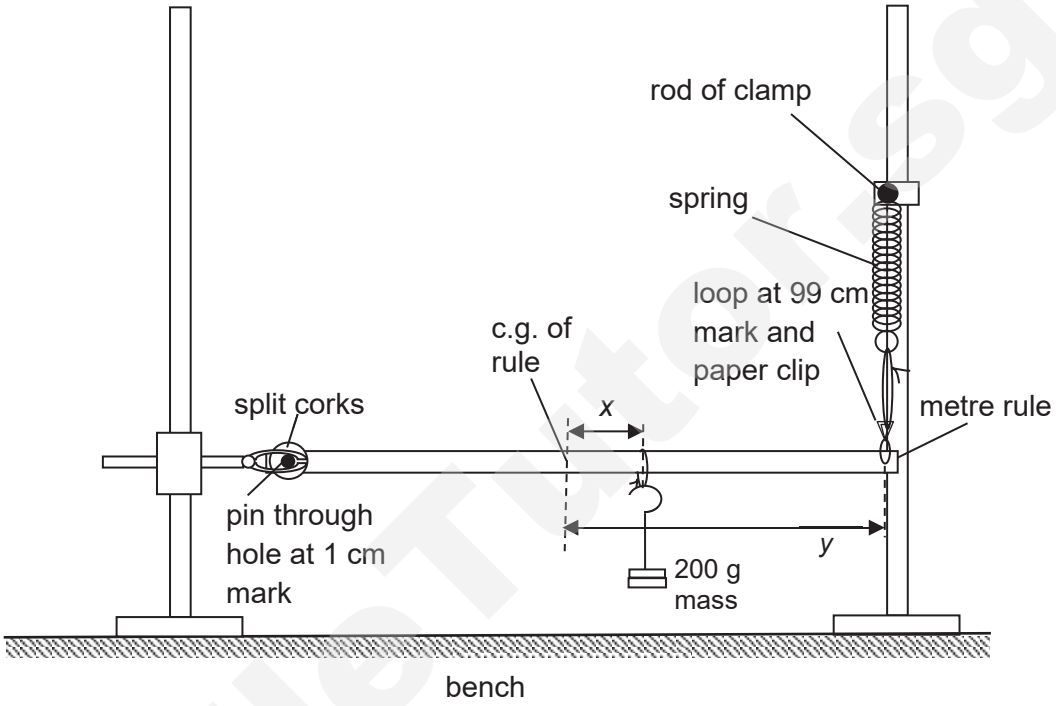


**Fig. 3.3**

**(ii)** Adjust the movable loop with the 200 g mass until *x* is around 15 cm. Adjust the apparatus until the spring and loop are vertical and the rule is horizontal. Ensure that the 200 g mass is further from the pin than the c.g. of the rule. The rule should be able to oscillate about the pin held by the split corks.

**(iii)** Measure and record *x* and *y*.

*x* = .....

*y* = .....
[1]

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

percentage uncertainty in *x* = .....[1]

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**(c)** Pull the 200 g mass down slightly and release. The rule will oscillate. Determine the period $T$ of the oscillations.

$T$ = .....[2]

**(d)** Increase $x$ and repeat steps **(b)(iii)** and **(c)**.

$x$ = .....

$T$ = .....
[2]

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**(e)** It is suggested that $x$ and $T$ are related by the expression

$$T = k\sqrt{M + \frac{x}{y}m}$$

where $k$ is a constant and $m$ is the 200 g hanging mass.

**(i)** Use your values from **(a)(iv)**, **(b)(iii)**, **(c)** and **(d)** to determine two values of $k$.

Give your values of $k$ to an appropriate number of significant figures.

first value of $k$ = .....

second value of $k$ = .....
[2]

**(ii)** State whether the results of your experiment support the suggested relationship in **(e)**.

Justify your conclusion by referring to your values in **(a)(iii)** and **(b)(iv)**.

.....

.....

.....

.....[1]

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**(f) (i)** You will now determine two more values of *k* using:

- the **half metre rule** with a loop of string through a hole at the 49 cm mark as shown in Fig. 3.4
- the **metre rule** with a loop of string through a hole at the 49 cm mark as shown in Fig. 3.5.

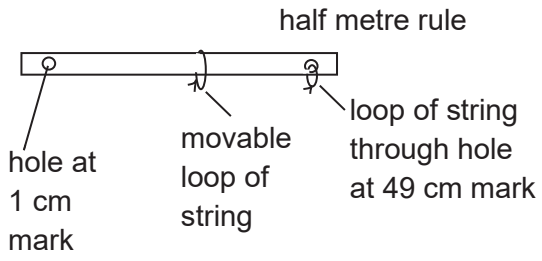


**Fig. 3.4**

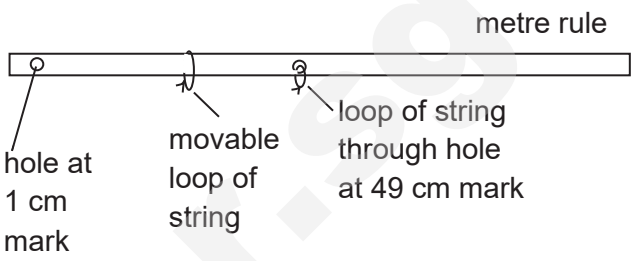


**Fig. 3.5**

*x* and *y* are measured from the 25 cm mark of both rules.

Ensure that the 200 g mass is further from the pin than the 25 cm mark of both the rules.

The value of *x* and *y* must be the **same** in both cases and the spring must be attached to the rule at the 49 cm mark.

You may take *M*, the mass of the **half metre rule** as 50.0 g.

Tabulate your results.

[3]



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**(ii)** Comment on your values of $k$ in **(e)(i)** and **(f)(i)**.

.....

.....

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.....

.....

.....[2]

**(g)** The behavior of the oscillating system depends on the location of the hole through which the loop is threaded.

It is suggested that the period $T$ is inversely proportional to $y$, the distance between the c.g. of the rule and the hole which the loop is threaded through.

Explain how you would investigate this relationship using the half metre rule.

Your account should include:
- your experimental procedure
- control of variables
- how you would use your results to show inverse proportionality

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.....[4]

[Total: 21]

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**4** Fig. 4.1 shows a copper rod and two steel bars.

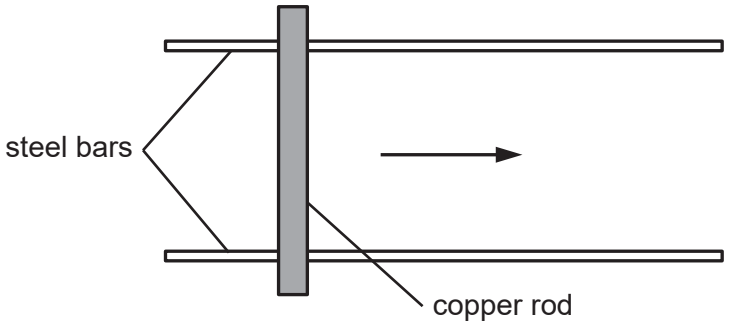


**Fig. 4.1**

When the rod moves at constant speed along the bars, a constant current is induced in the copper rod when the apparatus:

- forms part of a closed circuit
- is placed in a uniform magnetic field.

The value of the current $I$, using a copper rod of diameter $d$ moving at speed $v$ is

$$I = E d^p v^q$$

where $E$, $p$ and $q$ are constants.

Design an experiment to determine the values of $p$ and $q$.

You are provided with some copper rods of different diameters.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

**(a)** the equipment you would use,

**(b)** the procedure to be followed,

**(c)** how you would produce a uniform magnetic field,

**(d)** the control of variables,

**(e)** any precautions that should be taken to improve the accuracy and safety of the experiment.

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**Diagram**

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# 2019 Physics Prelim Practical Exam Apparatus List

## Question 1

1. One 1.5 V dry cell in holder
2. One switch
3. One resistor labelled Y
4. A length of resistance wire attached to a metre rule
5. A length of resistance wire coiled around a card (to be coiled back after use)
6. Nine connecting leads
7. One 0 – 200 mA digital ammeter
8. One 0 – 20 V digital voltmeter
9. One sliding rheostat

## Question 2

1. Two stands
2. Two bosses
3. Two clamps
4. Three identical springs connected to a metal ring
5. One 100 g mass hanger
6. Three 100 g masses
7. One set square
8. One 30 cm ruler
9. Heavy weights

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# 2019 Physics Prelim Practical Exam Apparatus List

## Question 3

1. One metre rule with three loops of thread (tied at 49 cm, 99 cm and a movable one)
2. One half metre rule with two loops of thread (tied at 49 cm and a movable one)
3. One spring attached to a loop of thread and a paper clip
4. One 100 g mass hanger
5. One 100 g mass
6. One pin
7. Two retort stands
8. Two sets of bosses and clamps
9. One stopwatch
10. Two split corks

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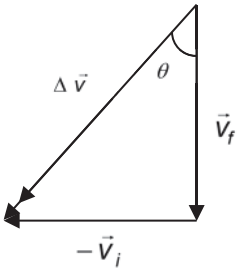
**Suggested Solutions:**

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

| Qn | Ans | Suggested Solution |
|---|---|---|
| **1** | **D** | $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$<br>$\Delta\vec{v} = \vec{v}_f + (-\vec{v}_i)$<br>  <br><br>$(\Delta v)^2 = (v_f)^2 + (v_i)^2$<br>$\Delta v = \sqrt{(7)^2 + (5)^2}$<br>$= 9 \text{ m s}^{-1}$<br>$\tan\theta = \frac{v_i}{v_f}$<br>$\tan\theta = \frac{5}{7}$<br>$\theta = 36°$ |
| **2** | **D** | Option A is incorrect.<br>Using $v^2 = u^2 + 2as$,<br>Acceleration, $a = \frac{v^2 - u^2}{2s}$<br>$= \frac{70^2 - 50^2}{2(432)}$<br>$= 2.78 \text{ m s}^{-2}$<br><br>Option B is incorrect.<br>Using $v = u + at$,<br>Time, $t = \frac{v - u}{a}$<br>$= \frac{70 - 50}{2.778}$<br>$= 7.2 \text{ s}$ |

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| Qn | Ans | Suggested Solution |
|---|---|---|
| | | Option C is incorrect.<br>Using $v = u + at$,<br>Time, $t = \frac{v-u}{a}$<br>$= \frac{70-55}{2.778}$<br>$= 5.4$ s<br><br>Option D is correct.<br>Using $v^2 = u^2 + 2as$,<br>$s = \frac{v^2-u^2}{2a}$<br>$= \frac{70^2-60^2}{2(2.778)}$<br>$= 234$ m |
| **3** | **C** | By Newton's second law,<br>Force exerted on the plate by the pellets<br>$F = \left\lvert\frac{\Delta p}{\Delta t}\right\rvert$<br>$= \left\lvert 0.8\times10^{-3}\times\frac{100}{60}\times(-4-5)\right\rvert$ (taking downward as +ve)<br>$= 0.012$ N |
| **4** | **B** | Taking rightward as positive,<br>By relative speed of approach = relative speed of separation<br>$v - 0 = v_Q - \left(-\frac{3v}{5}\right)$<br>$v_Q = \frac{2v}{5}$<br><br>Kinetic energy of Q<br>$= \frac{1}{2}(4m)\left(\frac{2v}{5}\right)^2$<br>$= \frac{8}{25}mv^2$ |
| **5** | **C** | Assume that the horizontal force at the top hinge is to the right,<br>Taking moment about bottom hinge,<br>$(T\sin\theta)d + (T\cos\theta)d = R_x(d) + W(0.5d)$<br>$(150\sin30°)0.50 + (150\cos30°)0.50 = R_x(0.50) + 20(9.81)(0.5)(0.50)$<br>$R_x = 107$ N (to the right) |

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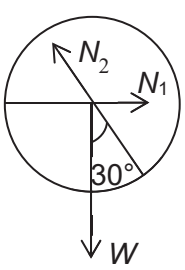
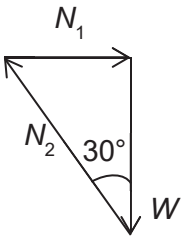
| Qn | Ans | Suggested Solution |
|---|---|---|
| 6 | C |   <br>Resolving the forces,<br>$N_2 \sin 30 = N_1 \quad (1)$<br>$N_2 \cos 30 = W \quad (2)$<br>$\frac{(1)}{(2)}: \quad \tan 30 = \frac{N_1}{W}$<br>$N_1 = W \tan 30 = 15 \tan 30 = 8.66 = 8.7$ N (2s.f.)<br><br>(Alternative: Using vector triangle)<br>$N_1 = W \tan 30 = 15 \tan 30 = 8.66 = 8.7$ N (2s.f.) |
| 7 | 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.<br><br>$EPE_{loss} = KE_{gain} + WD_{\text{friction}}$<br>$\frac{1}{2}kx^2 = (KE_{final} - KE_{initial}) + fd$<br>$KE_{final} = \frac{1}{2}kx^2 - fd \qquad (\text{since } KE_{initial} = 0)$ |
| 8 | D | At different positions along the vertical circular ramp, the normal contact force on the ball will be different. As such, the direction of resultant force and hence acceleration of the ball will not always directed towards the centre of the ramp, resulting a change in the speed. |
| 9 | A | $U = -\frac{GMm}{r} \Rightarrow -1.3 \times 10^8 = -\frac{GM \times 2.0}{6.4 \times 10^6} \Rightarrow GM = 4.16 \times 10^{14}$<br>$g = \frac{GM}{r^2} = \frac{4.16 \times 10^{14}}{(9 \times 10^6 + 6.4 \times 10^6)^2} \approx 1.8 \text{ N kg}^{-1}$ |
| 10 | B | $\frac{GMm}{r^2} = mr\omega^2 \Rightarrow r^3 = \frac{GM}{\omega^2}$<br>$\Rightarrow r^3 = \frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{\left(\frac{2\pi}{24 \times 60 \times 60}\right)^2} \Rightarrow r = 42297523 \text{ km}$<br>$v = r\omega = 42297523 \times \frac{2\pi}{24 \times 60 \times 60} \approx 3080 \text{ m s}^{-1}$ |

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| Qn | Ans | Suggested Solution |
|---|---|---|
| 11 | C | Temperature at equilibrium is 273.15 K<br>Heat lost by copper= Heat gained by ice<br>$m_{Cu}c\Delta T = m_{ice}c\Delta\theta + m_{water}L$<br>$5.0\times390\times\Delta T = 3.0\times2100\times(273.15-250)+0.8\times340000$<br>$\Delta T = 214.3$ K<br>$T = 273.15+214.3\approx490$K |
| 12 | C | Total translational kinetic energy $=\frac{3}{2}nRT$<br>C is correct. Since they have the same amount of gas molecules and the same temperature, their total $E_K$ are the same. |
| 13 | A | Option A: negative velocity and negative acceleration<br>Option B: negative velocity and zero acceleration<br>Option C: negative velocity and positive acceleration<br>Option D: zero velocity and positive acceleration |
| 14 | A | $E=\frac{1}{2}m\omega^2{x_0}^2$<br>When $x=\frac{x_0}{4}$, $PE=\frac{1}{2}m\omega^2\left(\frac{x_0}{4}\right)^2=\frac{1}{16}E$ |
| 15 | B | $\frac{I}{4}=I\cos^2\theta$<br>$\theta=60°$ |
| 16 | D | For stationary ware, the particles in adjacent segments are oscillating in antiphase. hence particles 1 and 2 are in antiphase with P.<br><br>On the other hand, the particles in alternate segments are oscillating in phase. hence particle 3 is in phase with P. |
| 17 | D | $y=\frac{\lambda D}{a}$<br>$\frac{(600\times10^{-9})(1.0)}{a}=\frac{(450\times10^{-9})(D)}{a}$<br>$D=1.3$ m |
| 18 | B | Removing electrons from Q will result in a larger positive charge which will cause a larger electric force upwards. Hence Q will accelerate upwards. |
| 19 | B | $E=-\frac{\Delta V}{\Delta x}$. Define positive as P to Q.<br>At regions around 0.040 m,<br>$E=-\frac{14-15}{0.050-0.030}=50$ V m$^{-1}$<br>Hence, the electric field is 50 V m$^{-1}$ towards Q. |

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| Qn | Ans | Suggested Solution |
|---|---|---|
| 20 | B | Using $I = Anvq$,<br>$v = \frac{I}{Anq} = \frac{I}{A} \times \frac{1}{nq}$<br>Hence, current per unit of cross-sectional area, $\frac{I}{A}$ is required. |
| 21 | D | Due to the high resistance of voltmeter, negligible current flows through it. Regardless of the slider position on the potentiometer P, the potential of the slider is always 4.0 V. Hence, the voltmeter is always measuring the e.m.f. of the battery. |
| 22 | A | Between X and Y, the network is made of parallel resistors of resistance 70 Ω, 70 Ω, (40+20+80=140) Ω and (50+30+60=140) Ω.<br><br>By proportionality, the 1.5 A current is divided into 6 parts, i.e. 0.25 A.<br>Current of 0.50 A flows through each of the two 70 Ω resistors.<br>Currents each of 0.25 A flow through the (40+20+80=140) Ω and (50+30+60=140) Ω. Resistors respectively.<br><br>Hence, the current in 30 Ω resistor is 0.25 A. |
| 23 | B | The magnetic force provides the centripetal force necessary for the charge to move in a circle.<br>$Bqv = \frac{mv^2}{r}$<br>$r = \frac{mv}{Bq}$<br>For choices A, B, C and D, the radius is $\frac{6mv}{Be}$, $\frac{3mv}{Be}$, $\frac{6mv}{Be}$ and $\frac{16mv}{Bq}$ respectively. |
| 24 | D | e.m.f.<br>$= \frac{\Delta\Phi}{\Delta t}$<br>$= \frac{\Delta(N\phi)}{\Delta t}$<br>$= \frac{6.8 \times 10^{-6} \times 2 \times 3.3 \times 96}{2.4 \times 10^{-3}}$<br>$= 1.795$<br>$\approx 1.8$ V |
| 25 | C | Effective horizontal length of the metal wire cutting the magnetic field = $2r$<br><br>Using $E = BLv$<br>$E = B \times 2r \times v$<br>$= 2Brv$ |

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| Qn | Ans | Suggested Solution |
|---|---|---|
| | | By Lenz' Law, the induced current in MN will give rise to a vertically upward force on the wire, opposing the wire falling. By Fleming's left hand rule, the induced current in MN will flow from M towards N. Hence, N will be at the higher potential. |
| **26** | **B** | Peak voltage in secondary coil is 90 V.<br>Resistor $R_2$ and $R_3$ are in parallel connection,<br>so total resistance in circuit connected to the secondary coil is 120 Ω.<br><br>R.m.s. voltage in secondary coil, $V_{\text{r.m.s.(2)}} = \frac{90}{\sqrt{2}}$ V<br><br>R.m.s. current in secondary coil, $I_{\text{r.m.s.(2)}} = \frac{\frac{90}{\sqrt{2}}}{120}$ A<br>Average power dissipated in $R_1$<br>$= (I_{\text{r.m.s.(2)}})^2 \times 80$<br>$= 22.5$<br>$\approx 23$ W |
| **27** | **A** | Using $E = \frac{p^2}{2m}$, since electrons are accelerated from rest through p.d. $V$,<br>$eV = E$<br>$= \frac{p^2}{2m}$<br><br>With $p = \frac{h}{\lambda}$,<br>$eV = \frac{1}{2m}\frac{h^2}{\lambda^2}$<br>$\Rightarrow \lambda \propto \frac{1}{\sqrt{V}}$ |
| **28** | **C** | Since $\Delta E = hf$, from the energy level diagram, the energy difference between emitted photons is lesser at higher frequencies.<br>Wavelength is inversely proportional to frequency, hence the spectrum is in opposite order. |
| **29** | **A** | The deflection of α-particles through very large angles imply that they have struck something heavy, indicating that most of the mass of the atom is concentrated there in the nucleus of the atom which is small relative to the size of the atom. |
| **30** | **B** | The decay sequence involves 2 α-decays and 2 β-decays.<br><br>$^{222}_{86}\text{Rn} \rightarrow {}^{218}_{84}\text{Po} \rightarrow {}^{214}_{82}\text{Pb} \rightarrow {}^{214}_{83}\text{Bi} \rightarrow {}^{214}_{84}\text{Po}$ |

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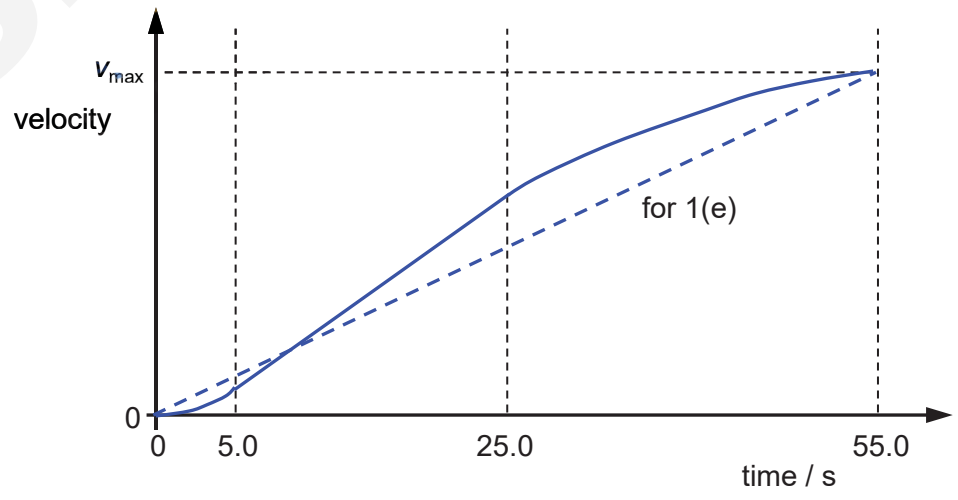
**Answers to 2019 JC2 Preliminary Examination Paper 2 (H2 Physics)**

**Suggested Solutions:**

| No. | Solution | Remarks |
|---|---|---|
| **1(a)** | Any two:<br>Air resistance varies with speed of aeroplane.<br>Friction runway exerts on aeroplane varies.<br>Mass of fuel in aeroplane decreases during take-off. | [2]<br>1 mark for each correct answer |
| **1(b)** | By Newton's 2nd law,<br>Change in momentum of the aeroplane<br>= area under the graph<br>= final momentum – initial momentum<br>= final momentum at take-off - 0<br><br>Momentum<br>$= \left(\frac{1}{2} \times 5.0 \times 1.13 \times 10^5\right) + \left(20.0 \times 1.13 \times 10^5\right) +$<br>$\left[\frac{1}{2}(1.13 + 0.97) \times 10^5 \times 30.0\right]$<br>$= 5.693 \times 10^6$<br>$\approx 5.69 \times 10^6$ N s | [1] for using area under graph<br><br>[1] for correct expression and numerical substitution<br><br>[1] for correct answer |
| **1(c)** | Using $p = mv$ ,<br>$v_{max} = \frac{p}{m}$<br>$= \frac{5.693 \times 10^6}{7.45 \times 10^4}$<br>$= 76.42$<br>$\approx 76.4$ m s$^{-1}$ | [1] for correct answer |
| **1(d)** |  | |

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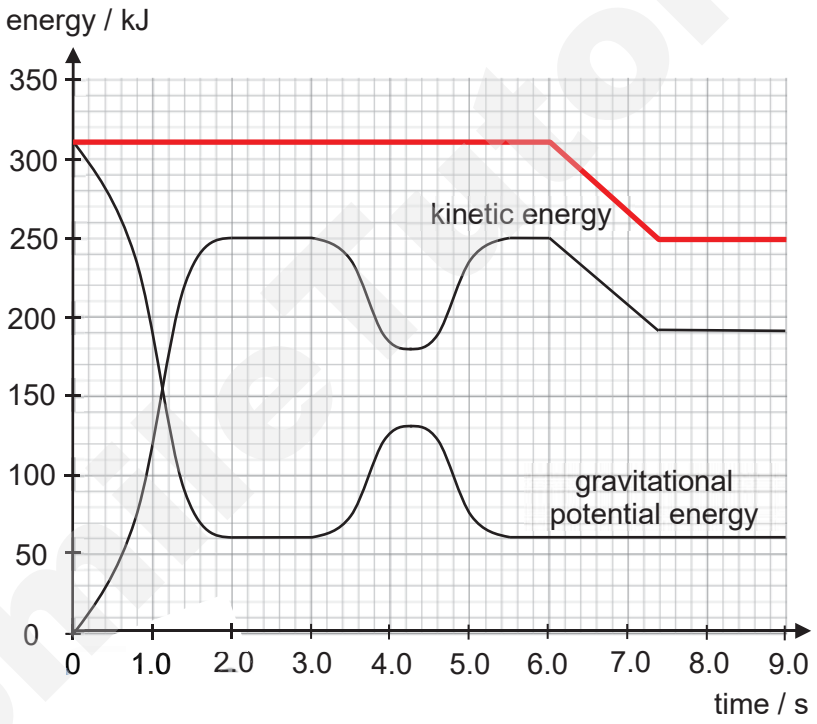
| No. | Solution | Remarks |
|---|---|---|
| | Note:<br>[1] Curve of increasing gradient from origin and line of constant gradient between 5.0 and 25.0 s.<br>[1] Line of decreasing positive gradient after 25.0 s. | |
| **1(e)** | Distance = area under graph<br>$= \frac{1}{2} \times 76.42 \times 55.0$<br>$= 2101$<br>$\approx 2200$ m (Method is underestimation, refer to Fig. 3.2)<br><br>Accept 2000 – 3000 m | [1] for correct estimation method<br><br>[1] for correct answer |
| **2(a)** |  | [1] horizontal line from $t$ = 0 s to $t$ = 6.0 s, with mechanical energy at 310 kJ<br><br>[1] straight line joining points (6.0, 310) and (7.4, 250), followed by horizontal line from $t$ = 7.4 s to $t$ = 9.0 s, with mechanical energy at 250 KJ |
| **2(b)** | From the Fig 2.2, $t$ = 3.0 s to $t$ = 4.3 s, the increase in gravitational potential energy is<br>$\Delta GPE = 130 - 60$<br>$= 70$ kJ<br><br>$mg\Delta h = 70000$<br>$\Delta h = \frac{70000}{380 \times 9.81}$<br>$= 18.778 \approx 19$ m<br><br>The increase in height, and therefore the diameter $d$ of loop, is 19 m. | [1] for correct substitution<br><br>[1] for correct answer |



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| No. | Solution | Remarks |
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| | | |
| **2(c)(i)** | start time = 6.0 s<br>end time = 7.4 s | [1] for correct start and end times. |
| **2(c)(ii)** | rate of loss of KE $= \dfrac{\text{loss of KE}}{\text{duration in zone A}}$<br>$= \dfrac{(250-190)\times 10^3}{7.4-6.0}$<br>$= 42857 \text{ W} \approx 43000 \text{ W}$ | [1] for correct substitution<br>[1] for correct answer |
| **2(c)(iii)** | From Fig 2.2, the car enters zone A with a KE of 250 kJ,<br>$\frac{1}{2}mv^2 = 250\ 000$<br>$v = \sqrt{\dfrac{2(250\ 000)}{380}}$<br>$= 36.274 \approx 36.3 \text{ m s}^{-1}$ | [1] for correct substitution<br>[1] for correct answer |
| **2(c)(iv)** | Using $P = Fv$,<br>$F = \dfrac{P}{v}$<br>$= \dfrac{42\ 857}{36.274}$<br>$= 1181.49$<br>$\approx 1200 \text{ N}$ | [1] for correct substitution<br>[1] for correct answer |
| **3(a)** | Internal energy is <u>determined by the state of the system</u> and it can be expressed as <u>the sum of a random distribution of kinetic and potential energies associated with the molecules of the system</u>. | [1] for correct answer |
| **3(b)** | $p = \frac{1}{3}\rho\langle c^2\rangle$<br>$= \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$<br>$\Rightarrow pV = \frac{1}{3}Nm\langle c^2\rangle$.....(1)<br><br>Subst $pV = nRT$ into (1)<br>$\frac{1}{3}Nm\langle c^2\rangle = nRT$<br>$\Rightarrow \frac{1}{2}m\langle c^2\rangle = \frac{3}{2}\frac{n}{N}RT$..... (2)<br>$\Rightarrow E_k \propto T$<br><br>Hence, the average kinetic energy of a molecule of an ideal gas is proportional to its thermodynamic temperature $T$. | [1] for showing the derivation of equation (1)<br><br>[1] for equating ideal gas equation correctly and correct workings. |

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<table>
<tr><th>No.</th><th>Solution</th><th>Remarks</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>3(c)(i)1.</td><td>Using $\Delta U = Q + W_{on}$ and $U = \frac{3}{2}nRT$,<br>$\frac{3}{2}nR\Delta T = Q + (0)$ ($\because$ B $\rightarrow$ C constant volume)<br><br>$\frac{3}{2}(0.024)(8.31)\Delta T = 250$<br>$\Delta T = 835.67$ K<br>$\therefore T = 976 + 835.67 \approx 1810$ K</td><td>[1] for showing<br>$\Delta U = Q + W_{on}$<br>$\frac{3}{2}nR\Delta T = Q + (0)$<br><br>[1] for correct substitution and $\Delta T$<br><br>[1] for correct $T$</td></tr>
<tr><td>3(c)(i)2.</td><td>Using $pV = nRT$,<br>$p = \frac{nRT}{V}$<br>$= \frac{0.024 \times 8.31 \times 1811.67}{0.32 \times 10^{-4}}$<br>$= 11291233$<br>$\approx 1.13 \times 10^{7}$ Pa</td><td>[1] for correct answer</td></tr>
<tr><td>3(c)(ii)</td><td>
<table>
<tr><th>change</th><th>heat supplied to gas / J</th><th>work done by gas / J</th><th>increase in internal energy / J</th></tr>
<tr><td>A to B</td><td>0</td><td>–200</td><td>200</td></tr>
<tr><td>B to C</td><td>250</td><td>0</td><td>250</td></tr>
<tr><td>C to D</td><td>0</td><td>350</td><td>–350</td></tr>
<tr><td>D to A</td><td>–100</td><td>0</td><td>–100</td></tr>
</table>
</td><td>[3] for all correct answers<br><br>Deduct 1 mark for every 2 wrong answers</td></tr>
<tr><td>4(a)(i)</td><td>The magnetic force provides the centripetal force required to keep the particle in a circular path.<br>$Bqv = \frac{mv^2}{r}$<br>$r = \frac{mv}{Bq}$<br>$= \frac{(9.11 \times 10^{-31})(5.0 \times 10^{7})}{(1.2 \times 10^{-3})(1.60 \times 10^{-19})}$<br>$= 0.2372$<br>$= 0.24$ m</td><td>[1] for correct expression and numerical substitution<br><br>[1] for correct answer</td></tr>
<tr><td>4(a)(ii)</td><td>No.<br>The plane of the circular path is perpendicular to the axis of the solenoid.</td><td>[1] for correct answer<br>[1] for correct explanation</td></tr>
</table>



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| No. | Solution | Remarks |
|---|---|---|
| **4(b)** | As the radius decreases, the <u>speed decreases</u> too.<br>The electron could be <u>losing kinetic energy</u> due to collision with air molecules (i.e. the space is not a perfect vacuum). | [1] for correct answer<br>[1] for correct reason |
| **4(c)** | $F_B = F_E$<br>$Bqv = qE$<br>$E = Bv$<br>$= (1.2\times10^{-3})(5.0\times10^{7})$<br>$= 6.0\times10^{4}$ N C$^{-1}$ | [1] for correct expression and numerical substitution<br>[1] for correct answer |
| **5(a)(i)** | Work function energy is the minimum amount of energy needed to liberate an electron from the metal surface. | [1] for correct answer |
| **5(a)(ii)** | The photons each of same magnitude of energy ($E$=$hf$) are received by the electrons in the metal surface.<br><br>The electrons nearest to the metal surface require the least amount of energy to be emitted as photoelectrons. Electrons deeper under the surface of the metal require more energy to be emitted. Hence, the emitted photoelectrons have a range of kinetic energies up to a maximum. | [1] for correct answer<br><br>[1] for correct answer |
| **5(a)(iii)** | Using Einstein's photoelectric equation, $\frac{hc}{\lambda} = \Phi + \mathrm{KE}_{max}$,<br>$\lambda = \frac{hc}{\Phi + \mathrm{KE}_{max}}$<br>$= \frac{6.63\times10^{-34}\times3.00\times10^{8}}{\left(4.07\times1.60\times10^{-19}\right)+3.65\times10^{-20}}$<br>$= 289.22\times10^{-9}$ m<br>$\approx 2.89\times10^{-7}$ m | [1] for correct expression and numerical substitution<br><br>[1] for correct answer |
| **5(b)(i)** | Time taken<br>$= \frac{4.07\times1.60\times10^{-19}}{3.0\times10^{-22}}$<br>$= 2170.7$<br>$\approx 2170$ s | [1] for correct answer |
| **5(b)(ii)** | Upon incident on the metal surface, the photons undergo 1 to 1 interaction with the electrons. The energy is transferred instantaneously to the electron which accounts for the instantaneous emission of electrons as photoelectrons without time lag.<br><br>Hence, this interaction shows that electromagnetic radiation travels as photons which are discrete packets of energy. | [1] for correct answer<br><br>[1] for correct answer |

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| No. | Solution | Remarks |
|---|---|---|
| **6(a)** | Isotopes are nuclides with the same number of protons but different number of neutrons. | [1] for correct answer |
| **6(b)(i)** | The binding energy of a nucleus is the minimum amount of energy required to break the nucleus into its constituent particles.<br><br>OR<br><br>The binding energy of a nucleus is the energy released when a nucleus is formed from its constituent particles. | [1] for correct answer |
| **6(b)(ii)** | Binding energy of tritium $= 3(2.83) = 8.49$ MeV<br><br>$8.49 \times 10^6 \times 1.60 \times 10^{-19}$<br>$= (1.00783u + 2 \times 1.00867u - m)(3.00 \times 10^8)^2$<br><br>$m = 3.01608\ u$ | [1] for BE of tritium<br><br>[1] for correct substitution<br><br>[1] for correct answer |
| **6(c)(i)** | ${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H}$ | [1] for correct answer |
| **6(c)(ii)1.** | BE of tritium – 2 × BE of deuterium = 4.03 MeV<br><br>8.49 – 2 × BE of deuterium = 4.03 MeV<br><br>BE of deuterium = 2.23 MeV | [1] for correct substitution<br><br>[1] for correct answer |
| **6(c)(ii)2.** | No. of reactions required per unit time<br>$= \dfrac{2.86 \times 10^9}{4.03 \times 10^6 (1.6 \times 10^{-19})}$<br><br>Mass of deuterium required per unit time<br>$= \left[ \dfrac{2.86 \times 10^9}{4.03 \times 10^6 (1.60 \times 10^{-19})} \right] (2 \times 2 \times 1.66 \times 10^{-27})$<br>$= 2.95 \times 10^{-5}$ kg | [1] for no. of reactions<br><br>[1] for correct substitution<br>[1] for correct answer |
| **7(a)** | It is impossible to determine exactly which nucleus and exactly when a particular nucleus will disintegrate, although statistically, it is possible to predict the fraction of nuclei of a pure radioactive element that will decay after a certain length of time if its decay characteristics are known. | [1] for which nucleus<br>[1] for when |
| **7(b)** | The half-life of a radioactive nuclide is the average time taken for a sample of the nuclide to decay to half its initial number of atoms/activity. | [1] for correct definition |
| **7(c)(i)** | ${}^{131}_{53}\mathrm{I} \rightarrow {}^{0}_{-1}e + {}^{131}_{54}\mathrm{Xe}$ | [1] for correct equation |



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| No. | Solution | Remarks |
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| | | [1] for correct mass and atomic numbers of Xe |
| **7(c)(ii)** | At the start, Te-131 decays quickly to I-131 due to the short half-life as compared to the long half-life of decay of I-131.<br><br>Hence, the activity decreases quickly as represented by PQ on the graph. | [1] for fast decay of Te-131 due to short half life<br>[1] for quick decrease in activity |
| **7(c)(iii)** | $\text{gradient} = \dfrac{12.0 - 9.95}{0 - 3.0}$<br>$= -0.683$ | [2] for correct gradient |
| **7(c)(iv)1.** | $A = A_0 e^{-\lambda t}$<br>$\lg A = \lg A_0 - (\lambda \lg e) t$<br>$\text{gradient} = -(\lambda \lg e)$<br>$= -0.683$<br>$\lambda = \dfrac{0.683}{\lg e}$<br>$= 1.57 \text{ hr}^{-1}$<br>$\text{half-life, } t_{1/2} = \dfrac{\ln 2}{\lambda}$<br>$= \dfrac{\ln 2}{1.57}$<br>$= 0.44 \text{ hours}$ (shown) | [1] for correct equation of graph<br><br>[1] for correct decay constant<br><br>[1] for correct half-life |
| **7(c)(iv)2.** | From the graph,<br>$A_0 = 1.0 \times 10^{12} \text{ Bq}$<br>$A_0 = \lambda N_0$<br>$N_0 = \dfrac{1.0 \times 10^{12}}{\dfrac{1.57}{60 \times 60}}$<br>$= 2.29 \times 10^{15}$ | [1] for correct expression and numerical substitution<br>[1] for correct answer |
| **7(c)(v)** | The activity remains relatively constant after 6 hours. Almost all the Te must have decayed into I. The half-life of I is long, hence the activity remains constant for a long period of time as compared to Te. | [1] All Te decayed into I |

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| No. | Solution | Remarks |
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| | | [1] The activity remains constant due to long half life |
| **7(c)(vi)** | $\lg A = 9.325$<br>$A = 2.11 \times 10^{9}$ Bq<br>Since all Te decayed to I,<br>$N_0 = 2.29 \times 10^{15}$<br>$A = \lambda N_0$<br>$2.11 \times 10^{9} = \lambda\left(2.29 \times 10^{15}\right)$<br>$\lambda = 9.214 \times 10^{-7}$ s$^{-1}$<br>$T_{1/2} = \dfrac{\ln 2}{9.214 \times 10^{-7}}$<br>$= 7.53 \times 10^{5}$ s<br>$= 209$ hours | [1] for calculating activity of I<br>[1] for correct decay constant of I<br>[1] for correct half-life |
| **7(d)** | The activities of the radioactive nuclides in this question have very high values hence the background radiation would be negligible. | [1] for correct explanation |
| **7(e)** | No, although the nuclides have high activities which is dangerous but their half-lives are relatively short so they will decay into stable isotopes quickly. | [1] for correct answer<br>[1] for relatively short half-lives |

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| No. | Solution | Remarks |
|---|---|---|
| 1(a) | Speed is a physical quantity and can only be defined in terms of other physical quantities.<br><br>Distance is a physical quantity, but second is a unit for time which cannot be used to define speed.<br><br>(A more appropriate definition for speed is distance travelled per unit time.) | [1]<br><br>[1] |
| 1(b) | Time to reach maximum height:<br>$t = \frac{u \sin\theta}{g}$<br><br>$R = (u\cos\theta)(2t)$<br>$= (u\cos\theta)(2\frac{u\sin\theta}{g})$<br>$= \frac{2u^2 \sin\theta\cos\theta}{g}$ | [1]<br><br>[1] |
| 1(c) | Maximum R occurs when $\sin 2\theta = 1$.<br>Hence $\theta = 45^o$ | [1] |
| 1(d) | $R_0 = \frac{u^2}{g}$<br>$g = \frac{u^2}{R_0}$<br>$= \frac{(12.6)^2}{16.3}$<br>$= 9.7399 \text{ m s}^{-2}$<br><br>$\frac{\Delta g}{g} = 2\frac{\Delta u}{u} + \frac{\Delta R_0}{R_0}$<br>$\frac{\Delta g}{9.7399} = \frac{2(3\%) + 4\%}{100\%}$<br>$\Delta g = 0.97$<br>$= 1 \text{ m s}^{-2}$<br><br>Therefore, $g = (10 \pm 1) \text{ m s}^{-2}$ | [1] for calculating $g$<br><br>[1] for calculating $\Delta g$<br><br>[1] |
| 2(a)(i) | Magnitude of change in GPE<br>$= (2.6)(0.0060) = 0.0156$ J | [1] for correct substitution and correct answer |
| 2(a)(ii) | Magnitude of change in EPE | [1] for correct substitution |

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| | $= \frac{1}{2}(0.0060)(2.6 + 4.0) = 0.0198$ J | [1] for correct answer |
| **2(b)(i)** | Total energy<br>= 0.0198 – 0.0156 = 0.0042 J | [1] for correct substitution |
| **2(b)(ii)** | $0.0042 = \frac{1}{2}\left(\frac{2.6}{9.81}\right)\omega^2(0.60 \times 10^{-2})^2$<br>$\omega = 29.671$ rad s$^{-1}$<br>$\omega \approx 30$ rad s$^{-1}$ | [1] for correct substitution<br>[1] for correct answer |
| **2(c)** | Loss in total energy = Work done against air resistance<br>$\frac{1}{2}\left(\frac{2.6}{9.81}\right)(29.671)^2(0.0060^2 - 0.0040^2) = F_v(0.0060 + 0.0040)$<br>$F_v = 0.2333$ N $= 0.23$ N | [1] for correct application of conservation of energy<br>[1] for correct substitution<br>[1] for correct answer |
| **3(a)** | A longitudinal wave is a wave in which the oscillation of the particles is parallel to the propagation of the energy of the wave. | [1] for oscillations of particles |
| **3(b)(i)** | phase difference $= \frac{\text{path difference}}{\lambda} \times 2\pi$<br>$\frac{3}{2}\pi = \frac{6.38 - 5.25}{\lambda} \times 2\pi$<br>$\lambda = 1.51$ m | [1] for correct equation and substitution<br>[1] for correct answer |
| **3(b)(ii)** | $v = f\lambda$<br>$= (220)(1.51)$<br>$= 331$ m s$^{-1}$ | [1] for correct equation and substitution.<br>[1] for correct answer |
| **3(c)** | $I = kA^2$<br>$3I = kA'^2$<br>$3kA^2 = kA'^2$<br>$A' = \sqrt{3}A$<br>resultant amplitude $= \sqrt{3}A + A = (\sqrt{3} + 1)A$<br>resultant intensity $= k(\sqrt{3} + 1)^2 A^2$<br>$= 7.46kA^2 = 7.46I$ | [1] for amplitude of $S_2$<br>[1] for resultant amplitude<br>[1] for resultant intensity |
| **4(a)(i)** | Path difference $= 2 \times 0.020$<br>$= 0.040$ m<br>Path difference = $\frac{\lambda}{2}$ | [1] for correct path difference |

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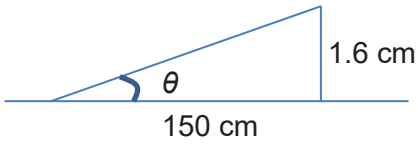
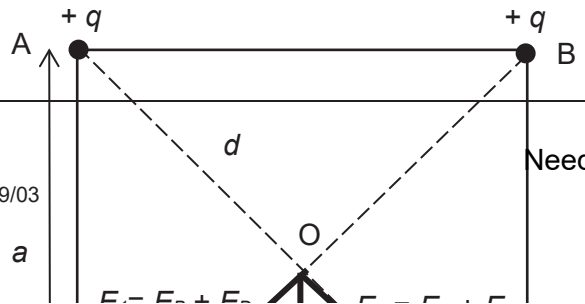
| | $\lambda = 2 \times 0.040$<br>$= 0.080$ m | [1] for correct wavelength |
| **4(a)(ii)** | The sound waves from path LXM and LYM travel in <u>opposite directions</u> and <u>meet</u>.<br><br>Since both waves are of <u>equal amplitude, frequency and speed</u>, they <u>superpose</u> to form a stationary wave. | [1]<br><br>[1] |
| **4(b)(i)** |  <br><br>$\theta = \tan^{-1}\left(\frac{1.6}{150}\right)$ $\theta = 0.61°$<br><br>angle between the two first orders $= 2\theta$<br>$= 2\tan^{-1}\left(\frac{1.6}{150}\right)$<br>$= 1.2°$ | [1] for correct $\theta$<br><br>[1] for correct answer |
| **4(b)(ii)** | $d \sin\theta = n\lambda$<br>$d \sin 0.61° = 1(600 \times 10^{-9})$<br>$d = 5.6253 \times 10^{-5}$ m<br>number of nylon threads per mm $= \frac{1 \times 10^{-3}}{d}$<br>$= \frac{1 \times 10^{-3}}{5.6253 \times 10^{-5}}$<br>$= 17.8$<br>$\approx 18$ | [1] for correct $d$<br><br>[1] for correct answer |
| **5(a)** | Electric field strength at a point is the electric force per unit positive charge placed at that point. | [1] |
| **5(b)(i) and (ii)** |  <br> | |



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| | Distance AO = BO = CO = DO = d, where<br>$d = \frac{1}{2}\sqrt{a^2 + a^2} = \frac{a}{\sqrt{2}}$<br>$E_A$, $E_B$, $E_C$ and $E_D$ are the electric field strength due to charges at A, B, C and D respectively.<br>$E_A = E_B = E_C = E_D = \frac{q}{4\pi\varepsilon_o\left(\frac{a}{\sqrt{2}}\right)^2} = \frac{2q}{4\pi\varepsilon_o a^2}$<br>$E_B$ and $E_D$ are in the same direction while $E_A$ and $E_C$ are in the same direction. Thus $E_1 = E_B + E_D$ and $E_2 = E_A + E_C$<br>$E_1 = E_2 = \frac{4q}{4\pi\varepsilon_o a^2} = \frac{q}{\pi\varepsilon_o a^2}$<br>The resultant electric field strength at point O is<br>$E = \sqrt{E_1^2 + E_2^2} = \frac{\sqrt{2}q}{\pi\varepsilon_o a^2}$ | [1] draw $E$ correctly<br>[1] for $\frac{a}{\sqrt{2}}$<br>[1] for $\frac{2q}{4\pi\varepsilon_o a^2}$<br>[1] |
| **(c)** | The particle accelerates from AB towards CD along a straight path.<br>Upon exiting CD, it decelerates. | [1]<br>[1] |
| **(d)** | Potential at C is<br>$V_C = V_A + V_B + V_D$<br>$= \frac{1}{4\pi\varepsilon_o}\left(\frac{q}{\sqrt{2}a} + \frac{q}{a} - \frac{q}{a}\right)$<br>$= \frac{q}{4\sqrt{2}\pi\varepsilon_o a}$<br>Minimum KE = change in p.e. as charge moves to infinity<br>$= qV_C = \frac{q^2}{4\sqrt{2}\pi\varepsilon_o a}$ | [1] for potential at C<br>[1] for conservation of energy<br>[1] for correct expression |
| **6(a)(i)** | From Fig. 6.2, there is <u>constant rate of decrease of magnetic flux density</u> at right angles to the plane of the coil. By Faraday's Law, <u>there is constant rate of decrease of magnetic flux linkage in the coil</u>, Hence, the induced e.m.f. across the ends of the coil is constant from $t$ = 0 s to $t$ = 2.5 s. | [1] for correct explanation<br>[1] for correct explanation |

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| **6(a)(ii)** | By Faraday's law,<br>e.m.f. = rate of change of magnetic flux linkage<br>$< E >= \frac{\Delta\Phi}{\Delta t} = \frac{\Delta(NBA)}{\Delta t}$<br>$< I > R = NA\frac{\Delta B}{\Delta t}$<br>$< I > \Delta t = \frac{NA\Delta B}{R}$<br>$\Delta Q = \frac{NA\Delta B}{R} \quad \left(\because I = \frac{\Delta Q}{\Delta t}\right)$<br>$= \frac{180 \times \frac{\pi}{4}\left(6.4 \times 10^{-2}\right)^2 \times 1.4 \times 10^{-2}}{1.5}$<br>$= 5.405 \times 10^{-3}$<br>$\approx 5.4 \times 10^{-3}$ C | [1] for $< E >= \frac{\Delta\Phi}{\Delta t} = \frac{\Delta(NBA)}{\Delta t}$<br><br>[1] for correct expression and numerical substitution<br><br>[1] for correct answer |
| **6(b)(i)** | Using $P = IV$,<br>$I_s = \frac{P}{V} = \frac{15}{6.0} = 2.5$ A<br><br>By $\frac{V_s}{V_p} = \frac{N_s}{N_p}$ and $V_s I_s = V_p I_p$,<br>$I_p = \frac{N_s}{N_p} I_s$<br>$= \frac{25}{1000} \times 2.5$<br>$= 0.0625$<br>$= 6.25 \times 10^{-2}$ A | [2] |
| **6(b)(ii)** | When the battery is first connected, current increases instantaneously in the primary coil, giving rise to increase in magnetic flux linkage in secondary coil. Hence, there is induced e.m.f. across the lamp. After some time, the current in the primary coil is constant. There is no more change in magnetic flux density in secondary coil. Hence, no e.m.f. across lamp. | [1] for correct explanation<br><br>[1] for correct explanation |
| **7(a)(i)** | 13.6 eV | [1] for correct answer |
| **7(a)(ii)** | KE of electrons $= \frac{2.00 \times 10^{-18}}{1.60 \times 10^{-19}}$<br>$= 12.5$ eV<br><br>Hence the highest state that the atom can be excited to is n=3.<br><br>Only the following transitions are allowed | [1] for correct highest state |

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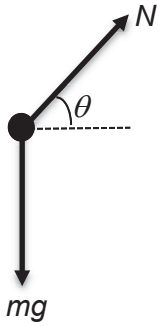
| | From n =3 to n=2<br>From n =2 to n=1<br>From n =3 to n=1<br><br>Hence number of different wavelengths of radiation that can be emitted = 3 | [1] for correct answer |
| **7(a)(iii)** | Zero.<br><br>The energy of the photon does not match exactly any of the energies required for the atom to get excited from the ground state to higher excited state hence the photons incident will not be absorbed by the atom. | [1]<br><br>[1] |
| **7(b)(i)** | From the graph, minimum wavelength $\lambda_{min}$ is the same for both spectra. | [1] |
| **7(b)(ii)** | KE lost by electron = energy of emitted X-ray photon<br>$eV = \frac{hc}{\lambda_{min}}$<br>$\lambda_{min} = 16 \times 10^{-12}$ m<br>$V = \frac{hc}{e\lambda_{min}} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{1.60 \times 10^{-19} \times 16 \times 10^{-12}}$<br>$= 7.77 \times 10^{4}$ V | [1] for correct substitution<br>[1] for correct answer |
| **8(a)** | The velocity changes as the direction of motion changes with time. So the motion is accelerated. By Newton's second law, a resultant force must be acting on it.<br>Since there is no change in its speed, there is no component of resultant force tangential to the motion, resultant force must be perpendicular to its motion (i.e. towards the centre of the motion). | [1]<br><br>[1] |
| **8(b)(i)** | $r = 0.08\cos(22^{o}) = 0.074175$<br>$N\sin\theta = mg$.....(1)<br>$N\cos\theta = \frac{mv^2}{r}$.....(2)<br>(1)/(2):<br>$\Rightarrow \tan\theta = \frac{gr}{v^2}$<br>$\Rightarrow v = \sqrt{\frac{9.81 \times 0.074175}{\tan(22^{o})}} = 1.3420 \approx 1.34$ ms$^{-1}$<br>  <br> | [1] for correct r<br>[1] for the 2 correct equations<br>[1] for correct substitution<br>[1] for correct answer |
| **8(b)(ii)** | No as there is no vertical component of the normal contact force to balance the weight. | [1] for correct answer |
| **8(c)(i)** | Gravitational potential at a point is the work done per unit mass in bringing a small test mass from infinity to that point. | [2] |

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| **8(c)(ii)** | $g = \frac{GM}{(R+h)^2} \Rightarrow GM = g(R+h)^2$<br>$\phi = -\frac{GM}{(R+h)} = -\frac{g(R+h)^2}{(R+h)} = -g(R+h)$ | [1] for correct expression<br>[1] for correct manipulation |
| **8(c)(iii)** | $\phi = -g(\text{R+h}) = -0.15(3.3\times10^6+1.4\times10^7) = -2595000$<br>Gain in gravitational potential energy = Loss in kinetic energy<br>$m\ (2595000) = \frac{1}{2}mv^2$<br>$\Rightarrow v = 2278.2 \approx 2280\ \text{m s}^{-1}$ | [1] for correct potential at P<br>[1] for correct method/ substitution<br>[1] for correct answer |
| **8(c)(iv) 1.** | $\Delta U = m(\Delta\phi) = 12000\ \times[(-3.2)-(-12.6)]\times10^6 \approx 1.13\times10^{11}\text{J}$ | [1] for correct substitution<br>[1] for correct answer |
| **8(c)(iv) 2.** | $g = -\frac{d\phi}{dr} = -\frac{\Delta\phi}{\Delta r} = -\frac{(-1.0)-(-5.2)}{6.5-1.5}\times\frac{10^6}{3.3\times10^6} \approx 0.255\ \text{N kg}^{-1}$ | [1] for correct substitution<br>[1] for correct answer |
| **8(c)(iv) 3.** | $g = \frac{\text{GM}}{(4\text{R})^2} = \frac{\text{GM}}{16\text{R}^2} = 0.255\text{N kg}^{-1}$<br>$g_{surface} = \frac{\text{GM}}{(\text{R})^2} = 0.255\times16 = 4.08\ \text{N kg}^{-1}$ | [1] for correct method<br>[1] for correct answer |
| **9(a)** | The volt is the potential difference between two points in a circuit in which one joule of electrical energy is converted to other forms of energy when one coulomb passes from one point to the other. | [1] for correct definition |
| **9(b)** | e.m.f. of a cell is the electrical potential energy converted from other forms of energy when unit charge flows through the cell.<br>p.d. is the work done in converting electrical potential energy to other forms of energy when unit charge flows across two points in the circuit. | [1] for correct explanation for e.m.f.<br>[1] for correct explanation for p.d. |
| **9(c)(i)** | $I = \frac{V}{R} = \frac{2.0}{8.0} = 0.25\ \text{A}$ | [1] for correct equation<br>[1] for correct answer |
| **9(c)(ii)** | $P = IV$<br>$I = \frac{0.50}{2.0} = 0.25\ \text{A}$<br>Total current through AX $= 0.25 + 0.25 = 0.50\ \text{A}$<br>$V_{A□} = IR = (0.50)(8.0) = 4.0\ \text{V}$ | [1] for correct current through bulb<br>[1] for correct total current<br>[1] for correct final answer |
| **9(c)(iii)** | $E = Ir + V$<br>$E = (0.50)(6.0) + 6.0 = 9.0\ \text{V}$ | [1] for correct equation<br>[1] for correct answer |
| **9(d)** | The advantage of using the variable resistor is that a larger current can pass through the bulb to achieve greater brightness. | [1] for valid advantage |

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| | The disadvantage is that the range of voltage that can be applied across the bulb is smaller. | [1] for valid disadvantage |
| **9(e)(i)** | As the sliding contact X is adjusted in the direction of B, the potential difference (p.d.) across AX increases. There will be a point along AB where the p.d. across AX is equal to the e.m.f. of cell $E_2$.<br><br>When this happens, no current will flow through $E_2$, hence giving zero galvanometer reading. | [1] for balanced potentials<br><br>[1] for no current |
| **9(e)(ii)** | The balance length AX will be too small to be reliable since the percentage uncertainty will be large as the value of the balance length approaches the value of the uncertainty of the measurement of the balance length. | [1] for stating small balance length<br><br>[1] for correct explanation |
| **9(f)(i)** | 1.10 V | [1] for correct answer |
| **9(f)(ii)** | Resistor across balance length CY<br>$R_{CY} = \frac{0.725}{1.000} \times 2.0$<br>$= 1.45\ \Omega$<br><br>Total resistance across AD = $R_{total}$<br><br>$V_{AB} = \frac{R_1}{R_{total}} \times V_{AD}$ --- (1)<br>$V_{CY} = \frac{R_{CY}}{R_{total}} \times V_{AD}$ --- (2)<br><br>$\frac{(2)}{(1)}$ $\frac{V_{CY}}{V_{AB}} = \frac{R_{CY}}{R_1}$<br><br>E.m.f. of thermocouple,<br>$V_{CY} = \frac{R_{CY}}{R_1} \times V_{AB}$<br>$= \frac{1.45}{110} \times 1.10$<br>$= 0.0145$ V (14.5 mV) | [1] for correct $R_{CY}$<br><br>[1] for correct expression of $V_{AB}$ and $V_{CY}$<br><br>[1] for correct answer |

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**2019 JC2 Prelim Physics Practical Suggested Mark Scheme**

Penalise for d.p. and unit once per question per instrument.
Penalise for not repeating once, applicable only for Q3.
All range are inclusive of the end values.

<table>
<tr><th>No.</th><th>Solution</th><th>Remark</th></tr>
<tr><td>1(a)(iv)</td><td>$V_0$ = 0.27 V</td><td>[1] for correct dp and units</td></tr>
<tr><td>1(a)(v)</td><td>first ammeter reading = 92.8 mA<br>second ammeter reading = 87.1 mA</td><td>[1] for correct dp and units</td></tr>
<tr><td>1(b)(iii)</td><td>$x$ = 30.0 cm<br>$I$ = 108.2 mA</td><td>[1] for correct dp and units<br>29 cm to 31 cm range for $x$.</td></tr>
<tr><td>1(c)</td><td>
<table>
<tr><th>$x$ / cm</th><th>$I$ / mA</th><th>$\frac{1}{x}$ / cm$^{-1}$</th></tr>
<tr><td>20.0</td><td>153.8</td><td>0.0500</td></tr>
<tr><td>30.0</td><td>108.2</td><td>0.0333</td></tr>
<tr><td>40.0</td><td>90.4</td><td>0.0250</td></tr>
<tr><td>50.0</td><td>78.4</td><td>0.0200</td></tr>
<tr><td>60.0</td><td>69.9</td><td>0.0167</td></tr>
<tr><td>70.0</td><td>62.9</td><td>0.0143</td></tr>
</table>
Note:<br>Range for $x$ minimum of 50 cm<br>Penalise if not significant range of $I$.<br>Trend of change : as $x$ increase, $I$ decreases.
</td><td>[1] for 6 sets of readings (see note)<br>[1] for correct d.p. for raw data<br>[1] for correct sf for processed data<br>[1] for correct calculation<br>[1] for correct headings and units</td></tr>
<tr><td>1(d)</td><td>Refer to attached graph.</td><td>[1] correct axes and units, scale<br>[1] correct plotting of points to half the smallest division<br>[1] best fit line (penalize for big scatter and curve)</td></tr>
<tr><td>1(d)</td><td>$gradient = P = \frac{140 - 74}{0.045 - 0.0185} = 2490$ mA cm<br>Substitute $(0.045, 140)$ into the equation,<br>$140 = (2490)(0.045) + Q$<br>$Q = 27.9$ mA</td><td>[1] correct labelling of gradient coordinates of triangle and correct size of triangle, correct substitution of the gradient<br>[1] for correct determination and units of $P$<br>[1] correct</td></tr>
</table>


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| | | calculation and units for $Q$ |
| **1(e)** | $L = \frac{2490}{27.9} = 89.2$ cm | [1] for correct calculation and units<br>Range :<br>0 m < L < 2 m |
| **1(f)(ii)** | $x$ = 40.0 cm<br>$I$ = 89.3 mA | 39 cm < x < 41 cm |
| **1(f)(iv)** | The point agrees with the pattern set by the other points on the graph as it is very close to the best fit line.<br><br>Comparing with (a)(v),<br>error in values of $I = \frac{92.8 - 97.1}{2} = 3$ mA<br>Z is well within the error range of ±3 mA. | [1] for (f)(ii), f(iii) and statement based on scatter of Z from best fit line<br><br>[1] for valid justification using (a)(v). Accept any logical reasoning. |
| **2(a)** | $S$ = 5.0 cm | |
| **2(b)(i)** | $S_1$ = 27.8 cm<br><br>$S_2$ = 17.6 cm | [1] for correct measurements with units<br>Range :<br>23cm < $S_1$ < 34cm<br>14cm < $S_2$ < 22cm |
| **2(b)(ii)** | $p$ = 17.8 cm<br><br>$q$ = 12.6 cm | [1] for correct calculation with units |
| **2(c)(i)** | $k$ = 25.4 N m$^{-1}$ | [1] for correct calculation |
| **2(c)(ii)** | $m^2g^2 = \frac{k^2p^2}{4} + k^2q^2$<br>$\left(\frac{p^2}{4} + q^2\right) = \frac{g^2}{k^2}m^2$<br>Plot $\left(\frac{p^2}{4} + q^2\right)$ vs $m^2$, gradient is $\frac{g^2}{k^2}$ so $k$ can be determined. | [1] for correct linearization<br><br>[1] for correct gradient |
| **3(a)(ii)** | $L = \frac{L_1 + L_2}{2}$<br>$= \frac{0.490 + 0.490}{2}$<br>$= 0.490$ m | [1]<br>- repeated<br>- nearest mm<br>- unit<br><br>48cm < $L$ < 50cm |

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| **3(a)(iii)** | percentage uncertainty $= \frac{\Delta L}{L} \times 100\%$<br>$= \frac{0.005}{0.490} \times 100\%$<br>$= 1\%$ | [1]<br>- $\Delta L$ between 2 to 5 mm<br>- answer 1 or 2 s.f. |
| **3(a)(iv)** | $M$ = 0.10811 kg | [1]<br>- either 1 d.p. |
| **3(b)(iii)** | $x$ = 0.150 m<br>$y$ = 0.490 m | [1] – nearest mm<br>Range of ±0.5cm for x and y:<br>14.5cm < $x$ < 15.5cm<br><br>Range of y depends on c.g. |
| **3(b)(iv)** | percentage uncertainty $= \frac{\Delta x}{x} \times 100\%$<br>$= \frac{0.002}{0.150} \times 100\%$<br>$= 1\%$ | [1]<br>- $\Delta$x = 2 or 3 mm<br>- answer 1 or 2 s.f. |
| **3(c)** | $N$ = 47<br>$t_1$ = 21.6 s<br>$t_2$ = 21.6 s<br>$T = \frac{t_1 + t_2}{2N} = \frac{21.6 + 21.6}{2(47)} = 0.460$s<br><br>No need to consider range here | [1] for $t$<br>- 1 d.p. in s<br>- more than 20s<br>- repeated readings<br>[1] for $T$ calculated correctly and in 3 s.f. |
| **3(d)** | $x$ = 0.380 m<br><br>$N$ = 40<br>$t_1$ = 22.9 s<br>$t_2$ = 22.8 s<br>$T = \frac{t_1 + t_2}{2N} = \frac{22.9 + 22.8}{2(40)} = 0.571$s | [1] $x$ in nearest mm<br><br>[1] $T$ calculated correctly and in 3 s.f. |
| **3(e)(i)** | First value :<br>$T = k\sqrt{M + \frac{x}{y}m}$<br>$0.460 = k\sqrt{0.10811 + \frac{0.150}{0.490}(0.200)}$<br>$k = 1.11785$<br>$= 1.12$ s kg$^{-0.5}$ | [1] for first $k$ |



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| | Second value :<br>$T = k\sqrt{M + \frac{x}{y}m}$<br>$0.571 = k\sqrt{0.10811 + \frac{0.380}{0.490}(0.200)}$<br>$k = 1.11297$<br>$= 1.11 \text{ s kg}^{-0.5}$ | [1] for second $k$<br><br>Penalize once for mistakes:<br>-wrong unit |
| **3(e)(ii)** | Percentage difference in values of $k$<br>$= \frac{1.12 - 1.11}{1.11} \times 100\%$<br>$= 0.9\%$<br>Percentage difference in values of $k$ is comparable to the percentage uncertainties of $x$ (and $L$)<br>Hence, the experimental results support the suggested relationship.<br><br>Note:<br>Accept answer that compare the percentage uncertainty of $x$. | [1]<br>- valid conclusion by comparing the percentage difference of $k$ .<br><br>Penalize for adding or subtracting the percentage uncertainties of $x$ and $L$. |
| **3(f)(i)** | | |

| $M$ / kg | $x$ / m | $y$ / m | $N$ | $t_1$ /s | $t_2$ /s | $T$ /s | $k$ / s kg$^{-0.5}$ |
|---|---|---|---|---|---|---|---|
| 0.0500 | 0.050 | 0.240 | 55 | 21.1 | 21.3 | 0.385 | 1.27 |
| 0.10811 | 0.050 | 0.240 | 35 | 21.2 | 21.1 | 0.604 | 1.56 |

[1] – table heading with symbols and units. (minimum need $M$, $N$, $t_1$ and $t_2$ )
[1] – all raw data in correct d.p.
[1] – all processed data calculated correctly.

$t_1$ and $t_2$ > 10s

$y$ must be 24.0 cm
$x$ must be same for both

| | | |
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| **3(f)(ii)** | Values of $k$ for (f) are 1.27, 1.56<br><br>The percentage difference for $k$ in (f) is:<br>$= \frac{1.56 - 1.27}{1.27} \times 100\%$<br>$= 23\%$<br><br>Values of $k$ for (e) (1.11 and 1.12) are **smaller** than that of (f).<br><br>Percentage difference for (e) (0.9%) is **smaller** than that of (f) | <br><br><br><br><br>[1] comment on $k$ magnitude<br><br>[1] comment on percentage uncertainty of $k$ |

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| **3(g)(i)** | - Drill 6 small hole at equal intervals between 28cm to 48cm of the half metre rule. Tie a small loop of thread through each of the holes.<br>- Measure the mass of the rule, *M*<br>- Attach the spring and loop at the 28cm mark. Hang the 200g mass at the 27cm mark.<br>- Adjust until the spring and loop is vertical and the rule is horizontal.<br>- Measure x and y.<br>- Displace the mass vertically and time the period T of the rule's oscillation.<br>- Repeat the experiment by attaching the spring to different holes to obtain 6 different values of y.<br>- Keep x constant.<br>- Plot a graph of *T* against $\frac{1}{y}$.<br>If a straight line graph through the origin is obtained, then the relationship is proven.<br><br>Accept lgT vs lg y with gradient = -1 (but cannot pass through origin) | [1]<br>repeat steps to vary *y* as shown in **(b)** and **(c)**.<br><br>[1] keep x constant<br><br>[1] plot graph<br><br>[1] straight line conclusion |

| No. | Solution | Remark |
|---|---|---|
| **4** | **Aim**: To determine the values of *p* and *q*.<br><br>From the expression<br>$I = E d^p v^q$<br>Linearising gives<br>1. $\lg(I) = q\lg(v) + \lg(E d^p)$ for keeping *d* constant, and<br><br>2. $\lg(I) = p\lg(d) + \lg(E v^q)$ for keeping *v* constant<br><br>1. To determine *q* (keep *d* constant, vary *v*)<br><br>**Independent variable**:<br>- Speed of copper rod, *v*, calculated by expression $F = \frac{B^2L^2v}{R}$, where copper rod is moving with constant speed v, perpendicular in the uniform magnetic field of flux density *B*, *L* is the separation of the steel bars, *R* is the resistance of the copper rod of length *L*, *F* is the magnetic force acting in the opposite direction of its velocity. *R* can be measured by ohmmeter for copper rod of length *L*, diameter *d*.<br><br>**Dependent variable**:<br>- Induced current in the copper rod, $I$, measured by a microammeter in a closed circuit connected to the copper rod. | [1] correct independent, dependent and controlled variables |


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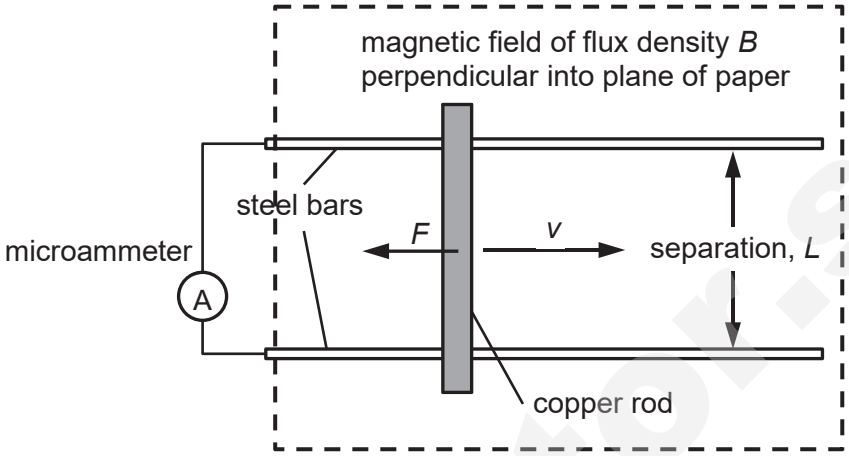
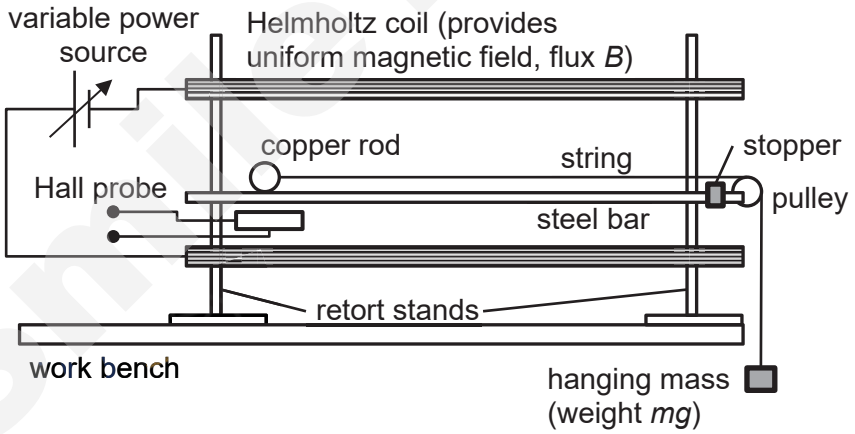
**Controlled variables**:
- Diameter of copper rod, *d*, measured by micrometer screw guage.
- Separation of the steel bars to be at constant separation *L*.

**Diagram** :




top view

[2] show closed circuit with ammeter and direction of magnetic field




side view

[1] show closed circuit with Helmholtz coil, Hall probe, hanging mass load and pulley

**Procedure** :

a) Set up the apparatus as shown above.

b) Switch on the power to the Helmholtz coil, and check the uniformity of the magnetic field between the upper and lower coils with a Hall probe. Record the Hall output voltage and check voltage calibration for the magnetic flux density *B*.

[1] how to produce a uniform magnetic field and any sensible method of producing uniform field

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| | c) Record the mass *m* of the slotted mass attached to the string connected to the centre of the copper rod over a frictionless pulley using an electronic balance. | [1] how to obtain *v* |
| | d) Using the expression $mg = \frac{B^2L^2v}{R}$, obtain $v = \frac{mgR}{B^2L^2}$. | |
| | e) Measure a distance *s* from the release point to the rubber stopper along the steel bar with a metre rule.<br>f) Release the copper rod and record the time *t* with a stopwatch for the rod to travel a distance *s*, obtain $v = \frac{s}{t}$ to check against the constant speed *v* calculated in (d). | [1] to measure $v = \frac{s}{t}$ with the measuring instruments |
| | g) Record the induced current $I$ in the copper rod with a microammeter.<br>h) Repeat steps (c) to (g) using different masses *m* to obtain 6 sets of data of *m, d, t, v* and $I$. | [1] for repeat readings at constant *d* |
| | i) From $I = Ed^pv^q$, $\lg(I) = q\lg(v) + \lg(Ed^p)$<br>Plot a graph of $\lg(I)$ against $\lg(v)$, *q* is the gradient. | [1] use of log or ln linearised equation, plot the correct graph and how to determine *q* |
| | 2. To determine *p* (keep *v* constant, vary *d*)<br><br>**Independent variable**:<br>- Diameter of copper rod, *d*, measured by micrometer screw gauge.<br><br>**Dependent variable**:<br>- Induced current in the copper rod, $I$, measured by a microammeter in a closed circuit connected to the copper rod.<br><br>**Controlled variables**:<br>- Separation of the steel bars to be at constant separation *L*.<br>- Speed of the copper rod *v*, calculated from $v = \frac{mgR}{B^2L^2}$ and checked by steps (e) and (f). | [1] correct independent, dependent and controlled variables<br><br>[1] for micrometer screw gauge or vernier calipers |
| | j) Repeat steps (b) to (g) using copper rods of different diameters *d* to obtain 6 sets of data of *m, d* and $I$.<br>k) From $I = Ed^pv^q$, $\lg(I) = p\lg(d) + \lg(Ev^q)$<br>Plot a graph of $\lg(I)$ against $\lg(d)$, *p* is the gradient. | [1] for repeat readings at constant *v*<br>[1] use of log or ln linearised equation, plot the correct graph and how to determine *p* |

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| | **<u>Further details</u>** :<br>*Precautions to improve accuracy:*<br>- Measure the separation of the steel bars at both ends of the rail to ensure the bars are parallel at constant separation *L*.<br>- For each value of *m*, repeat the experiment to obtain average values of *v* and $I$, so as to reduce random errors and check if terminal velocity is reached.<br><br>*Safety precautions*:<br>- Clamp 2 rubber stoppers at the end of the steel bars to prevent the copper rod from falling off the bench.<br>- Ensure the retort stands and steel bars are firmly clamped onto the bench and secured respectively to prevent them from toppling about during the experiment.<br>- Wear thick rubber gloves when switching off the power to the Helmholtz coil in between data taking to prevention electrocution. | [1] for any 1 correct answer<br><br>[1] for any 1 correct answer |

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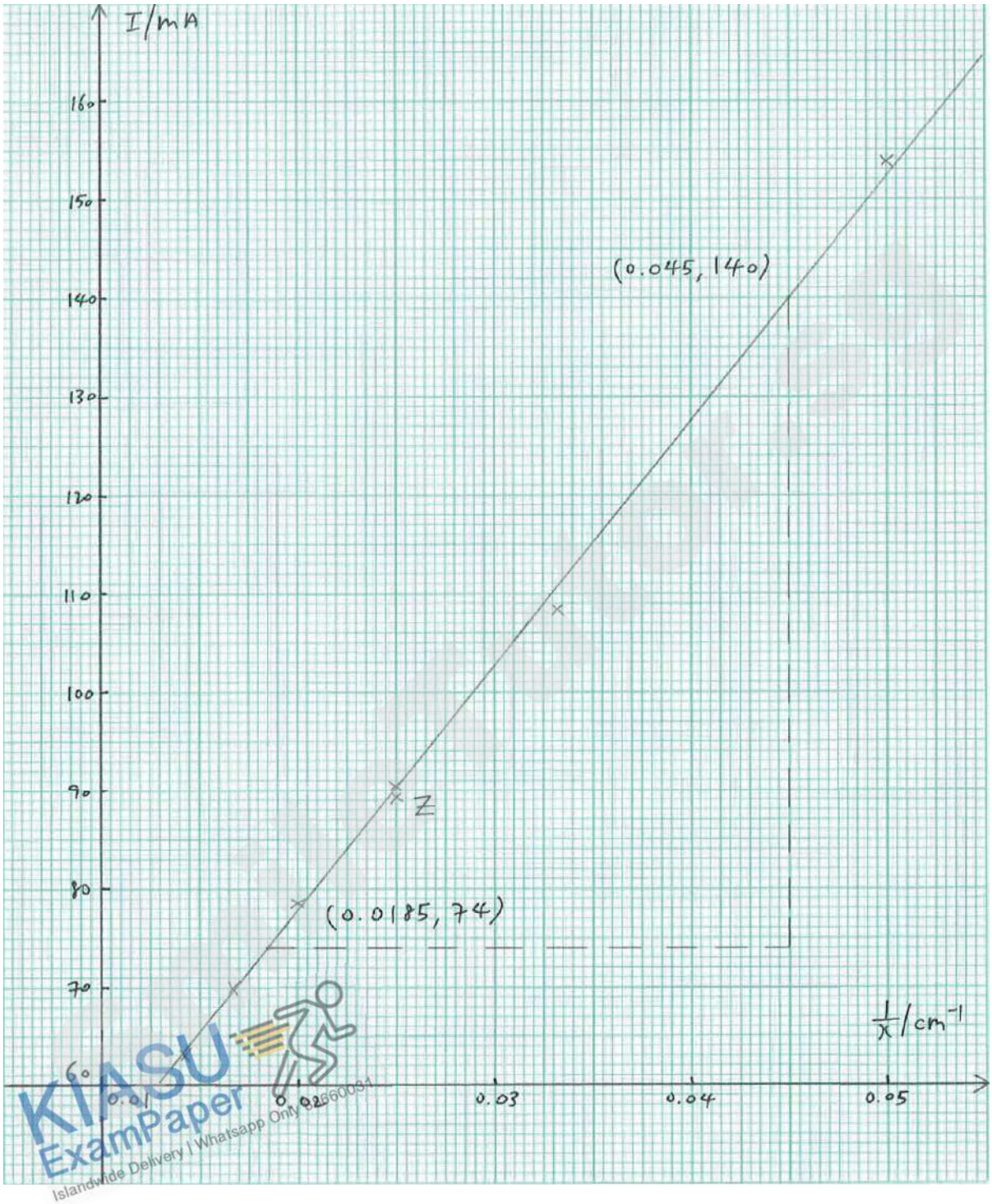


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# 2019 Preliminary Exams

## Pre-University 3

**H2 PHYSICS** **9749/01**

**Paper 1 Multiple choices** **23 September**

**1 hour**

Additional Material: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Write your name, class, admin number on the Multiple Choice Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Multiple Choice 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 approved scientific calculator is expected, where appropriate.


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**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 | $h$ | = | $6.63 \times 10^{-34}\ \text{Js}$ |
| 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 | $g$ | = | $9.81\ \text{m s}^{-2}$ |

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -Gm/r$ |
| temperature | $T/\text{K} = T/^\circ\text{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin\omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos\omega t$<br>$= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current / voltage | $x = x_0 \sin\omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** The human head consists of the skull, brain, eyes, teeth, and the facial muscles and skin.

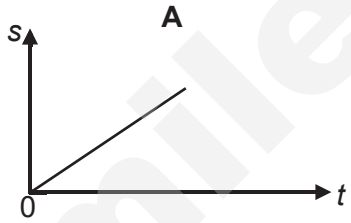
What is a good estimation of the weight of the head of a typical adult?

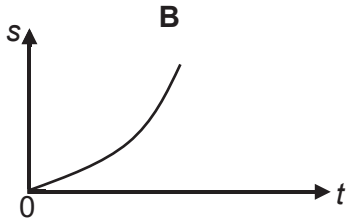
**A** 1.0 kg **B** 3.0 kg **C** 5.0 kg **D** 7.0 kg

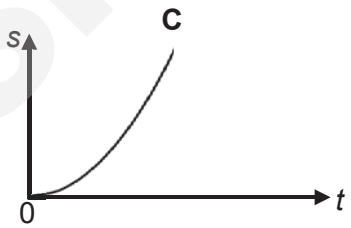
**2** A car driver steps down on the accelerator when the traffic lights go green. The force on the car varies with time as shown, with time $t = 0$ as the moment when the traffic lights go green.

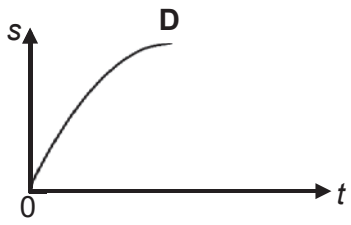



Which of the following graphs best represents how the displacement $s$ of the car varies with time $t$?

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3 A stone is thrown vertically upwards in a medium in which the viscous drag cannot be neglected. If the times of flight for the upward motion $t_u$ and the downward motion $t_d$ (to return to the same level) are compared, which of the following statement is corrent?

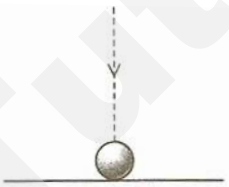
**A** $t_d < t_u$, because at a given speed the net accelerating force when the stone is moving downwards is greater than the retarding force when it is moving upwards.

**B** $t_d < t_u$, because the stone is moving with the greatest speed at the moment of projection and so greatest effect of the viscous drag.

**C** $t_d = t_u$, because viscous drag always opposes motion and so will affect motion of the stone with the same effect whether the stone is moving upwards or downwards.

**D** $t_d > t_u$, because at a given speed the net accelerating force when the body is moving downwards is smaller than the retarding force when it is moving upwards.

4 A ball falls vertically on to a horizontal surface. The momentum of the ball just before it hits the surface is $mv$.



The ball collides inelastically with the surface and rebounds from it.

What is a possible value for the magnitude of the change in momentum of the ball from just before until just after contact with the surface?

**A** 0.25$mv$

**B** 1.0$mv$

**C** 1.25$mv$

**D** 2.0$mv$

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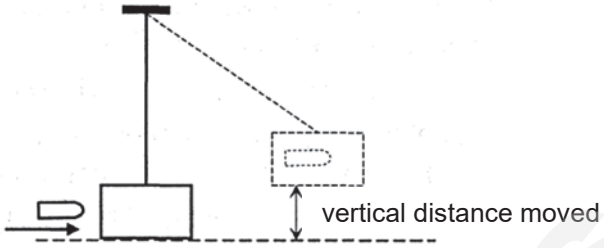
**5** A small plastic bullet of mass *m* is fired horizontally into a suspended block of wood of mass *M* and becomes embedded in the block, which rises up as shown in the diagram below.

Which of the following statements regarding the bullet and the wooden block is correct?




**A** The total mechanical energy of the bullet and block is conserved because they move with the same velocity after the collision.

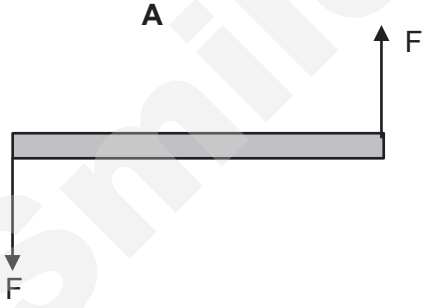
**B** The gravitational potential energy gained by the block is equal to the loss in kinetic energy by the bullet.

**C** There is heat produced in the collision because the collision is inelastic.

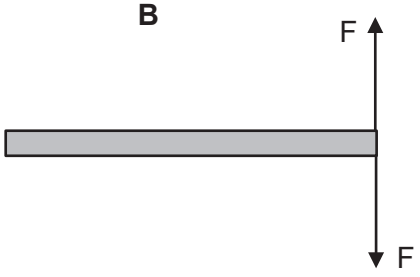
**D** The total horizontal momentum of the bullet and block is not conserved because there is a resultant horizontal force acting on them.

**6** In which situation could the pair of forces applied to the rigid bar produce a couple?

**A**




**B**




**C**




**D**

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**7** A balloon of mass 15.0 g is filled with helium to a volume of 4.50 $m^3$ and attached to the ground via a light elastic cord of constant k = 80 N $m^{-1}$. The wind blows on the balloon such that the elastic cord makes an angle of 60° to the ground. Density of air is 1.29 kg $m^{-3}$ and density of helium is 0.180 kg $m^{-3}$.

What is the extension of the elastic cord when the balloon is at equilibrium in the above position?

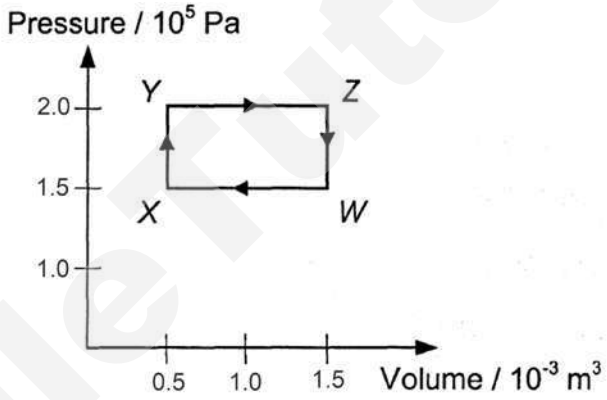
**A** 0.615 m

**B** 0.650 m

**C** 0.705 m

**D** 0.750 m

**8** An ideal gas undergoes the cycle of pressure and volume changes $W \rightarrow \square \rightarrow \square \rightarrow \square \rightarrow W$ as shown in the diagram below.




What is the net work done on the gas?

**A** - 50 J

**B** 50 J

**C** - 150 J

**D** 150 J

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**9** A spring that has natural length of 20 cm takes 5.0 J of work to be stretched by 5.0 cm.

Given that the spring obeys Hooke's Law, what is the additional work required to stretch it a further 5.0 cm?

**A** 5 J

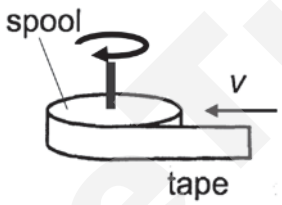
**B** 10 J

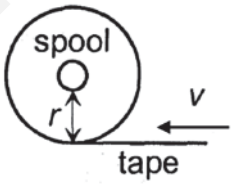
**C** 15 J

**D** 20 J

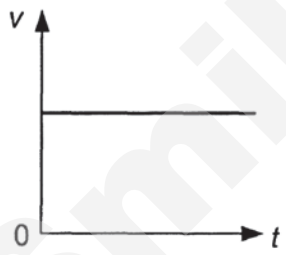
**10** A straight length of tape winds onto a spool rotating about a fixed axis with constant angular velocity, such that the radius of the roll increases at a steady rate.

Which one of the following graphs below correctly shows how the speed $v$ at which the tape moves towards the roll varies with time $t$?

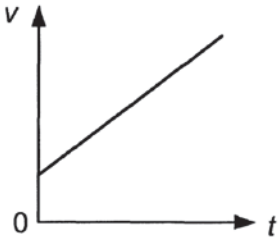


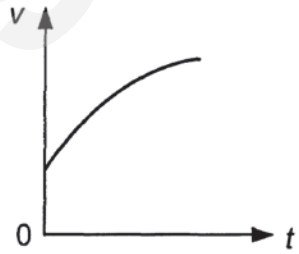

**A**



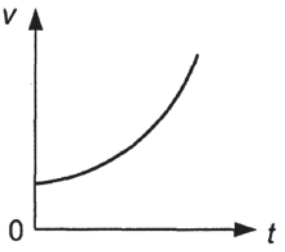

**B**




**C**




**D**

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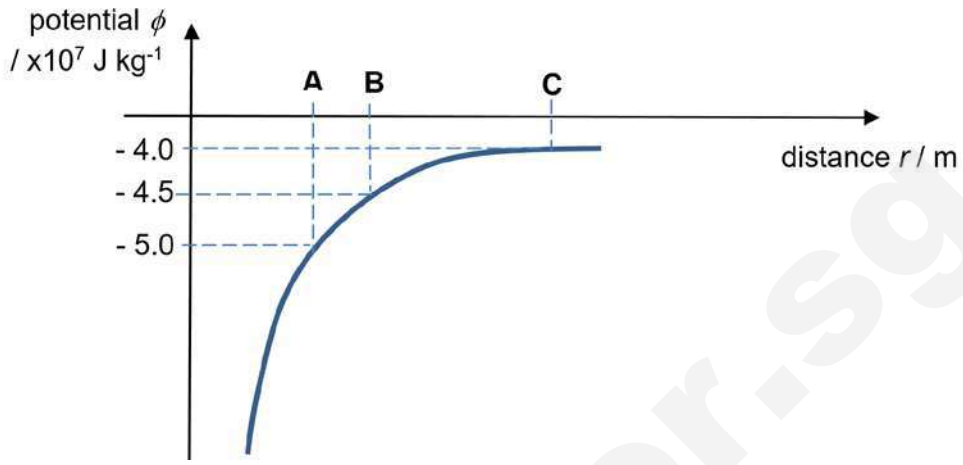
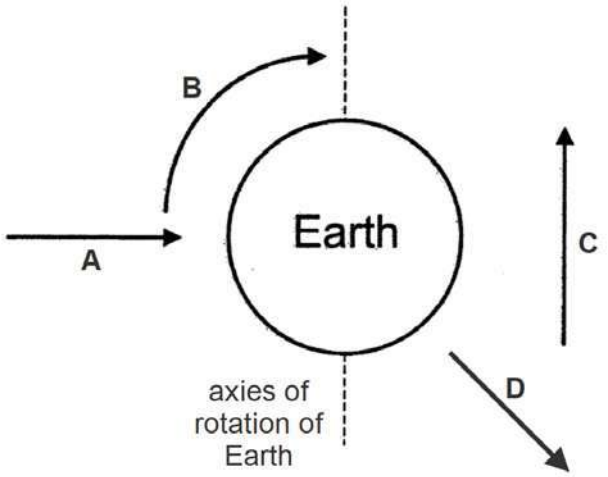
**11** The graph (not to scale) below shows how the gravitational potential $\phi$ of Earth varies with distance $r$ from its centre, with values of $\phi$ given for three positions **A**, **B**, and **C**. Mass of Earth is $6.0 \times 10^{24}$ kg.




What are the distances **AB** and **BC**?

| | distance **AB** / x $10^6$ m | distance **BC** / x $10^6$ m |
|---|---|---|
| **A** | 0.89 | 1.1 |
| **B** | 0.89 | 1.8 |
| **C** | 8.9 | 11.1 |
| **D** | 8.9 | 17.8 |

**12** The diagram below shows four possible paths of a spacecraft moving near the Earth but well above any influence of the atmosphere.




Which path is **not** possible unless the spacecraft fires its rockets as it follows the path?

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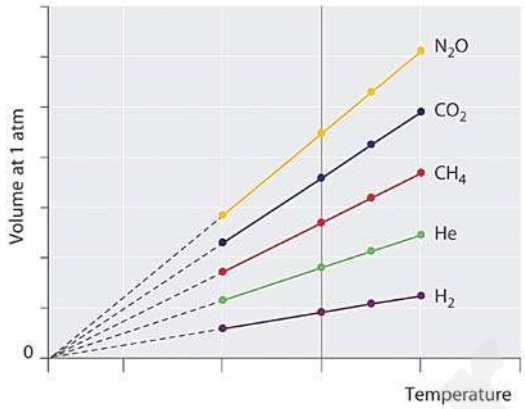
**13** A student takes some measurements to plot graphs of volume versus temperature for different amounts of selected gases at 1 atm pressure, as shown in digram below. He observed that all the plots extrapolate to the same point $T_o$ on the temperature-axis, regardless of the type or the amount of the gas.




Which of the following rows are correct regarding $T_o$?

| | **value of $T_o$** | **nature of $T_o$** |
|---|---|---|
| **A** | - 273.16 °C | It is the temperature at which water exists in all of its three states. |
| **B** | - 273.15 °C | It is the temperature at which no more heat can be removed from a system. |
| **C** | 0 °C | It is the melting point of ice. |
| **D** | 273.16 K | It is the temperature at which the particles in a substance becomes motionless. |

**14** Which of the following statements concerning phase change and internal energy is ***false*** ?

**A** During boiling, all the heat supplied causes both the internal kinetic and potential energies to increase.

**B** During melting, all the heat supplied causes the increase in internal potential energy only.

**C** The mean kinetic energy of the liquid molecules at boiling point is about the same as that of the molecules which have just vaporised.

**D** The mean kinetic energy of the molecules just before and after melting is about the same.

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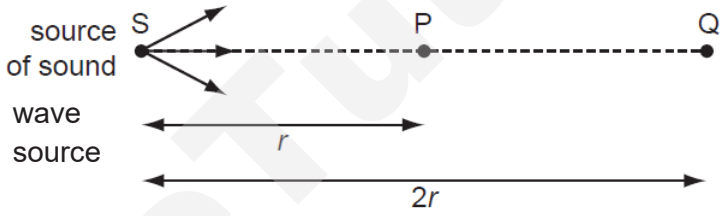
**15** A vertical spring-mass system has a natural period of 1.25 s. A periodic force with frequency of 2.50 Hz is then applied to the system such that it oscillates with amplitude of 1.5 cm and reaches a steady state. The mass is observed to be at the bottom amplitude position at time $t = 0$.

What is the speed and direction of movement of the mass after 0.15 s?

| | speed / $m s^{-1}$ | direction of movement |
|---|---|---|
| **A** | 0.111 | downwards |
| **B** | 0.167 | downwards |
| **C** | 0.111 | upwards |
| **D** | 0.167 | upwards |

**16** The intensity $I$ of a sound at a point P is inversely proportional to the square of the distance $r$ of P from the source of the sound.




At point Q, distance $2r$ from source S, air molecules oscillate with amplitude 6.0 μm. Point P is at distance $r$ from S.

What is the amplitude of oscillation of air molecules at P?

**A** 0.75 μm

**B** 1.5 μm

**C** 3.0 μm

**D** 12.0 μm

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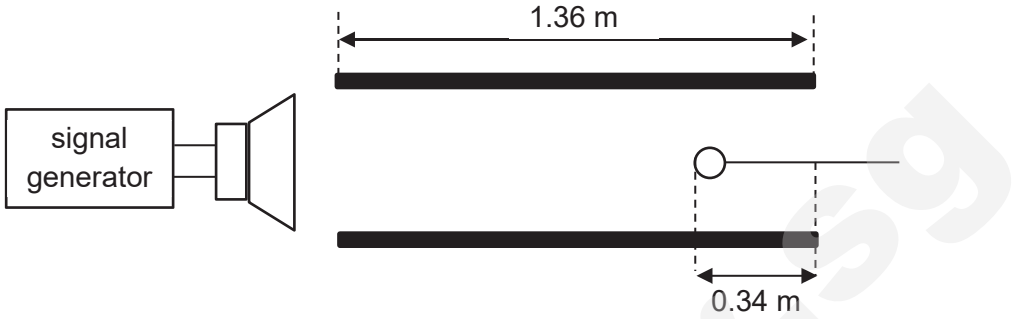
**17** A speaker connected to a signal generator is placed infront of an open tube of length 1.36 m.

A small microphone is inserted inside the tube. It detects the first position with zero intensity at a distance of 0.34 m from the end. The microphone is then fixed in this position.

The speed of sound in the tube is 340 $ms^{-1}$.




The frequency of the signal generator is now increased until the microphone again detects zero intensity.

What is this new frequency?

**A** 750 Hz

**B** 1000 Hz

**C** 1500 Hz

**D** 3000 Hz

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

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

**A** The new distance is smaller than 19 cm.

**B** The distance remains the same.

**C** The new distance is larger than 19 cm.

**D** The blue grain of sand cannot be resolved.

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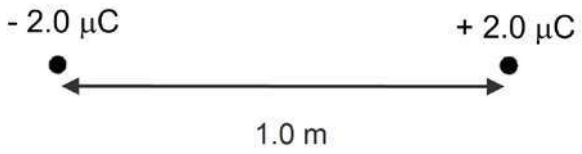
**19** A pair of equal and opposite charges each of 2.0 μC is separated by 1.0 m as shown below.




What is the magnitude of the electric field strength at the midpoint between the two charges?

**A** 0 $Vm^{-1}$

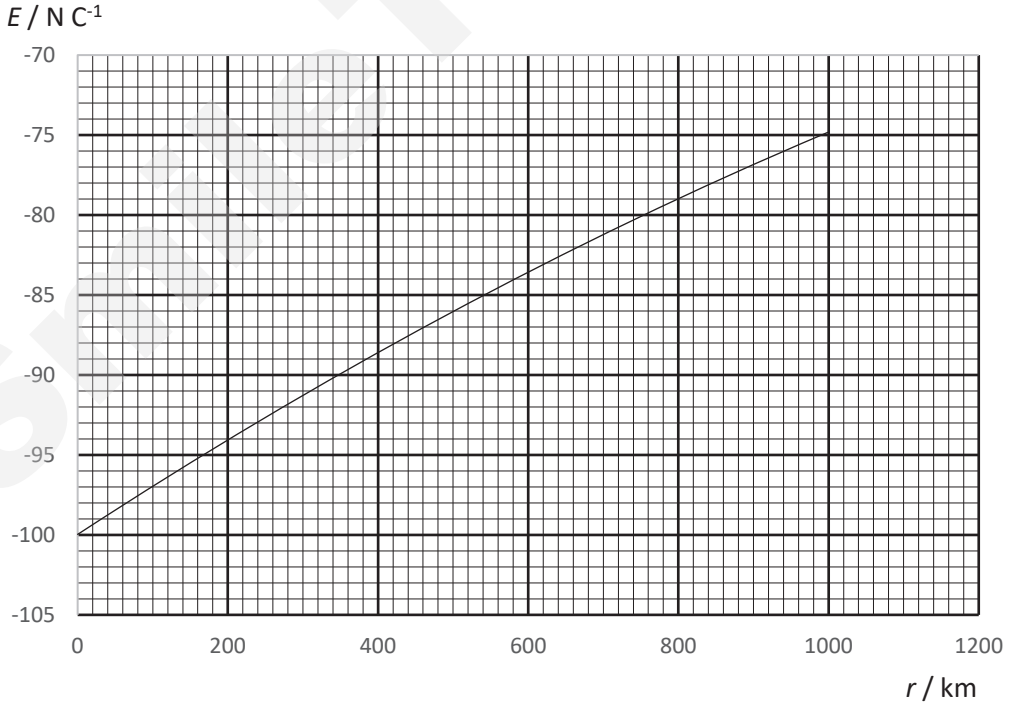
**B** 3.6 $x10^4$ $Vm^{-1}$

**C** 7.2 $x10^4$ $Vm^{-1}$

**D** 1.4 $x10^5$ $Vm^{-1}$

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

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




Which of the following is the electric potential of Earth at 500 km above its surface?

**A** $- 2.25 \times 10^{-5}$ V

**B** $- 7.50 \times 10^{-5}$ V

**C** the gradient of the tangent of graph at *r* = 500 km

**D** the area between the graph and *r* axis from infinity to *r* = 500 km

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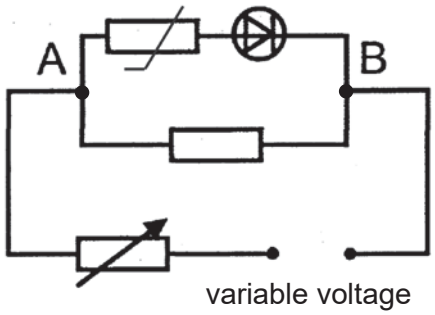
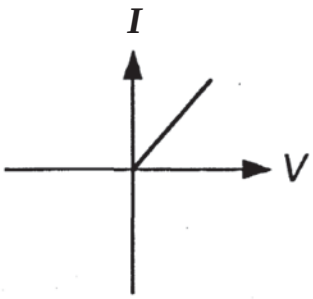
**21** A circuit is set up as shown below.

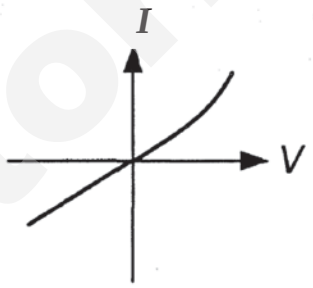



Which of the following $I$-$V$ graphs represent the current through, and voltage across, points AB?

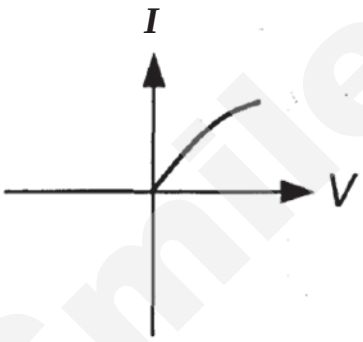
**A**



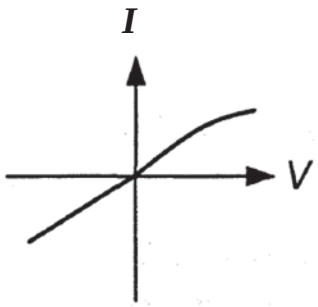

**B**




**C**




**D**

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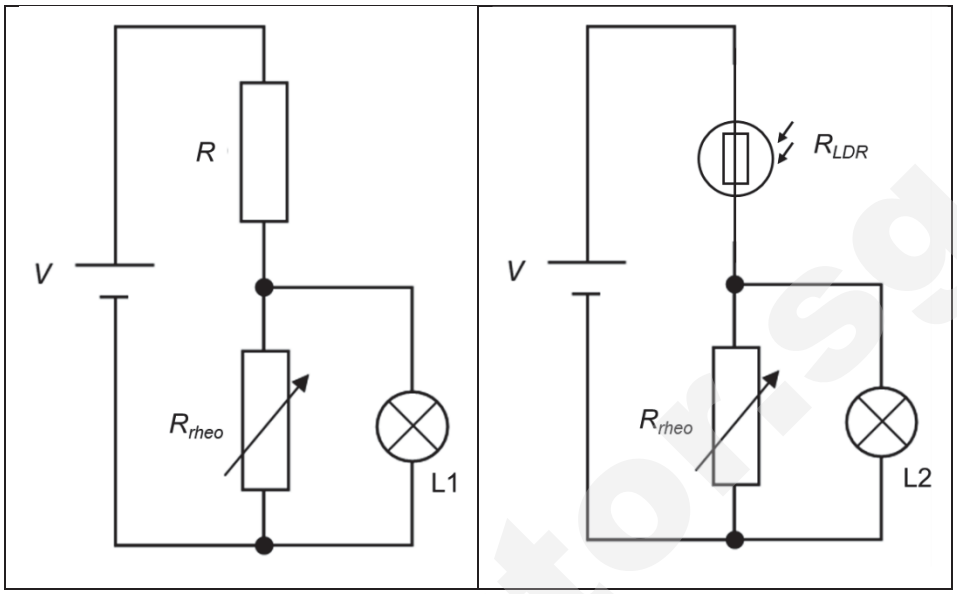
**22** A fixed resistor and a light dependent resistor (LDR) are placed in two identical circuits far from each other. Initially when the circuit is connected, the resistance of the LDR $R_{LDR}$ , the rheostat $R_{rheo}$ and the fixed resistor $R$ are equal. Assume the batteries have negligible internal resistance.




Which of the following correctly describes the brightness of L1 and L2 when varying $R_{rheo}$ in both circuits?

| | ***$R_{rheo}$ increases*** | ***$R_{rheo}$ decreases*** |
|---|---|---|
| **A** | L1 is brighter than L2 | L1 is brighter than L2 |
| **B** | L1 is brighter than L2 | L2 is brighter than L1 |
| **C** | L2 is brighter than L1 | L1 is brighter than L2 |
| **D** | L2 is brighter than L1 | L2 is brighter than L1 |

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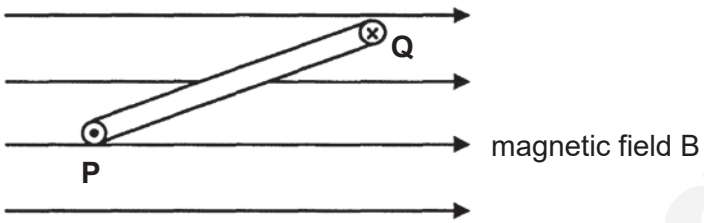
**23** Diagram below shows a plan view of a current carrying rectangular coil in a uniform magnetic field B. The current in side **P** is flowing perpendicularly out of the plane of the paper, the current in side **Q** is flowing perpendicularly into the plane of the paper.

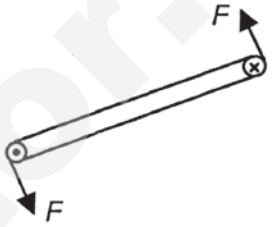



Which one of the following correctly shows the directions of the forces that act on the sides of the coil?

**A**



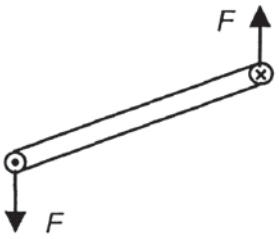

**B**




**C**




**D**




**24** In a cross-field velocity selector apparatus, when the magnetic field *B* is applied at right angles to the electric field *E*, ions of charge *q* and speed *v* are selected to pass through.

In order to select ions of speed smaller than *v*, which of the following adjustments should be made?

**A** increase q

**B** increase E

**C** increase B

**D** decrease B

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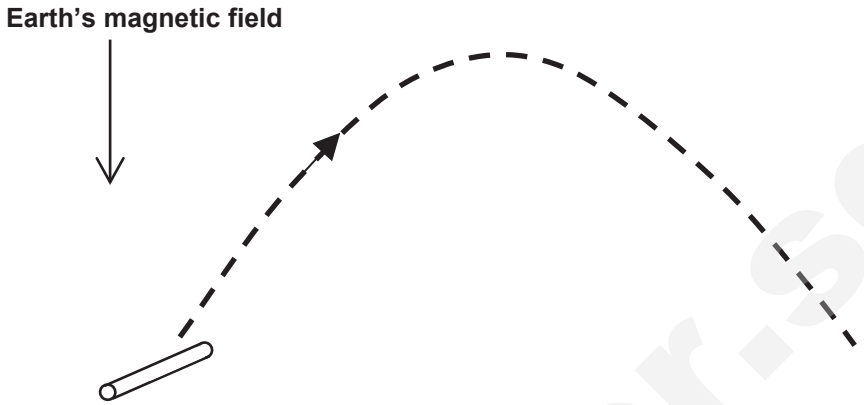
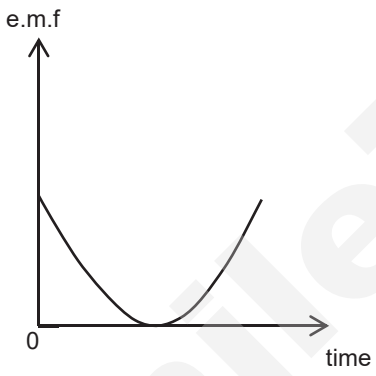
**25** A metal rod is thrown such that it moves in a parabolic path. Along its movement, the metal rod's long axis remains perpendicular to the earth's magnetic field. It can be assumed that air resistance is negligible, the Earth's magnetic field is pointing downwards and is uniform throughout the rod's trajectory.

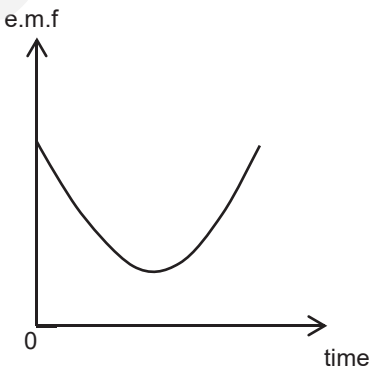



Which of the following graphs show the variation of the e.m.f. induced between both ends of the rod with time?

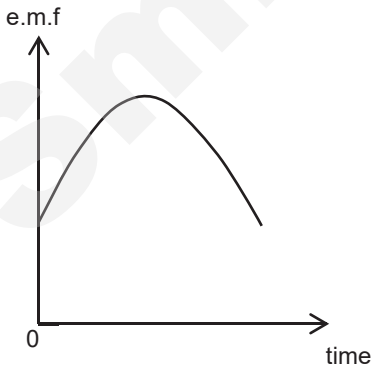
**A**



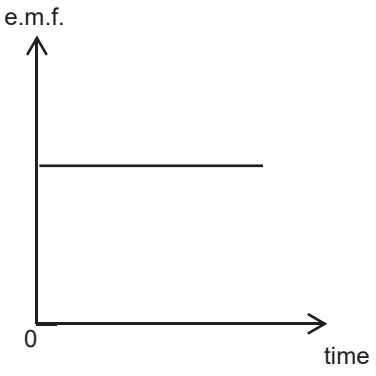

**B**




**C**




**D**

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**26** The a.c. mains voltage supply ***V*** of a certain country is given by the expression

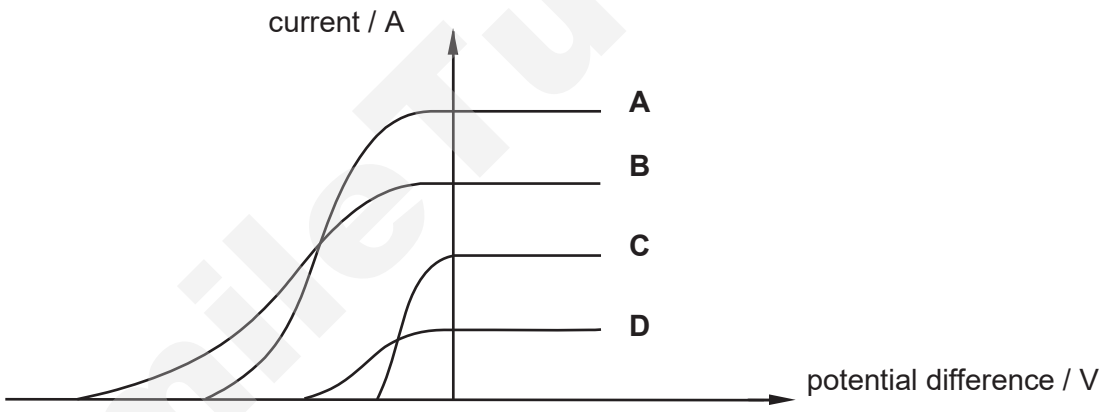
$$V = 141 \sin(314t) \quad \text{V}.$$

A device of resistance 200 Ω is connected to the mains.

What is the frequency of the a.c. mains, and the average power **<*P*>** delivered to the device?

| | **frequency / Hz** | **<*P*> / W** |
|---|---|---|
| **A** | 50 | 50 |
| **B** | 50 | 100 |
| **C** | 100 | 50 |
| **D** | 100 | 100 |

**27** The figure below shows the currents observed in a photocell circuit as a function of the potential difference between the plates of the photocell when light beams A, B, C and D were each directed in turn at the cathode.




Which of the beams has the lowest wavelengths?

**28** The uncertainty in the position of an electron is 43 nm. What is the minimum uncertainty in its velocity?

**A** $7.9 \text{ m s}^{-1}$

**B** $8.0 \text{ m s}^{-1}$

**C** $1.7 \times 10^{3} \text{ m s}^{-1}$

**D** $1.7 \times 10^{4} \text{ m s}^{-1}$

**29** In the Rutherford scattering experiment, most α-particles passed through the foil undeflected.

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Which one of the following is a correct conclusion from this result?

**A** $\alpha$-particles were helium nuclei.

**B** The nucleus has a positive charge.

**C** Most of the mass of an atom is within the nucleus.

**D** The diameter of the nucleus is much less than the diameter of the atom.

**30** A student claims that certain types of radiation carry enough energy to break bonds between molecules and ionise atoms, and so causes “radiation sickness”.

Which of the following statements with regard to the above claim is correct?

**A** Radiation sickness can be caused by microwaves.

**B** Ionising radiation can consist of gamma rays, alpha particles and beta particles.

**C** Ionising radiation cannot consist of alpha particles and beta particles as these are not waves.

**D** Radiation sickness can only be caused by human-made radiation and not by natural sources of radiation.

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Class | Adm No

Candidate Name: _____

millennia institute

# 2019 Preliminary Exams
## Pre-University 3

**H2 PHYSICS** **9749/02**

Paper 2 Structured Questions **17 September**

Candidates answer on the Question Paper. **2 hours**

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

**Do not turn over this page until you are told to do so.**

Write your full name, class and Adm number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams 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 | | / 5 |
| 2 | | / 10 |
| 3 | | / 13 |
| 4 | | / 10 |
| 5 | | / 10 |
| 6 | | / 10 |
| 7 | | / 22 |
| Presentation | | |
| Total | | / 80 |



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**Data**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -Gm/r$ |
| temperature | $T/\text{K} = T/^\circ\text{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin\omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos\omega t$<br>$= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current / voltage | $x = x_0 \sin\omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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

**1** The length of a piece of paper is measured as 280 ± 1 mm. Its width is measured as 230 ± 2 %. Area *A* is the area of one side of the piece of paper.

**(a)** State the value of *A* and its actual uncertainty to the appropriate number of significant figures.

*A* = …… ± …… $mm^2$ [3]

**(b)** The accepted value of *A* is $8.00 \times 10^4$ $mm^2$.
Use your answer in **(a)** to distinguish between *accuracy* and *precision*.

accuracy ……

……

……

precision ……

……

…… [2]

[Total: 5]

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**2 (a) (i)** Explain what is meant by the term *work done*.

……..…….....

……..……..... [1]

**(ii)** Hence derive the equation

$$E_p = mgh$$

for the potential energy change of a mass $m$ moved through a vertical distance $h$ near the Earth's surface.

[3]

**(b)** A typical escalator in a mall rises at an angle of 45° to the horizontal. It lifts people through a vertical height of 32 m in each minute. 60 people can fit on the escalator and there is a constant stream of people such that the escalator is always fully loaded. It can be assumed that all passengers remain standing still while on the escalator and the average mass of one passenger is 55 kg.

**(i)** Calculate the power needed to lift the passengers when the escalator is fully loaded.

power = …… W [2]

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**(ii)** The total frictional force acting against motion of the escalator is $1.5 \times 10^4$ N when the escalator is fully loaded.

**1.** Calculate the power needed to overcome the friction.

power = ..... W [2]

**2.** In lifting the passengers and overcoming friction, the motor is only 70% efficient due to other forms of energy loss. Calculate the power input for the motor driving the fully loaded escalator.

power = ..... W [2]

[Total: 10]

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**3 (a) (i)** With reference to the first law of thermodynamics, explain why there is considerable difference in magnitude between the specific latent heats of fusion and vaporisation for the same material.

……

……

……

……

…… [4]

**(ii)** Ethanol has a melting point of -120 °C and a boiling point of 78 °C. The specific latent heat of fusion is 110 J $g^{-1}$ and specific latent heat of vaporisation is 840 J $g^{-1}$. The density and specific heat capacity of liquid ethanol are 0.79 g $cm^{-3}$ and 2.4 J $g^{-1}$ $K^{-1}$ respectively.

Calculate the minimum thermal energy required to fully vapourise 2.0 $cm^3$ of ethanol that is initially at 30 °C.

required thermal energy = …… J [4]

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**(b)** Some gas, assumed to behave ideally, is contained within a cylinder which is surrounded by insulation to prevent loss of heat, as shown in Fig. 3.1.

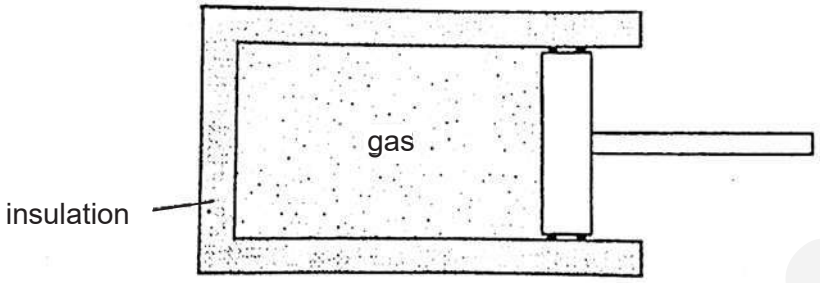


**Fig. 3.1**

Initially, the volume of gas is $2.9 \times 10^{-5}$ m$^3$, its pressure is $2.6 \times 10^6$ Pa and its temperature is 790 K.

**(i)** The gas expands to a volume of $2.9 \times 10^{-4}$ m$^3$ and its temperature decreases to 314 K. Calculate the pressure of the gas after this expansion.

pressure of gas after expansion = ..... Pa [2]

**(ii)** The work done by the gas during the expansion is 91 J. Determine the change in the internal energy of the gas during the expansion.

change in internal energy = ..... J [1]

**(iii)** Explain the meaning of internal energy, and use your result in **(b)(ii)** to explain why a decrease in the temperature of the gas takes place during the expansion.

.....

.....

.....

..... [2]

[Total: 13]

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**4 (a)** Define *electric field strength* and state its SI unit.

……..……..……..

**(iv)** State the gain in kinetic energy of the proton.

gain in kinetic energy = …… J [1]

**(c)** In a classical model of the hydrogen atom, the electron revolves around the positive nucleus, which is made up of single proton. Since the proton is very massive compared to the electron, the proton can be assumed stationary as the electron goes around it in a circular orbit. The radius of this circular orbit is taken to be $5.3 \times 10^{-11}$ m, which is the radius of the hydrogen atom.

Estimate the average electric current along the electron's orbit.

electric current = …….. A [4]

[Total: 10]

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**5** An alternating current varies with time in the way shown in Fig. 5.1.

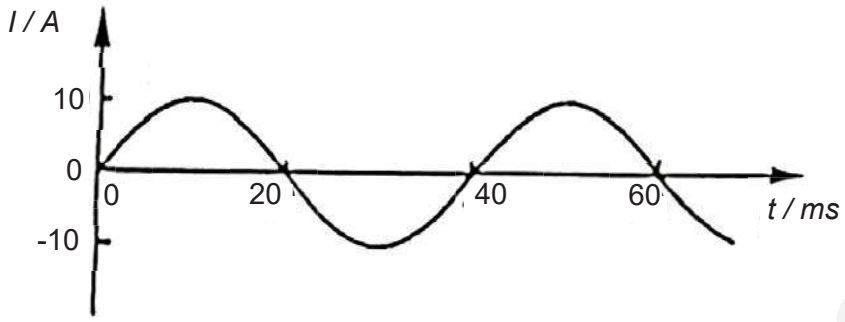


**Fig. 5.1**

**(a)** **(i)** By reference to heating effect, explain what is meant by the *root-mean-square* (r.m.s.) value of an alternating current.

……

……

…… [2]

**(ii)** Determine the frequency of the alternating current.

frequency = …… Hz [1]

**(iii)** Determine the peak value of the alternating current.

peak value of current = …… A [1]

**(iv)** Determine the root-mean-square value of the alternating current.

root-mean-square value of current = …… A [1]

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**(v)** In the space below, sketch a graph to show how the power supplied by this alternating current to a resistor of resistance 5 Ω varies with time. Label values of peak power and period on the Y-axis and X-axis respectively.

[2]

**(b) (i)** Explain what is meant by an *ideal transformer*.

……

…… [1]

**(ii)** The current shown in Fig. 5.1 is in the 300-turn primary coil of an ideal transformer. The secondary coil of the transformer has 6000 turns. Calculate the transformer's peak output current.

peak output current = …… A [2]

[Total: 10]

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**6 (a)** In the space below draw a diagram of the setup used to demonstrate the photoelectric effect, and use it to explain how the photoelectric effect provides evidence for the particulate nature of electromagnetic radiation.

……

……

……

……

……

……

……

……

…… [4]

**(b)** State, with a reason, what modifications to the apparatus in the setup in **(a)** would be required, separately, to increase

**(i)** the energy of a photoelectron,

……

……

……

…… [1]

**(ii)** the rate of production of photoelectrons.

……

……

……

…… [2]

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**(c)** Describe and explain an experiment that gave rise to a model for the wave nature of light.

……

……

……

……

……

……

…… [3]

[Total: 10]

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**7** The National Electrical Code (NEC), is an adoptable standard for the safe installation of electrical wiring and equipment in some countries. It is part of the National Fire Codes series published by the National Fire Protection Association (NFPA), a private trade association. Despite the use of the term "national", it is not a federal law. It is typically adopted by states and municipalities in an effort to standardize their enforcement of safe electrical practices. In some cases, the NEC is amended, altered and may even be rejected in lieu of regional regulations as voted on by local governing bodies. The "authority having jurisdiction" inspects for compliance with these minimum standards.

A type of wire used for interior wiring of houses, hotels, office buildings, and industrial plants, is referred to as wire “A”. Wire “A” is permitted to carry no more than a specified maximum amount of current. The “wire gauge” is a standard method used to describe the diameter of wires.

Table 7.1 shows the diameter d and resistance R of a constant length L of the wire for various wire gauges. The constant length L for this set of data is 1.00 m.

**Table. 7.1**

| Wire Gauge | d / mm | R / mΩ |
|---|---|---|
| 14 | 0.27 | 19.0 |
| 12 | 0.32 | 13.9 |
| 10 | 0.38 | 9.70 |
| 8 | 0.46 | 6.60 |
| 6 | 0.56 | 4.40 |
| 5 | 0.91 | 1.68 |

$I_{max}$ is the maximum amount of current that can flow in wire “A” of 1.00 m before it overheats. The graph of $I_{max}$ against the diameter of the gauge d is plotted in Fig. 7.1 below.

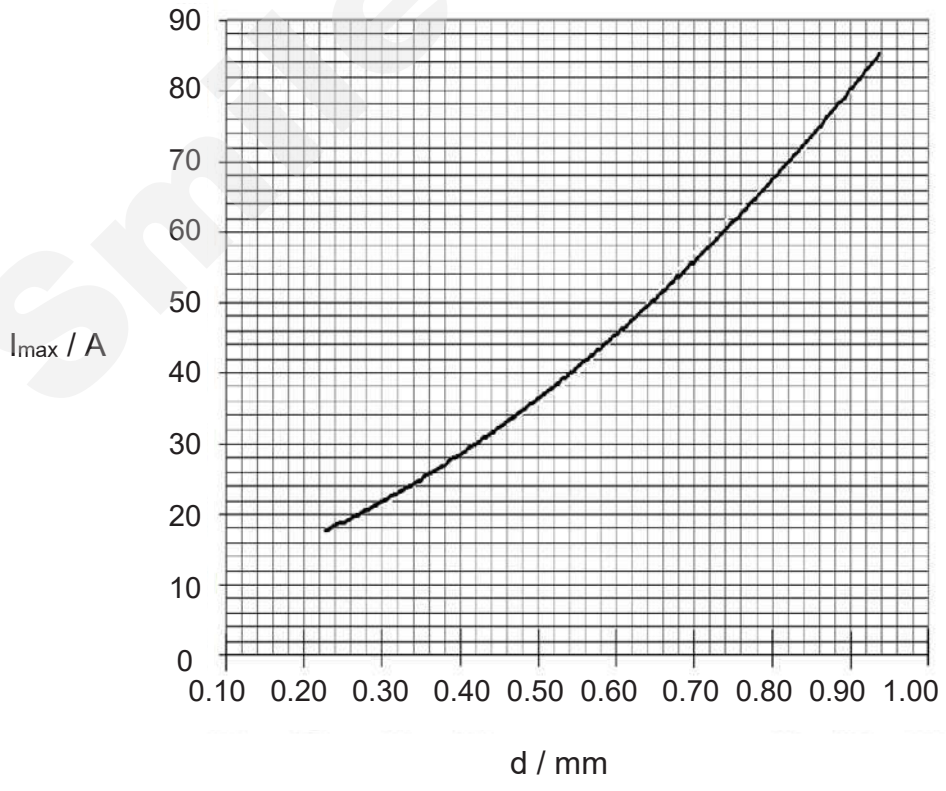


**Fig. 7.1**

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A student, who is investigating how the resistance of wire “A” depends on the diameter of the wire, believes that resistance R of wire “A” is related to diameter d by the following equation:

$$R = kd^n$$

where k and n are constants.

The student uses Table. 7.1 to compute the data in Table 7.2 so that he can test his hypothesis.

**Table. 7.2**

| ln (d / mm) | lg (R / mΩ) |
|---|---|
| -0.57 | 1.28 |
| -0.49 | 1.14 |
| -0.42 | 0.987 |
| -0.33 | 0.820 |
| -0.25 | 0.643 |
| -0.041 | 0.225 |

The student then plots the variation of lg (d / mm) with lg (R / mΩ) on a graph. The graph is shown in Fig. 7.2.

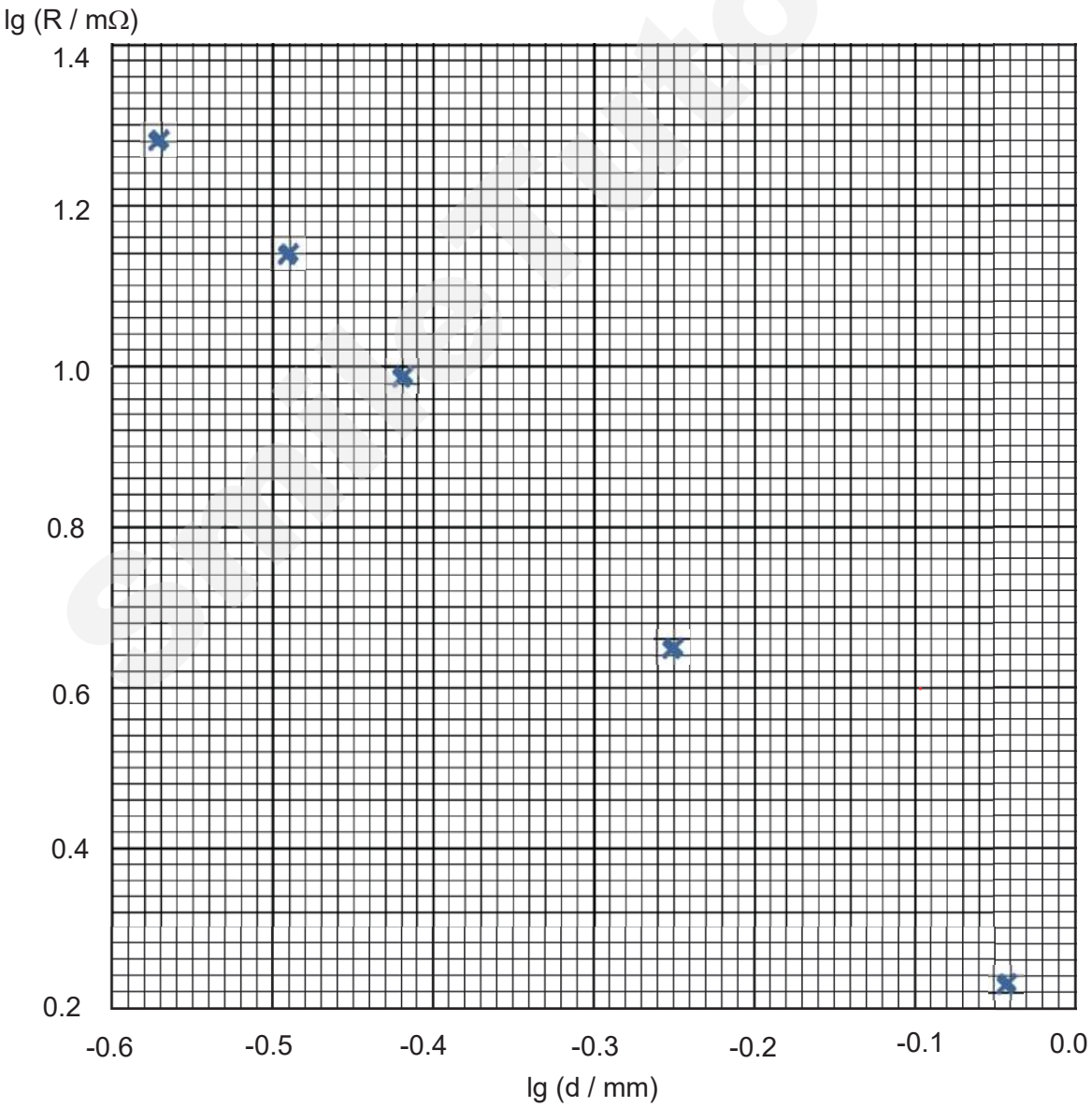


**Fig. 7.2**

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**(a)** **(i)** Use Table 7.1 to suggest qualitatively the relationship between diameter d and resistance R.

……

……

…… [1]

**(ii)** Explain why the graph of Fig. 7.2 supports the student's hypothesis.

……

……

……

…… [2]

**(b)** **(i)** Plot the point for d = 0.46 mm on Fig. 7.2. [1]

**(ii)** Complete Fig. 7.2 by drawing the line of best fit. [1]

**(iii)** Determine the value of n from your line.

n = …… [2]

**(c)** Use Fig. 7.2 to find the resistance R of wire "A" with diameter 0.73 mm.

R = …… Ω [3]

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**(d)** If $k = 4\rho L / \pi$, determine the value of $\rho$, where L is the length of the wire. Include an appropriate unit for $\rho$.

$\rho$ = ..... [4]

**(e)** A boiler, with resistance of 6.0 kΩ and rated at 5.4 MW is to be connected to two wire "A"s of length 1.00 m each as shown in Fig. 7.3 below.

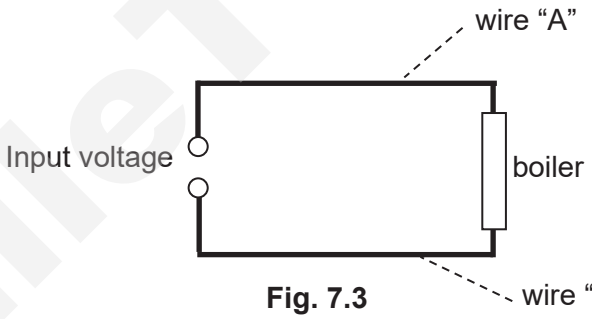


**Fig. 7.3**

**(i)** Determine the thinnest permissible wire that can be used with the boiler. Choose a suitable gauge from Table 7.1 and explain your choice.

.....

..... [3]

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**(ii)** Suggest a reason why a manufacturer would use the thinnest possible wire.

……

…… [1]

**(iii)** State and explain an advantage of using a thicker wire for this boiler.

……

……

…… [2]

**(iv)** Calculate the potential difference across each of the 1.00 m wires for the gauge selected in **(e)(i)**.

potential difference = …… V [2]

[Total: 22]

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# 2019 Preliminary Exams
# Pre-University 3

## H2 PHYSICS 9749/03

Paper 3 Long Structured Questions **19 September**

Candidates answer on the Question Paper. **2 hours**

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

**Do not turn over this page until you are told to do so.**

Write your full name, class and Adm number in the spaces at the top of this page.
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You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue total or correction fluid.

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

**Section A**
Answer **all** questions.
**Section B**
Answer **one** question only.

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

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

| For Examiner's Use | | |
|---|---|---|
| **Sect A** | | |
| 1 | | /10 |
| 2 | | /12 |
| 3 | | /10 |
| 4 | | /10 |
| 5 | | /10 |
| 6 | | /8 |
| **Sect B** | | |
| 7 | | /20 |
| 8 | | /20 |
| Presentation | | |
| Total | | /80 |

This question paper consists of **23** printed pages and **1** blank page.

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**Data**

| | |
|---|---|
| speed of light in free space | $c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$ |
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| the Avogadro constant | $N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$ |
| the Boltzmann constant | $k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$ |
| gravitational constant | $G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$ |
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**Formulae**

| | |
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| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

**1 (a)** Fig. 1.1 shows the velocity-time graph of a small particle as it passes a point O.

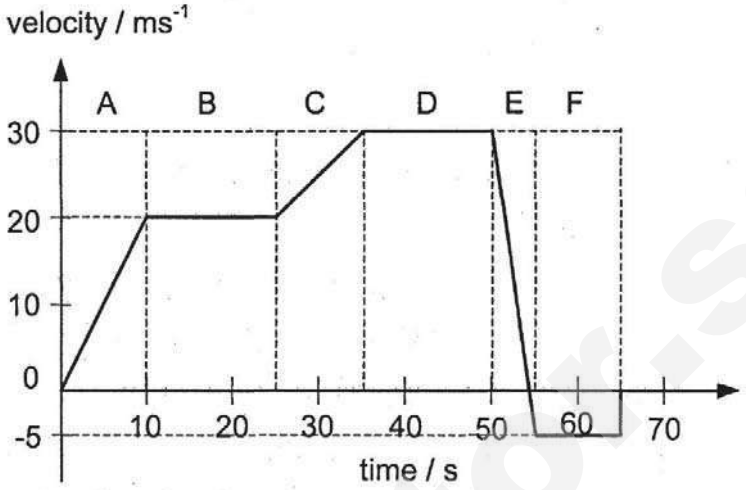


**Fig. 1.1**

**(i)** Describe qualitatively what happens in sections E and F of the journey.

.....

.....

.....

..... [2]

**(ii)** Without doing any calculation, sketch the shape of the corresponding displacement-time graph in Fig. 1.2.

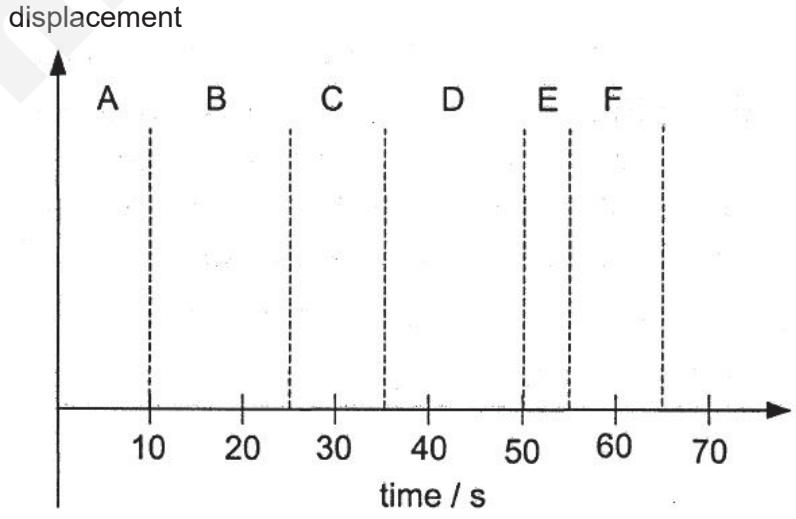


**Fig. 1.2**

[3]

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**(b)** The small particle is placed at height *h* on a frictionless 30° ramp, as shown in Fig. 1.3. When released at point **A**, the block slides down the ramp to point **B** and then falls 1 m to the floor. It lands in the small hole **C** which is located 1 m from the end of the ramp.

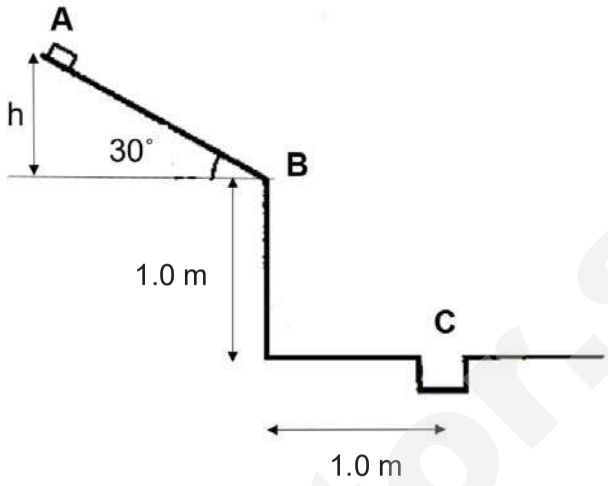


**Fig. 1.3**

**(i)** Show that the velocity at **B** is 3.9 m $s^{-1}$.

[3]

**(ii)** At what height *h* should the small particle be released in order to land in the hole **C**?

*h* = ..... m [2]

[Total: 10]

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**2** Data for the Earth and the Moon are given below:

$$\frac{\text{Radius of Earth}}{\text{Radius of Moon}} = 3.7$$

$$\frac{\text{Mass of Earth}}{\text{Mass of Moon}} = 81$$

Separation of the Moon from Earth is $3.84 \times 10^8$ m and the gravitational field strength due to Earth at its surface is 9.8 N $kg^{-1}$.

**(a)** Calculate the gravitational field strength due to the Moon at its surface.

gravitational field strength = ..... N $kg^{-1}$ [3]

**(b)** There is a point on the line between the Earth and the Moon at which their combined gravitational field strength is zero.

Calculate the distance between this point and the centre of the Earth.

distance = ..... m [2]

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**(c)** The Moon orbits around the Earth with a period of 27.3 days.

**(i)** Calculate the angular speed of the Moon.

angular speed = …….. rad $s^{-1}$ [1]

**(ii)** Calculate the mass of the Earth.

mass = …… kg [2]

**(iii)** Determine the gravitational force between the Earth and the Moon.

gravitational force = …….. N [2]

**(iv)** The force calculated in **(c)(iii)** is very large. Suggest why this force has negligible effect on the motion of the Earth.

…….

……

[2]

[Total: 12]

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**3 (a)** Explain the meaning of the following terms as applied to waves. You may include labelled diagrams as part of your explanation.

**(i)** polarisation

.....

.....

..... [2]

**(ii)** constructive interference

.....

.....

..... [2]

**(b)** Two polarising disks whose planes are parallel are centered on a common axis. The direction of the polarising axis in each case relative to the common vertical direction are as shown in Fig. 3.1. A plane polarised beam of light parallel to the vertical reference direction is incident from the left on the first disk with an intensity of $I_i$.

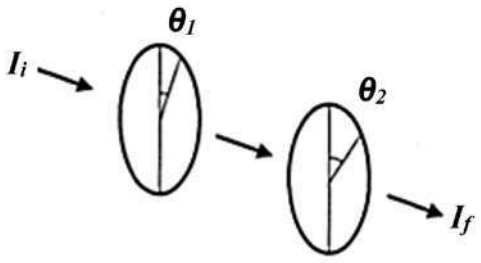


**Fig. 3.1**

Calculate the transmitted intensity $I_f$ when $\theta_1 = 20.0°$ and $\theta_2 = 40.0°$. Leave your answer in terms of $I_i$.

$I_f$ = ..... [2]

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**(c)** Point source P, consisting of light with wavelength 630 nm, passes through a narrow slit and is incident on a screen at a distance of 2.4 m from the slit. Fig. 3.2 below shows the variation of intensity $I$ of the light on the screen with distance $x$ along the screen.

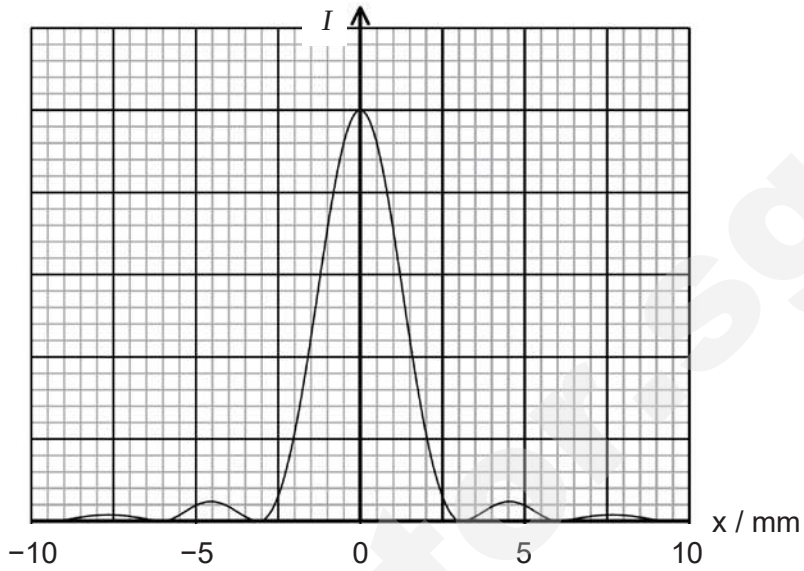


**Fig. 3.2**

**(i)** Use Fig. 3.2 to determine the width of the slit.

width = …… mm [2]

**(ii)** State the effect on the pattern on the screen if the width of the single slit is reduced.

……

……

…… [2]

[Total: 10]

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**4** **(a)** A wire has a diameter of 1.10 mm and is 98 m long.

The resistivity of copper is $1.1 \times 10^{-6}$ Ω m.

**(i)** Calculate the resistance of this wire.

resistance = …… Ω [1]

**(ii)** When the wire hangs vertically, suspended from one end, it stretches slightly under its own weight.

State and explain what happens to the resistance of the wire.

……

……

…… [1]

**(b)** The wire in **(a)** is shortened and 1% of its total length is used to form wire PQ.

**(i)** Wire PQ is then connected to a cell of e.m.f. $E_1$ and internal resistance $r$ in series with variable resistor $R$ as shown in Fig. 4.1.

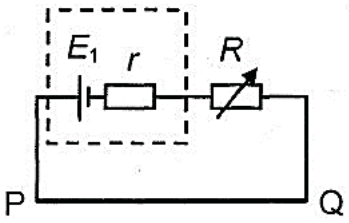


**Fig. 4.1**

Express the potential difference per unit length of PQ in terms of $E_1$, $r$ and $R$.

[3]

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**(ii)** Fig. 4.2 shows a potentiometer circuit that can be used to determine the internal resistance $r$ of cell $E_1$. A standard cell of e.m.f. $E_2$ of negligible internal resistance is used in the branch circuit. $E_1$ and $E_2$ have e.m.f. of 12.0 V and 1.5 V respectively. When the resistance of the variable resistor is 1.0 Ω, the balanced length is obtained when the length of JQ is twice the length of PJ.

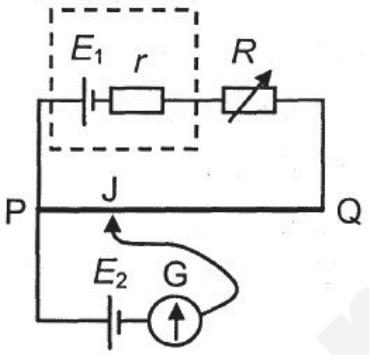


**Fig. 4.2**

**1.** Calculate the value of internal resistance, $r$.

$r$ = ..... Ω [3]

**2.** The resistance of the variable resistor $R$ is now increased. Suggest why the resistance $R$ cannot be higher than a particular value if the potentiometer in Fig. 4.2 is to be able to determine the value of internal resistance $r$.

.....

.....

.....

..... [2]

[Total: 10]

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**5** A magnetic sail or magsail was proposed by Zubrin in 1991 to launch a spacecraft into space. A loop of cable is attached to the spacecraft, generating magnetic field. Fig. 5.1 shows a simplified diagram of a magsail, consisting of a circular loop of cable carrying a current $I$. The spacecraft is propelled by deflecting solar winds which consists of charged particles.

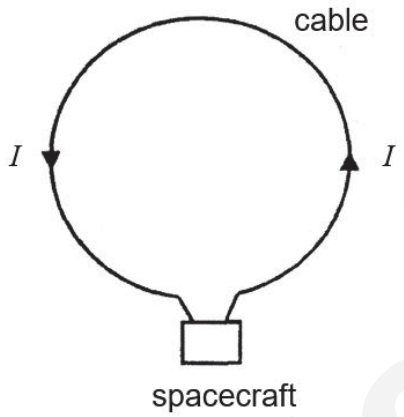


**Fig. 5.1**

**(a)** Explain how the magsail gets its propulsion from the deflection of the charged particles of solar winds.

……...

……...

……... [2]

**(b)** Suggest why the magsail cannot be propelled by photons.

……...

……... [1]

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**(c)** In Fig. 5.2, a magsail carrying a current $I$ of 3.0 kA catches a solar wind consisting protons of kinetic energy 500 keV. The direction of the solar wind is along the plane of the page. The cable forms a circular shape with diameter 128 m.

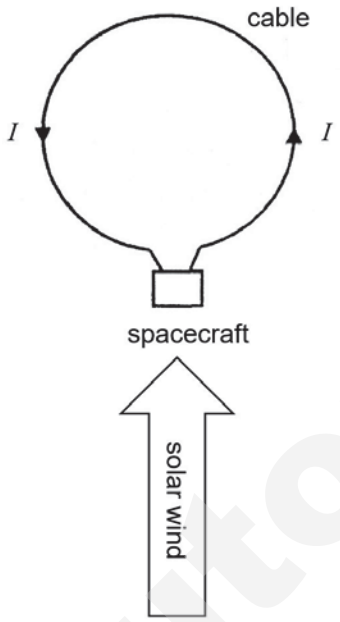


**Fig. 5.2**

**(i)** By considering only the magnetic field within the coil, draw the direction of the force experienced by the magsail and label it **F** in Fig 5.2. [1]

**(ii)** Calculate the speed of the protons.

speed of the protons = …….. m $s^{-1}$ [2]

**(iii)** Determine the magnetic flux density at the centre of the coil.

magnetic flux density = ……. T [2]

**(iv)** Hence, calculate the force experienced by a proton passing through the centre of the coil.

force = …… N [2]

[Total: 10]

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**6** Fig. 6.1 shows a magnetic field of flux density $5.0 \times 10^{-5}$ T passing through a short-circuited coil of wire at an angle of 60° to the plane of the horizontal non-magnetic table on which the coil rests. The coil has 400 turns and an area of 25 $cm^2$.

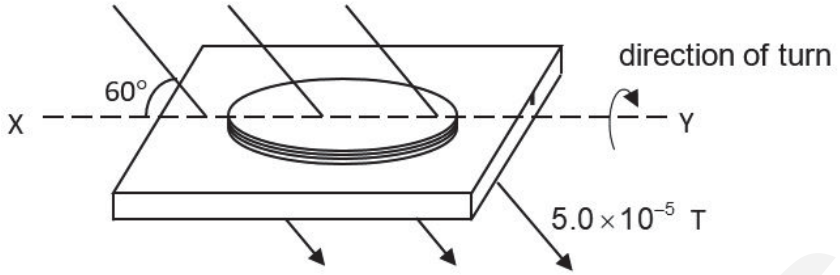


**Fig. 6.1**

**(a)** Calculate the magnetic flux linkage through the coil of wire at the above-mentioned position.

flux linkage = …….. Wb-turns [2]

**(b)** After an initial push, the coil rotates by 180° about the axis XY in the direction shown in Fig. 6.1 in a duration of 2.5 s. Calculate

**(i)** the change in magnetic flux linkage of the coil,

change in flux linkage = …… Wb-turns [1]

**(ii)** the average e.m.f. induced.

e.m.f. = …… V [2]

**(c)** On Fig. 6.1, indicate the direction of the induced current in the coil immediately as it is being turned from the position shown. [1]

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**(d)** Explain why the coil slows down and stops after it turns over by 180°. State the energy changes that take place.

……..

……..

…….. [2]

[Total: 8]

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## Section B

Answer **one** question from this Section in the spaces provided.

**7** **(a)** State the conditions for a body to remain in static equilibrium.

.....

.....

..... [2]

**(b)** A uniform rod of length L and weight 120 N is supported by two springs as shown in Fig. 7.1. A 400 N weight is suspended one quarter way from the left end.

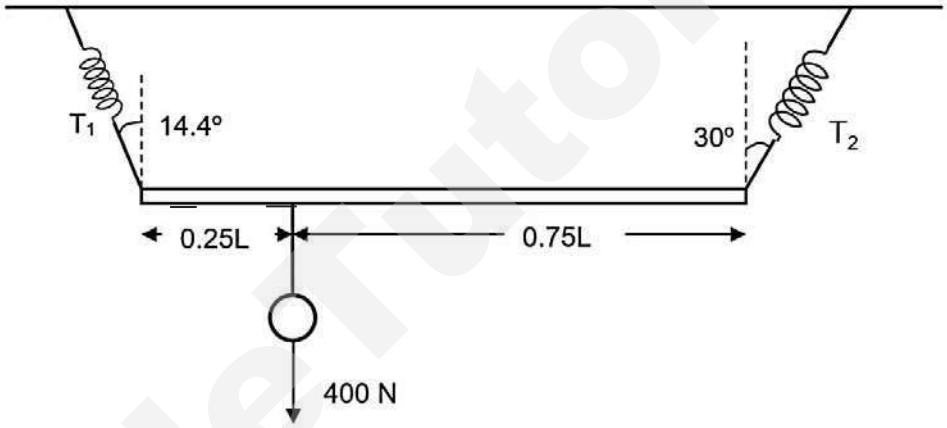


**Fig. 7.1**

Determine the tensions $T_1$ and $T_2$ that are exerted on the springs.

$T_1$ = .....N

$T_2$ = .....N [4]

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**(c)** Distinguish between frequency and angular frequency for a body undergoing simple harmonic motion.

……

……

…… [2]

**(d)** A block of mass *m* which is 38 g is attached to two identical stretched springs, as shown in Fig. 7.2. Assume that no resistive forces act on the system.

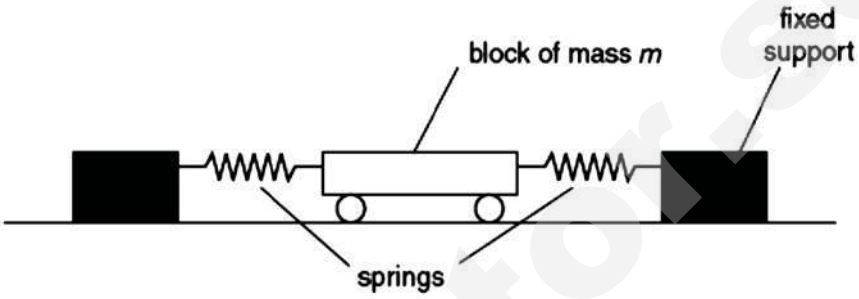


**Fig. 7.2**

**(i)** Both springs obey Hooke's Law and each has a spring constant *k*. The block is displaced a horizontal distance *x* and released.

By considering Newton's Laws, show that the initial acceleration *a* of the mass *m* is given by

$$a = -\frac{2kx}{m}$$

.

[2]

**(ii)** The mass oscillates with simple harmonic motion of frequency 3.2 Hz and amplitude 2.8 cm.

Determine the total energy of the oscillation.

total energy = …… mJ [2]

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**(iii)** At a particular instant, the kinetic energy of the mass is equal to the elastic potential energy of the springs. Calculate the distance from the equilibrium position at which this occurs.

distance = …….. m [3]

**(iv)** On Fig. 7.3, use your answers in **(d)(ii)** and **(d)(iii)** to sketch the variation with displacement *x* of

**1.** the total energy of the oscillation (label this graph T), [1]

**2.** the kinetic energy of the mass (label this graph K), [1]

**3.** the elastic potential energy of the springs (label this graph P). [1]

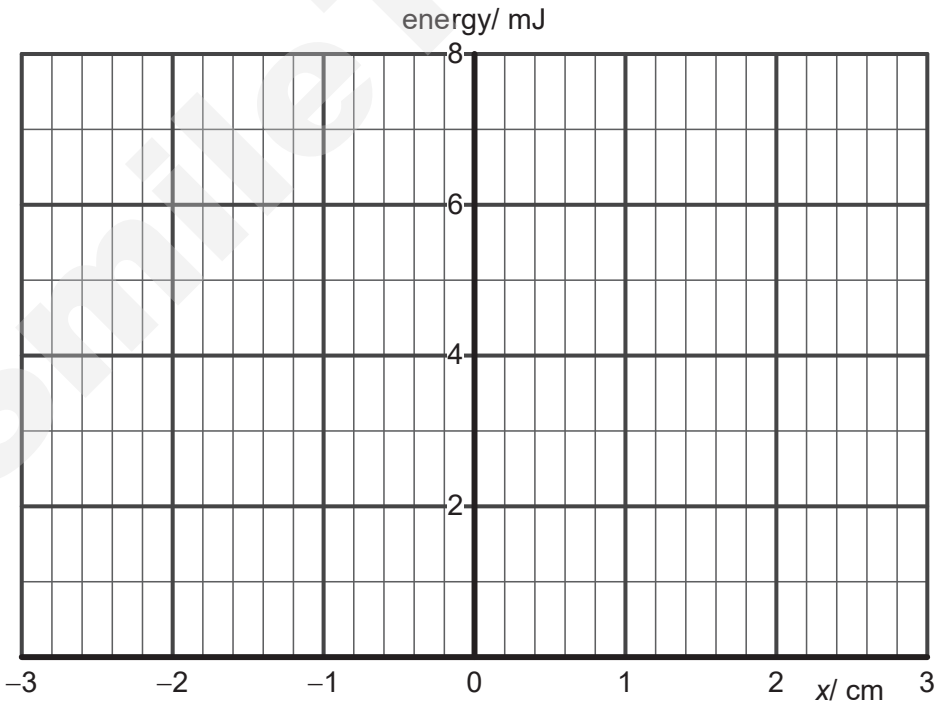


**Fig. 7.3**

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**(e)** The system in Fig. 7.2 is now rearranged such that mass *m* oscillates vertically on only one of the springs, as shown in Fig. 7.4.

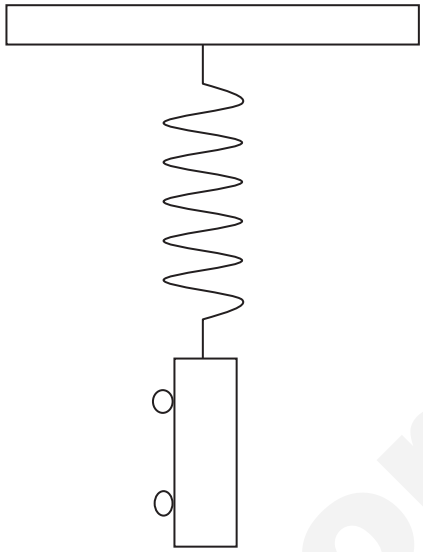

**Fig. 7.4**

By considering energy changes of the vertical spring-mass system, suggest and explain how the graphs in Fig. 7.3 would differ.

……...

……..

…….. [2]

[Total: 20]

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

……

……

…… [1]

**(b)** In a collision between a neutron and a uranium nucleus, the force that the neutron exerts on the uranium nucleus varies with time as shown in Fig. 8.1.

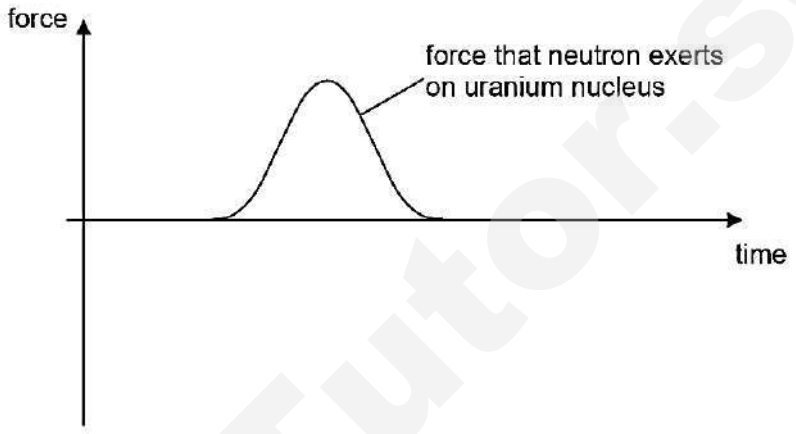


**Fig. 8.1**

**(i)** Sketch on Fig. 8.1, a graph of the force that the uranium nucleus exerts on the neutron. [1]

**(ii)** Explain how your answer to **(b)(i)** is consistent with **(a)**.

……

……

…… [2]

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**(c)** In 1914, James Chadwick showed that the energies of the beta particles emitted for a radioactive source had a distribution of energies rather than with a distinct single value of energy.

Figure 8.2 shows the energy spectrum for beta particles emitted during the decay of Bismuth-210 ($^{210}_{83}$Bi). The intensity (vertical axis) indicates the number of beta particles emitted with each particular kinetic energy (horizontal axis).

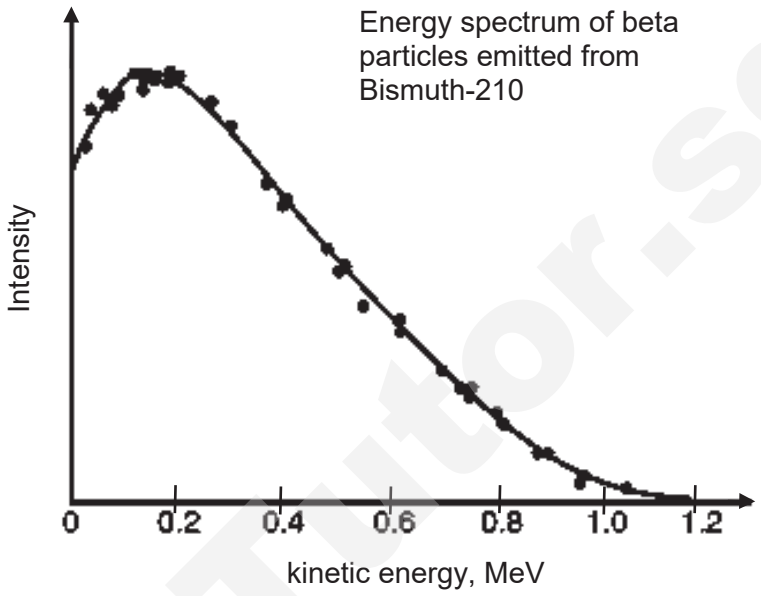


**Fig. 8.2**

**(i)** **1.** From Fig.8.2, determine *Q*, the maximum possible energy of the beta particle emitted.

*Q* =..... MeV [1]

**2.** Hence calculate the maximum speed of the beta particle.

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

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**3.** A Bismuth $^{210}_{83}Bi$ nuclide, decays into Polonium (chemical symbol: Po), emitting a beta particle with the maximum possible energy in the process.

Using your answer in **(c)(i)1.**, determine the mass of the resultant Polonium nucleus, in terms of $u$, and express your answer to 3 decimal places. (mass of a $^{210}_{83}Bi$ nucleus is 209.939 $u$; mass of proton $m_p$ is 1.00729 $u$; mass of neutron $m_n$ is 1.00867 $u$).

mass=…… $u$ [3]

**(ii)** From Fig. 8.2, identify the most probable energy for the beta particle.

most probable energy value = …… MeV [1]

**(iii)** The continuous spectrum of kinetic energy values of the emitted beta particles presented a problem to physicists up to 1930s. If a stationary nucleus decayed into a beta particle and a stable daughter nucleus only, it should lead to a distinct single value of energy for the emitted beta particle.

Explain, using conservation of linear momentum and energy, how the continuous spectrum of beta particle energies gave rise to this problem.

……..

……

……

……

……..

…… [2]

**(iv)** Suggest what was proposed by physicists to resolve the problem in **(c)(iii)**.

……

…… [1]

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**(d)** Radioactive isotopes are often introduced into the body through the bloodstream. Their spread through the body can then be monitored by detecting the appearance of radiation in different organs. Iodine-131 ($^{131}I$), a beta emitter with a half-life of 8.04 days, is one such tracer. Suppose a scientist introduces a sample of $^{131}I$ with an activity of 375 Bq into the body and watches it spread to the organs.

**(i)** Define decay constant.

……..

…….. [1]

**(ii)** Assuming that all of the $^{131}I$ atoms in the sample went to the thyroid gland, calculate the decay rate in the thyroid 2.5 weeks later. Assume that none of the $^{131}I$ is eliminated by the body through physiological means.

decay rate = …….. Bq [3]

**(iii)** Calculate the mass of $^{131}I$ required to produce an activity of 375 Bq.

mass = …….. kg [3]

[Total: 20]

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Class Adm. No.

Candidate Name: _____

H

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# 2019 Preliminary Exams
## Pre-University 3

**PHYSICS** **9749/04**

Paper 4 Practical **03 September**

**2 hour 30 mins**

Candidates answer on the Question Paper.

Additional Materials: As listed on the Confidential Instructions.

**READ THESE INSTRUCTIONS FIRST**

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

Answer **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1, and a maximum of one hour for Questions 2 and 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| Q1 | / 21 |
| Q2 | / 13 |
| Q3 | / 9 |
| Q4 | / 12 |
| TOTAL | / 55 |


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**1** In this experiment, you will investigate an electrical circuit that involves a wire attached to a metre rule.

**(a) (i)** Measure and record the diameter *d* of the wire.

*d* = ..... [1]

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

*A* = ..... [1]

**(iii)** Estimate the percentage uncertainty for the cross sectional area *A* of the wire.

percentage uncertainty of *A* = ..... [2]

**(b) (i)** Assemble the circuit shown in Fig. 1.1. Resistor **X** is of value 10 Ω.

A, B and C are crocodile clips. Connect C to the screw on the wooden strip.

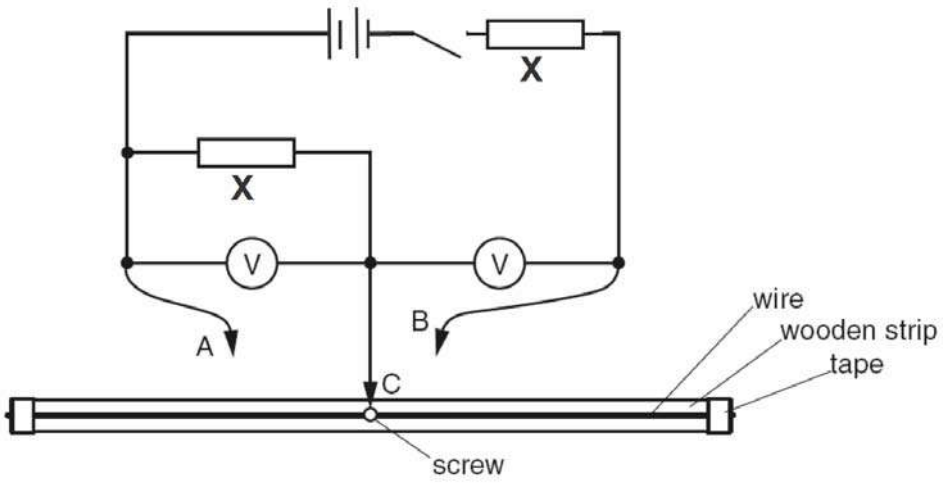


**Fig. 1.1**

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**(ii)** Connect A to the wire at a distance *p* of approximately 20 cm from the screw, as shown in Fig. 1.2.

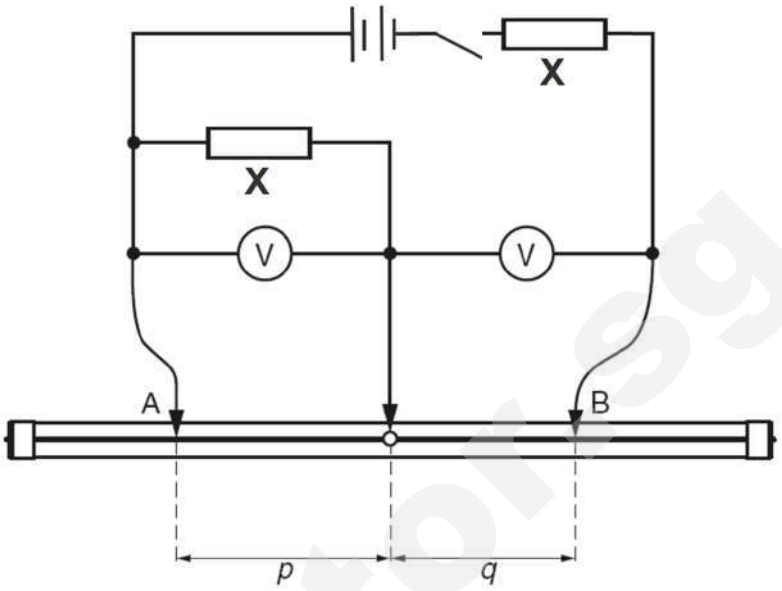


**Fig. 1.2**

**(iii)** Close the switch.

**(iv)** Connect B on the other side of the screw so that the two voltmeter readings **have the same value V**.

The distance between the screw and B is *q*, as shown in Fig. 1.2. Measure and record the voltmeter reading V and the distances *p* and *q*.

V = ……

*p* = ……

*q* = ……
[2]

**(v)** Open the switch.

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**(c)** Vary $p$ and repeat **(b)(ii)** to **(b)(v)**. Keep distance $p$ to be above 10 cm.

[5]

**(d)** $p$ and $q$ are related by the expression

$$p = aq + bpq$$

where $a$ and $b$ are constants.

Plot a suitable graph to determine the values of $a$ and $b$.

$a$ = ……

$b$ = ……

[6]

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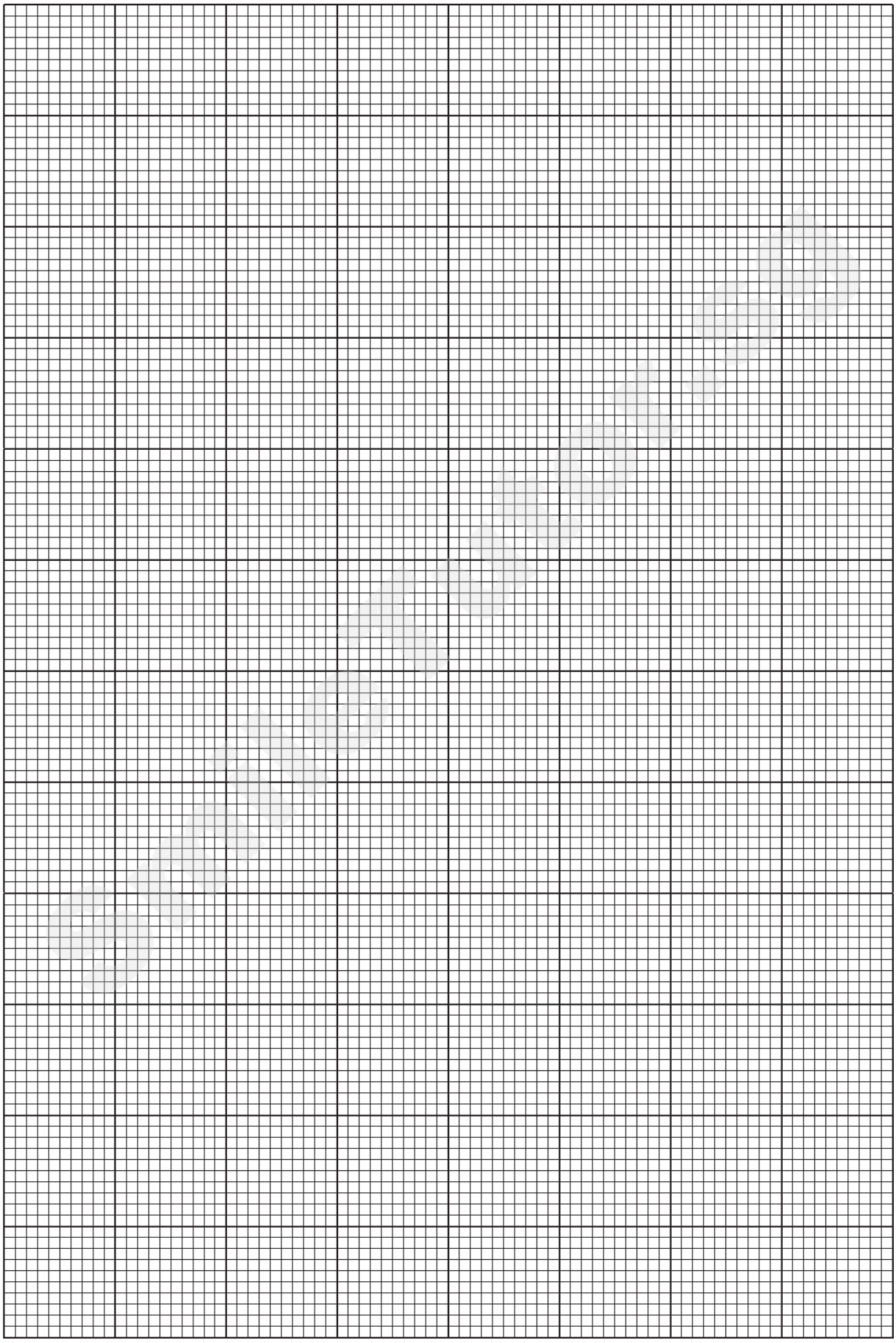

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**(e)** Theory suggests that

$$\text{constant } b = \frac{\rho}{A\,\mathbf{X}}$$

where $A$ is cross sectional area and $\rho$ is resistivity of the constantan wire respectively.

The resistivity of constantan is known to be $4.9 \times 10^{-7}\ \Omega$m.

Determine whether the suggestion is possible. Justify your conclusion by referring to your value in **a(iii)**.

.....

.....

..... [2]

**(f)** **(i)** Suggest one significant source of error in this experiment.

.....

.....

.....

..... [1]

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

.....

.....

..... [1]

[Total: 21]

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**2** In this experiment, you will investigate the motion of a mass and a spring.

**(a)** You are provided with a spring.

**(i)** Measure and record the diameter *d* of the coiled section of the spring as shown in Fig. 2.1. Record the number *N* of turns in the coiled section.

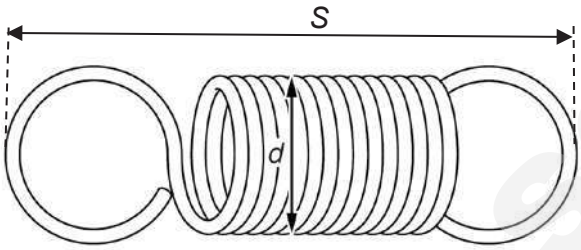


**Fig. 2.1**

*d* = .....

*N* = .....
[2]

**(ii)** Calculate the length *L* of wire used to make the coiled section of the spring.

*L* = ..... [1]

**(iii)** The length of the unstretched spring is *S*, as shown in Fig. 2.1.

Measure and record *S*.

*S* = ..... [1]

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**(b) (i)** Set up the apparatus as shown in Fig. 2.2 with the mass suspended from the spring and secured with Blu-Tack.

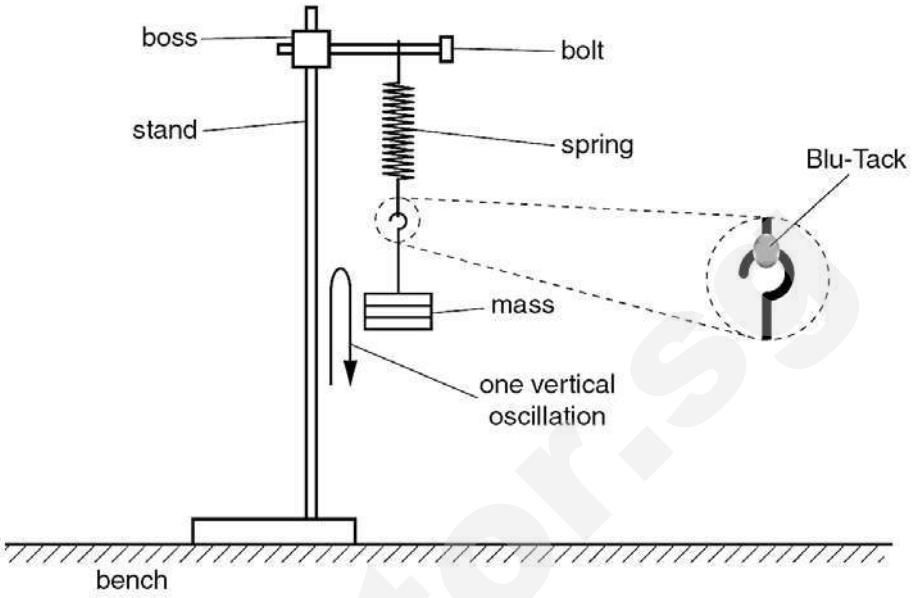


**Fig. 2.2**

**(ii)** Pull the mass down approximately 2 cm and release it. One vertical oscillation is shown in Fig. 2.2.

Measure and record the time *t* for the mass to make 10 vertical oscillations.

*t* = ……..…… [1]

**(c) (i)** Lower the bolt until the bottom of the stationary mass is approximately 6 cm above the bench, as shown in Fig. 2.3.

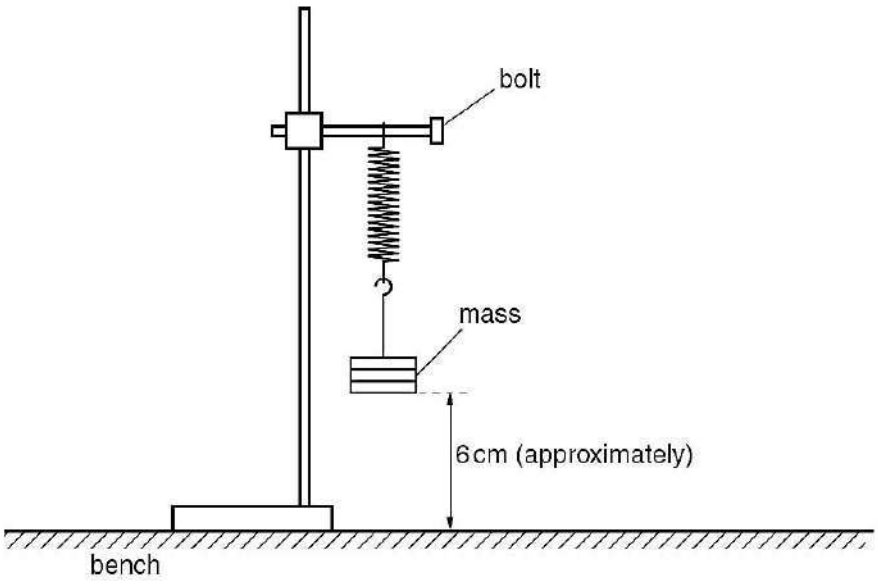


**Fig. 2.3**

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**(ii)** Pull the mass down until it touches the bench.

Release the mass and watch the loop on the bolt, looking to see if the loop rises above the bolt producing a gap at the top of the first oscillation as shown in Fig. 2.4.

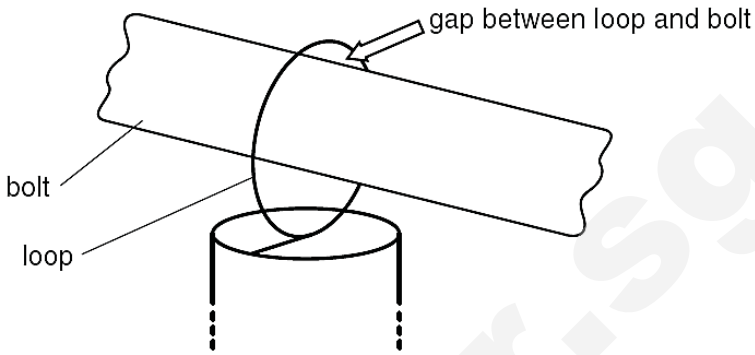


**Fig. 2.4**

**(iii)** Keep raising the bolt and repeating **(c)(ii)** until the loop just rises above the bolt at the top of the first oscillation.

With the mass stationary, measure and record the distance *D* from the bottom of the mass to the bench.

*D* = ……..…… [1]

**(d)** Estimate the percentage uncertainty in your value of D.

percentage uncertainty = ……..…… [1]

**(e)** It is suggested that the relationship between D, *t*, and *L* is

$$D = k t^2 L$$

where *k* is a constant.

Calculate *k*.

Give your value of *k* to an appropriate number of significant figures.

*k* = ……..…… $s^{-2}$ [1]

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**(f)** The behavior of the oscillating system depends on the properties of the spring and mass. It is suggested that the time $t$ is proportional to the number $n$ of springs joined in a series, i.e. end–to-end configuration.

**(i)** Explain how you would investigate this relationship using the same apparatus.

Your account should include

- your experimental procedure
- control of variables
- how you would use your results to show proportionality
- why you might not have enough results to reach a valid conclusion.

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..... [4]

**(ii)** Suggest a change to the spring that will improve your procedure in **(f)(i)**.

.....

.....

.....

..... [1]

[Total: 13]

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**3** In this experiment, you will investigate how the rise of temperature of a vessel of water is related to the mass of boiling water added to it.

**(a)** On the inside of a styrofoam cup about half-way up, there is a line drawn.

Make two further marks on the inside of this cup, equally spaced between the drawn line and a point near the top of the styrofoam cup.

**(i)** Collect some water at room temperature in the styrofoam cup up to the **bottom** line. Measure and record the temperature $T_o$ of this water.

$T_o$ = ……..…… [1]

**(ii)** Measure and record the mass $M_o$ of the styrofoam cup and the water.

$M_o$ = ……..…… [1]

**(iii)** Using the other styrofoam cup, collect some boiling water and pour this into the first styrofoam cup, until the water level reaches one of your drawn marks.

Measure and record the highest temperature $T_1$ of the water in the cup.

$T_1$ = ……..……

**(iv)** Measure and record the total mass $m_1$ of the cup and its contents.

$m_1$ = ……..……

**(v)** Calculate and record the rise in temperature $R$ and the mass $M$ of boiling water added to the cup.

$R$ = ……..……

$M$ = ……..……
[1]

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**(vi)** Estimate the percentage uncertainties in your values of $R$ and $M$.

percentage uncertainty of $R$ = ……

percentage uncertainty of $M$ = ……
[1]

**(b)** Pour away the water in the cup.

Repeat steps **a(i)** to **(a)(v)** to get another set of data for $R$ and $M$.

$R$ = ……

$M$ = ……
[1]

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**(c)** It is suggested that

$$\frac{1}{R} = \frac{\square}{M} + \square$$

where $\square$ and $\square$ are constants, and $\frac{\square}{\square}$ is equal to the mass of water in **(a)(ii)**.

**(i)** Use your values from **a(i)** to **a(v)** and **(b)** to calculate for value of $\frac{\square}{\square}$ **.**

Give your value of $\frac{\square}{\square}$ to an appropriate number of significant figures. Include an appropriate unit.

$\frac{\square}{\square}$ = ..... [2]

**(ii)** State whether the results of your experiment support the suggested relationship in **(c)**.

Justify your conclusion by referring to your values in **(a)(ii)** and **(a)(vi)**.

.....

.....

.....

..... [1]

**(iii)** State and explain why it would be a better practice to use a graphical method using more data points to determine the value of $\frac{\square}{\square}$ **.**

.....

.....

.....

..... [1]

[Total: 9]

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**4** When a light source is positioned behind a grating, bright spots can be observed if a screen is placed at a suitable position in front of the grating.

$\theta$ is the angle between the perpendicular line from middle of the grating to the middle bright spot on the screen and the line from middle of the grating to the third bright spot from the middle. The relationship between angle $\theta$, number of lines per cm of the grating $N$, and frequency $f$ of the light source, is

$$\sin \theta = 3 k N^{a} f^{b}$$

where $a$, $b$ and $k$ are constants.

Design an experiment to determine the values of $a$ and $b$.

You are provided with laser pointers of different frequencies, and also gratings of different $N$ values.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

**(a)** the equipment you would use

**(b)** the procedure to be followed

**(c)** how you would produce a set of obvious bright spots

**(d)** the control of variables

**(e)** any precautions that should be taken to improve accuracy and safety of the experiment.

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**Diagram**

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.....

## Question 1

**Apparatus requirements (per set of apparatus unless otherwise specified)**

Wooden strip of length 90.0 cm, with approximate cross-section 2 cm x 1 cm. See Note 1.

One woodscrew of approximate length 2 cm. See Note 1.

105 cm length of resistance wire. The wire should have a resistance of approximately 20 Ω $m^{-1}$. Constantan, 36 swg is used. See Note 1.

3 V d.c. power supply (e.g. two 1.5 V cells).

Switch.

Eleven connecting leads.

Three crocodile clips, suitable for connecting to leads. See Note 2.

Two voltmeters, each with a range of 0–20 V (taped over to show only 20 V range) and reading to 0.01 V. Multimeters set to this range are suitable provided the range switch is fixed and any unused terminals are covered.

One resistor with resistance 10 Ω with power rating 0.5 W (e.g. RS Components productcode 132-012). It should be fitted with terminals to enable connection to leads, and covered with label **X. (X for 10 Ohms)**

~~One rheostat~~

Metre rule with a millimetre scale.

**Notes**

**1** Screw the woodscrew into the wooden strip half-way along its length. Wrap the middle of the resistance wire tightly around the woodscrew. Wrap the ends of the resistance wire over the ends of the wooden strip, and secure them with tape, as shown in Fig. 1.1.

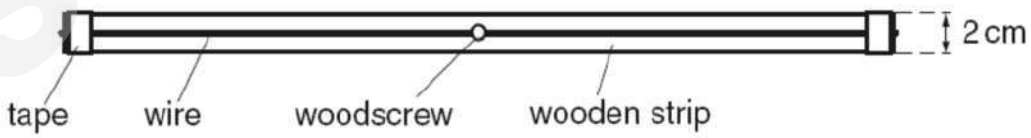


Fig. 1.1

**2** Jaws of the crocodile clips should be cleaned so that they make good electrical contact with wire.

**Information required by Examiners**

Resistance per metre of the resistance wire. Sample set of numerical results.

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*Instructions for Lab*

# Question 2

**Apparatus requirements (per set of apparatus unless otherwise specified)**

Expendable spring with approximate outside diameter 15 mm, approximate coiled length 20 mm and approximate spring constant 25 N $m^{-1}$ (e.g. Philip Harris product code B8G87194).

M10 bolt of length at least 8 cm.

Stopwatch reading to 0.1 s or better.

One Retort Stand.

Boss suitable for clamping the bolt horizontally to the stand.

1 g of Blu-Tack.

Mass hanger and masses with a total mass of 300 g. See Note 1.

Half-metre rule (or metre rule) with a millimetre scale.

Vernier Callipers

**Notes**

**1** Slotted masses should be taped securely to the mass hanger.

**2** The apparatus should be laid out on the bench. If it is to be used by another candidate, then it should be restored to its original state.

**Information required by Examiners**
Sample set of numerical results.

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*Instructions for Lab*

## Question 3

**Apparatus requirements (per set of apparatus unless otherwise specified)**

One styrofoam cup with a line drawn using a pen, at half-way up on inside of the cup

One styroforam cup

Hot water at 98 degree

Weighing balance

Cotton gloves

Alcohol in Glass Thermometer , read to 1 degree.

**Information required by Examiners**
Sample set of numerical results.

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# 2019 Preliminary Exams

Pre-University 3

**H2 PHYSICS** **9749/01**

**Paper 1 Multiple choices**

**ANSWERS**

| | | | | | |
|---|---|---|---|---|---|
| 1 | C | 11 | A | 21 | B |
| 2 | C | 12 | C | 22 | C9 |
| 3 | D | 13 | B | 23 | A |
| 4 | C | 14 | A | 24 | C |
| 5 | C | 15 | D | 25 | D |
| 6 | A | 16 | D | 26 | A |
| 7 | C | 17 | A | 27 | B |
| 8 | A | 18 | C | 28 | D |
| 9 | C | 19 | D | 29 | D |
| 10 | B | 20 | D | 30 | B |

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1

**ANS: C**

Typical weight of an adult's head is 4.5 to 5.0 kg

Model the head as a sphere of radius ~ 10 cm
Comparing weight of this Volume x denisity of water = 4.1 kg,
density of head must be bigger than density of water => closest and slightly higher estimate is 5 kg

2

**ANS: C**

Graph of $s = ut + \frac{1}{2} at^2$ with constant a

With zero gradient at t = 0

3

**ANS: D**

With use of a FBD, to see that

on the way up, Net retarding force = mg + Drag

on the way down, Net accelerating force = mg - Drag

so takes long time to move down back to same vertically level

4

**ANS: C**

Initial momentum = 1 mv downwards

If elastic , change in p = 2 mv upwards

If Inelastic, change in p must be more than 1 mv, but less than 2 mv.

Only C = 1.25mv is a possible answer

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**5** **C** This is a completely inelastic collision. Hence, total mechanical energy is **not** conserved.
A is wrong.

Gravitational potential energy gained by both block and bullet is equal to the loss in kinetic energy by the bullet.
B is wrong.

The total horizontal momentum of the two masses is conserved because the resultant horizontal force acting on them is zero.
D is wrong.

**6** **Answer: A**

The 2 forces that form a Couple must have same magnitude, in opposite directions , and not acting through the same point.

**7** **Answer: C**

Since the balloon is in equilibrium,

upthrust on balloon = weight of balloon and helium + $F_s$ cos30

$$\rho_{air} V_{balloon} g = \rho_{helium} V_{balloon} g + m_{balloon} g + ke \cos 30$$

$$(1.29)(4.50)g = (0.180)(4.5)g + \left(\frac{15}{1000}\right)g + (80)e\,cos30$$

56.94705 = 7.9461 + 0.14715 + 69.282 *e*

*e* = 0.705 m

**8** **Answer: A**

net work done on the gas

= -ve of area enclosed (as more work is doby BY gas when it expands from Y to X)

= $(0.5 \times 10^5)(1.0 \times 10^{-3})$ = - 50 J

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**9 Answer: C**

Work done to stretch it 5.0 cm: ½ k $(0.05)^2$ = 5 K = 4000 N/m

Work done to stretch by further 5 cm, i.e. x = 10 cm :

½ (4000) $(0.10)^2$ = 20 J Additional work required = 20 – 5 = 15 J

**10 Answer: B**

Velocity = Radius x Angular velocity

$v = r\,\omega$

Keeping $\omega$ constant, $v$ *proportional* r

.

Since the radius r of the roll increases at a steady rate,v proportional to *t*

**11 Answer: A**

$$\emptyset = -\frac{GM}{r}$$

$r\_A = -\frac{GM}{\emptyset\_A}$ and $r\_B = -\frac{GM}{\emptyset\_B}$

BA= r_B – r_A

$$= -GM\left(\frac{1}{\emptyset_B} - \frac{1}{\emptyset_A}\right)$$

= 0.89 x $10^6$ m

$r\_C = -\frac{GM}{\emptyset\_C}$ and $r\_B = -\frac{GM}{\emptyset\_B}$

CB= r_C – r_B

$$= -GM\left(\frac{1}{\emptyset_C} - \frac{1}{\emptyset_B}\right)$$

= 1.11 x $10^6$ m

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**12 Answer: C**

C is incorrect because to keep moving in a straight line in path C, the spacecraft needs additional force with a radial component to act against pull of Earth's gravity.

This force needs to be adjusted in a way so as to be always equal and opposite to Earth's pull, such that it counteracts the radial acceleration.

Path B would not need any force from rocket if the gravitational force acting on spacecraft is just sufficient to provide the centripetal force to maintain the circular motion.

Paths A and D are paths of free fall when rockets are switched off; D on the way up, A on the way down.

**13 Answer: B**

Absolute zero = 0 K or - 273.15 °C

It is the temperature at which no more heat can be removed from a system.

Also It is the temperature at which the particles in a substance becomes motionless.

It is the *theoretical* temperature limit and has not been achieved as yet.

**14 Answer: A**

Mean K.E. of molecules depends on the absolute temperature.

**15 Answer: D**

An oscillating system will have the same frequency as that of the periodic force applied to it. Thus the system will have a frequency of 2.50 Hz after being subjected to the force, and period
T = 1/2.5 = 0.40 s

So 0.15 s = 0.375 T

$v = 1.5 (2\pi/0.4) \cos (2\pi/T (0.375T))$

$= 16.7 \text{ cm s}^{-1}$

As t = 0.15 s is less than half a period, the mass would still be moving upwards.

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**16 Ans: D**

**$I \alpha 1/x^2$**

$I_Q/I_P = (1/2)^2 = ¼$

$I_Q/I_P = (A_Q/ A_P )^2 = (6 / A_P^2 ) = 1/4$

$A_P = 12.0$ μm

**17 Ans: A**

Zero intensity => node detected

At distance 0.34 m => 2nd Harmonics Standing Waves for a Node to fit ,
=> 0.34 m = ¼ wavelength, Wavelength = 1.36 m
Initial freq f = 340/1.36 = 250 Hz

The next higher frequency to have a Node at 0.34 m is when
0.34 m = ¾ wavelength , Wavelength' = 4/3 (0.34) = 0.45333 m
New freq f' = 340/0.45333 = 750 Hz

**18 Ans: C**

blue light from the sand has smaller Wavelength.

By $\theta \approx \lambda$ / b, and by small angle approximation,

Range proportional to b/ $\lambda$ , so smaller wavelength, larger Range

**19 ANS: D**

$E = Q / 4\pi\varepsilon_o r^2$

Distance from midpoint to each charge is 0.50 m

Electric field strength due to one point charge,

$E= Q / 4\pi\varepsilon_o r^2 = (2.0x10^{-6}) / 4\pi(8.85 \times 10^{-12} )(0.50)^2$

$E=7.19x10^4$ $Vm^{-1}$

Electric field due to both charges is double the value above because the charges are unlike. $E = 1.4 \times 10^5$ $Vm^{-1}$

**20 ANS: D**

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field strength of the electric field at a point is numerically equal to the potential gradient at that point

so integral (area) of E-r graph gives the electric potential

**21 ANS: B**

When the current is in the positive direction, the diode allows it to flow through the NTC thermister. The upper portion of the graph is slightly decreasing in gradient due to the properties of the thermistor.

When the current flows in the opposite direction, the diode prevents it from passing through the bulb. It flows through the other branch of the parallel connection instead. A resistor obeys Ohm's law so current varies proportionally to the voltage.

**22 Answer: C**

<u>When $R_{rheo}$ increases</u>
In the circuit with resistor R,
p.d. V across $R_{rheo}$ increases,
brightness of L1 increases ($V^2/R_{L1}$).
In the circuit with resistor $R_{LDR}$,
p.d. V across $R_{rheo}$ increases,
brightness of L2 increases and more light shines onto LDR
which decreases $R_{LDR}$, causing $V_{rheo}$ to increase further,
which causes L2 to shine brighter.
Thus L2 is brighter than L1.

<u>When $R_{rheo}$ decreases</u>
In the circuit with resistor R,
p.d. V across $R_{rheo}$ decreases,
brightness of L1 decreases ($V^2/R_{L1}$).
In the circuit with resistor $R_{LDR}$,
p.d. V across $R_{rheo}$ decreases,
brightness of L2 decreases and less light shines onto LDR
which increases $R_{LDR}$, causing $V_{rheo}$ to decrease further,
which causes L2 to shine less brightly.
Thus L1 is brighter than L2.

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**23 ANS: A**

Use Fleming's Left Hand Rule, to derive the direction of the force, which is perpendicular to the magnetic field and current.

**24 ANS: C**

Selected velocity v = E/B

So for *v* to decreases, *B* should increases.

**25 ANS : D**

Horizontal velocity component is constant

And so rate of change of flux linkage is constant

**26 ANS: A**

$2\pi f = 314$

f = 50 Hz

$\langle P \rangle = \frac{1}{2} V_p^2/R = 50$ W

**27 Ans: B**

B has the lowest wavelength/ highest frequency as it has the largest stopping potential. Stopping potential is a measure of the maximum KE of the photoelectrons which is dependent on the frequency of the radiation.

**28 ANS: D**

$$\Delta x \, \Delta p \geq h \quad , \quad \Delta p = m \Delta v$$

$$\therefore \Delta v = \frac{h}{\Delta x \, . m} = \frac{6.63 \times 10^{-34}}{} \left( \frac{1}{43 \times 10^{-9} \times 9.1 \times 10^{-31}} \right)$$

$$\Delta v = 1.7 \times 10^{4} \; m s^{-1}$$

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**29 ANS: D**

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The inference from most $\alpha$- particles passed through the foil undeflected is that the diameter of the nucleus is much less than the diameter of the atom.

**30 ANS: B**

A – micro wave is non-ionising radiation

C – particle bombardment is also ionising radiation

D – radiaiton sickeness can be caused by sources whether natural or man-made.

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**2019 Prelim H2 Physics**
**Paper 2 Solution**

| | | |
|---|---|---|
| 1(a) | Area = 280 x 230 = 64400 mm$^2$<br><br>$\frac{\Delta A}{A} = \frac{\Delta L}{L} + \frac{\Delta W}{W}$<br><br>$\frac{\Delta A}{A} = \frac{1}{280} + \frac{2}{100}$<br><br>= 0.0236<br>$\Delta A$ = 0.0236 X 64400 = 2000 mm$^2$<br><br>$A$ = 64000 ± 2000 mm$^2$ | M1<br><br>M1<br><br>A1 |
| 1(b) | Accuracy refers to the closeness between the measured value 6.4 x 10$^4$ and the accepted or true value 8.00 x 10$^4$. ***As percentage difference of*** $\frac{80000-64400}{80000}$ ***x 100% = 19.5% is big,*** the measurement is not accurate***. *Will not penalize students if percentage difference is not calculated.***<br><br>Precision refers to the degree of scattering among repeated measurements. **As the maximum percentage uncertainty of** $\frac{2000}{64000}$ **x 100% =3.1% is small,** *the measurement is precise***. *Will not penalize students if percentage difference is not calculated.*** | B1<br><br>B1 |
| 2(a)(i) | Work is done when a force moves its point of application in the direction of the force. | B1 |
| 2(a)(ii) | The mass m is moved without acceleration up a height h, and magnitude of the F = mg<br><br>Since $E_P$ = work done by Force F<br>= force x distance moved cos θ<br>= mg x h cos 0°<br>= mgh | M1<br><br>M1<br>M1 |
| 2(b)(i) | Power = 60 x 55 x 9.81 x 32 / 60<br>= 17300 W | M1<br>A1 |
| 2(b)(ii)1. | Power = 1.5 x 10$^4$ x 32 / (60 sin 45°)<br>= 11300 W | M1<br>A1 |
| 2(b)(ii)2. | Power input = (17300 + 11300) x (100/70)<br>= 40900 W | M1<br>A1 |

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| | | |
|---|---|---|
| 3(a)(i) | The first law of thermodynamics states that the increase in the internal energy ΔU of a system is equal to the sum of the heat Q supplied to the system and work done W on the system.<br>The latent heat of vaporisation is considerably higher because evaporation involve a considerably greater molecular separation and volume increase than melting.<br>Hence, it involves a considerably greater increase in potential energy, and considerably more work has to be done by the system. | B1<br>B1<br>B1<br>B1 |
| 3(a)(ii) | Mass of the ethanol = 0.79 x 2 = 1.58 g<br>Energy required from 30 °C to 78 °C = 2.4 x1.58 x (78 – 30) = 182 J<br>Energy required for boiling= 840 x 1.58 = 1327 J<br>Required thermal energy = 1327 + 182 = 1509 J | C1<br>C1<br>C1<br>A1 |
| 3(b)(i) | $\frac{P1V1}{T1} = \frac{P2V2}{T2}$<br>$\frac{2.6x10^{6}x2.9x10^{-5}}{790} = \frac{P2x2.9x10^{-4}}{314}$<br>Pressure of the gas = 103000 Pa | M1<br>A1 |
| 3(b)(ii) | ΔU = Q + W<br>= 0 + -91<br>= -91 J<br>Change in internal energy = -91 J | A1 |
| 3(b)(iii) | Internal energy of a system is the sum of kinetic energies and potential energies associated with the gas molecules. As the gas behaves ideally, internal energy is just the sum of kinetic energies of the gas molecules and it is proportional to the temperature of the gas system.<br>A decrease in the internal energy of the gas that behaved ideally indicates a decrease in the average kinetic energy of the molecules, which would be reflected as a drop in temperature. | B1<br>B1 |

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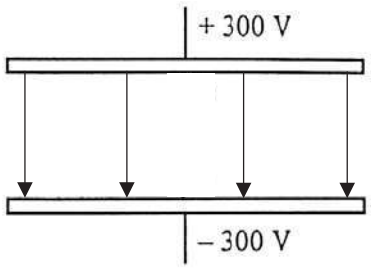
| | | |
|---|---|---|
| 4(a) | Electric field strength is the electric force per unit <u>positive</u> charge at a point, due to an electric field.<br>SI unit is N $C^{-1}$. | B1<br><br>A1 |
| 4(b)(i) |  | <br><br><br><br>A1 |
| 4(b)(ii) | Electric field strength = 600 /0.012<br>= 50000 N $C^{-1}$ | <br>A1 |
| 4(b)(iii) | Work done = 600 x 1.6 x $10^{-19}$<br>= 9.6 x $10^{-17}$ J | A1 |
| 4(b)(iv) | gain in kinetic energy = 9.6 x $10^{-17}$ J | A1 |
| 4(c) | Electric force provides the centripetal force<br>$e^2 / (4 \pi \varepsilon_o r^2) = m_e r \omega^2$<br>$\omega^2 = (1.6 \times 10^{-19})^2 / [(4 \pi \varepsilon_o)(9.11 \times 10^{-31})(5.3 \times 10^{-11})^3]$<br>$\omega = 4.12 \times 10^{16}$ rad $s^{-1}$<br><br>Since $T = 2\pi/\omega = 1.53 \times 10^{-16}$ s<br>$I = Q/t = 1.6 \times 10^{-19} / (1.53 \times 10^{-16})$<br>$= 1.05 \times 10^{-3}$ A | M1<br><br><br>A1<br><br>M1<br><br>A1 |

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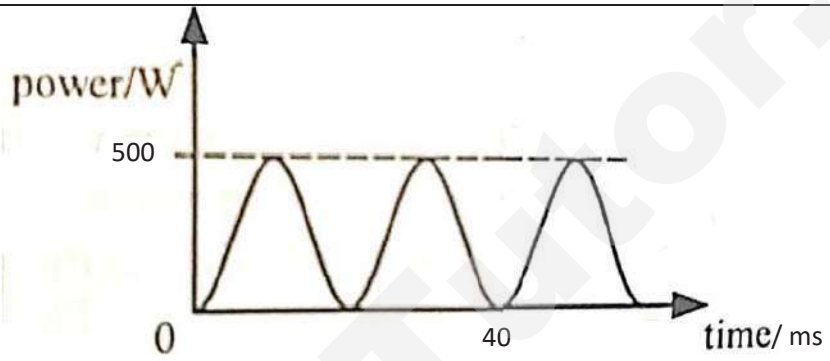
| | | |
|---|---|---|
| 5(a)(i) | The root-mean-square value of an alternating current is the equivalent value of a steady direct current that will dissipate heat at the same average rate as the alternating current, in a given resistor. | B1<br>B1 |
| 5(a)(ii) | Frequency = 1 / (40 x $10^{-3}$)<br>= 25 Hz | <br>A1 |
| 5(a)(iii) | Peak value = 10 A | A1 |
| 5(a)(iv) | Root-mean-square value of current = 10 / √(2)<br>= 7.07 A | <br>A1 |
| 5(a)(v) |  <br>Both axes are labelled sufficiently<br>Shape of graph is correct | <br>A1<br>A1 |
| 5(b)(i) | An ideal transformer is a device that steps up or steps down the voltage of an alternating supply without power loss. | B1 |
| 5(b)(ii) | Np/Ns =Is/Ip<br>300/6000 = Is/10<br>Is= 0.5 A | <br>M1<br>A1 |

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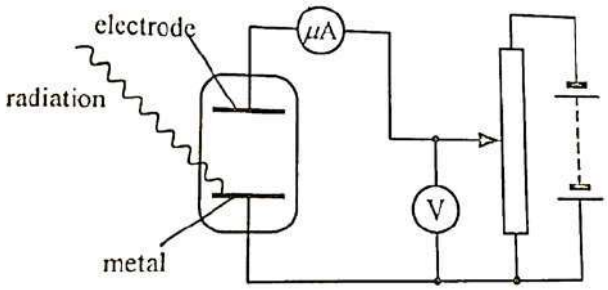
|---|---|---|
| 6(a) |  <br>Photoelectric effect refers to the phenomenon that when some <u>metal surfaces are illuminated</u> by light, <u>electrons are emitted</u>.<br><br>When the metal surface is illuminated with light even at a very <u>low intensity</u>, the flow of current in the ammeter indicates that <u>photoelectrons are emitted almost instantaneously</u>, as long as light is <u>above a threshold frequency</u>.<br><br>This led to the idea that light exists as <u>particle-like photons</u>, each having a quantum of energy which can be absorbed by a an electron in the metal surface, releasing the electron to move towards the electrode. | B1<br><br>B1<br><br>B1<br><br>B1 |
| 6(b)(i) | The energy of a photoelectron can be increase by using radiation with <u>higher frequency</u>. This is because each electron only absorbs <u>energy from one photon</u>. | B1 |
| 6(b)(ii) | The rate of production of photoelectrons can be increased by <u>increasing the intensity</u> of the radiation.<br>This is because it is proportional to the <u>rate of photons arriving at the metal</u> which is in turn proportional to the intensity of the radiation. | B1<br><br>B1 |
| 6(c) | The <u>diffraction of light</u> demonstrates the wave nature of electromagnetic radiation, which is inconsistent with the evidence shown by the photoelectric effect.<br>Diffraction is the <u>bending and spreading of waves when it passes through an aperture</u>, giving raise to a wider image on the screen than the aperture.<br><u>Only waves have this property</u>. Particles would only travel in a straight line, thus resulting in an image the same size as the aperture.<br><br>OR ANY OTHER EXPERIMENTS THAT PROVE WAVE NATURE OF LIGHT. | B1<br><br>B1<br><br>B1 |

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|---|---|---|
| 7(a)(i) | As diameter of the wire d increases, resistance of the wire R decreases. | B1 |
| 7(a)(ii) | Taking natural logarithm of $R = kd^n$, $\lg R = n \lg d + \lg k$. $R = kd^n$ is valid because the graph lg R against lg d is a straight line. | B1<br>B1 |
| 7(b)(i) | Plotting the point for d = 0.46 mm correctly. | M1 |
| 7(b)(ii) | Drawing the best fit line correctly. | M1 |
| 7(b)(iii) | n = (0.34 – 1.2) / (-0.1 + 0.53)<br>= -2.0 | M1<br>A1 |
| 7(c) | lg (0.73) = -0.137.<br><br>At lg d = -0.137, lg R = 0.41.<br>$R = 10^{0.41}$<br>= 2.57 mΩ<br>= $2.57 \times 10^{-3}$ Ω | M1<br><br>M1<br><br><br>A1 |
| 7(d) | Y = m X + c<br>(1.14) = -2.0 (-0.5) + c<br>c = 0.14<br><br>$k = 10^{0.14} = 1.38$ mΩ $mm^2$<br><br>$k = 4\rho L / \pi$<br>$1.38 = 4\rho(1000) / \pi$<br>ρ = 0.00108 mΩ mm (no mark for unit) | <br><br>M1<br><br>M1<br><br>M1<br>A1 |
| 7(e)(i) | Consider boiler:<br>Using $P = I^2R$<br>$5.4 \times 10^6 = I^2 (6 \times 10^3)$<br>I = 30 A<br>From graph, when I = 30 A, d = 0.42 mm<br>Since minimum diameter required is 0.42 mm.<br>therefore use wire **gauge 8** | <br>M1<br><br><br>M1<br><br>A1 |
| 7(e)(ii) | Lower manufacturing cost | B1 |
| 7(e)(iii) | For the same resistivity, thicker wires have lower resistance and as a results, there is lower power losses in them. | B1<br>B1 |
| 7(e)(iv) | Using V = IR<br>= 30 $(6.6 \times 10^{-3})$<br>= 0.198 V | M1<br><br>A1 |

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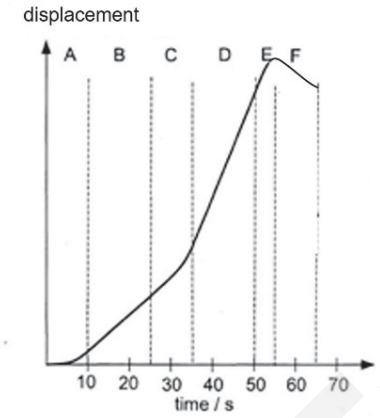
# 2019 Prelim Exams Paper 3 Answers

| | | | | |
|---|---|---|---|---|
| 1 | (a) | (i) | In Section E, the object undergoes a constant deceleration of 7 m $s^{-2}$ until velocity becomes zero at t = 55 s, after which the particle reverses its direction as the velocity changes from positive to negative.<br><br>In Section F, the particle travels at a constant velocity of 5 m $s^{-1}$ in the direction towards the starting point. | B1<br><br>B1 |
| | | (ii) |  <br>Sections B, D and F - Linear graphs<br>Sections A and C – increasing distance at increasing rate<br>Section E – increasing distance at decreasing rate, then decreasing distance<br>(allow ecf from 1(a)(i) for Section E) | B1<br>B1<br>B1 |
| | (b) | (i) | Consider the projectile motion from B to C:<br><br>$S_y = u_{By}t + ½ at^2$<br>$1 = u_{By}t + ½ (9.81) t^2$<br>$1 = u_B \sin 30^\circ t + ½ (9.81) t^2$ ----Eqn (1)<br><br>$S_x = u_{Bx}t$<br>$1 = u_B \cos 30^\circ t$<br>Rearranging, $t = \frac{1}{\cos 30 u_B}$<br>Substitute into equation (1)<br>$1 = u_B (0.5) \frac{1}{\cos 30 u_B} + ½ (9.81) (\frac{1}{\cos 30 u_B})^2$<br>$1 = 0.57735 + \frac{6.5399}{U_B{}^2}$<br>Solving, $U_B$ = 3.9 m $s^{-1}$ | M1<br><br>M2<br><br>M3 |
| | | (ii) | Lost in GPE = gain in KE<br>$mgh = ½ m (U_B)^2$<br>h = 0.775 m | M1<br>A1 |



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| **2** | **(a)** | Since g $\alpha$ M/r,<br>$\frac{g_M}{g_E} = (\frac{M_M}{M_E})(\frac{r_E}{r_M})^2$<br>$= (1/81)(3.7)^2$<br>$= 0.169$<br><br>Therefore, g due to Moon = 0.169 X 9.81<br>$= 1.66\ N\ kg^{-1}$ | | M1<br><br>C1<br><br><br>A1 |
| | **(b)** | $\frac{GM_E}{r^2} = \frac{GM_M}{(3.84\times10^8-r)^2}$<br>$81 = \frac{r^2}{(3.84\times10^8-r)^2}$<br>$r = 3.46 \times 10^8$ m | | M1<br><br><br><br>A1 |
| | **(c)** | **(i)** | $\omega = 2\pi/T$<br>$= 2\pi/(27.3 \times 24 \times 60 \times 60)$<br>$= 2.66 \times 10^{-6}$ rad $s^{-1}$ [1] | <br><br><br>A1 |
| | | **(ii)** | Gravitational acceleration provides centripetal acceleration.<br><br>$GM/r^2 = r\omega^2$<br>$M = r^3\omega^2/G$<br>$= (3.84 \times 10^8)^3 \times (2.66 \times 10^{-6})^2 / 6.67 \times 10^{-11}$<br>$= 6.0 \times 10^{24}$ kg | <br><br><br><br>M1<br><br>A1 |
| | | **(iii)** | Mass of Moon = 1/81 Mass of Earth<br><br>$F = GM_EM_M/r^2$<br>$= [6.67 \times 10^{-11} (6.0 \times 10^{24})^2 / 81] / (3.84 \times 10^8)^2$ [1]<br>$= 2.01 \times 10^{20}$ N | <br><br><br>M1<br>A1 |
| | | **(iv)** | The acceleration the moon causes on the Earth is very small as the Earth has a large mass.<br><br>$a = F/m = 2.01 \times 10^{20} / 6.0 \times 10^{24} = 3.35 \times 10^{-5}$ m $s^{-2}$ | B1<br><br>A1 |

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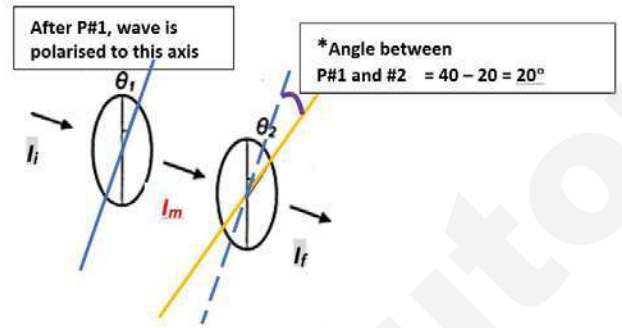
| **3** | **(a)** | **(i)** | Un-polarlised light consists of light waves, which are transverse waves, with different planes of oscillation.<br>Polarisation is the phenomenon in which the vibrations giving rise to waves are <u>restricted in a direction of vibration</u>, <u>perpendicular to the direction of wave propagation.</u> | B1<br>B1 |
| | | **(ii)** | Constructive interference occurs when the superposition of two waves produce a resultant wave of greater amplitude. | B1<br>B1 |
| | **(b)** | |  <br>After Polariser 1 (#1):<br>$I_m = I_i\ cos^2 20$<br><br>After Polariser 2 (#2):<br>$I_f = I_m\ cos^2\mathbf{20}$<br>= $(I_i\ cos^2 20)(cos^2\mathbf{20})$<br>**= 0.780** $I_i$ | C1<br><br>A1 |
| | **(c)** | **(i)** | sin $\theta$ = $\lambda$ /b<br>$sin\theta = \frac{0.003}{2.4} = \frac{\lambda}{b}$<br>$b = 5.04 \times 10^{-4}\ m$ = 0.504 mm<br><br>Allow range of x from 0.003 to 0.0035 m | C1<br><br>A1 |
| | | **(ii)** | b↓ , sinθ↑, θ↑<br>increase in width of central maximum,<br><br>effect: (either) maxima are farther,<br>(or) therefore the bright fringes have lower intensity (to get the second mark) | B1<br><br>B1 |

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| **4** | **(a)** | **(i)** | R = $\frac{\rho l}{A} = \frac{1.1\times10^{-6}\times98}{\pi(\frac{1.1\times10^{-3}}{2})^2}$<br>= 113 Ω | | A1 |
| | | **(ii)** | As the wire stretches, its length increases and it cross sectional area decreases. From $R = \frac{\rho l}{A}$, R will increase. | | B1 |
| | **(b)** | **(i)** | $R_{PQ} = 1\% \times 113 = 1.13\Omega$<br>$V_{PQ} = \frac{R_{PQ}}{R_{PQ} + R + r} \times E_1$<br>$V_{PQ}$= $\frac{1.13}{1.13+R+r} \times E_1$<br><br>$V_{PQ}$ per unit length<br>= $\frac{\frac{1.13}{1.13+R+r}\times E_1}{0.98}$<br>= $\frac{1.15}{1.13+R+r} \times E_1$ | | M1<br><br>C1 for correct R and length of PQ<br><br>A1 |
| | | | **1.** | Length PJ = 1/3 x 0.98 = 0.327 m<br>Using (b)(i) ans,<br>$V_{PJ} = 0.327\times\frac{1.15}{1.13 + R + r} \times E_1$<br>$=0.327\times\frac{1.15}{1.13 + 1.0 + r} \times 12$<br>At balanced length, $V_{PJ} = E_2$<br>$0.327\times\frac{1.15}{1.13+1.0+r} \times 12 = 1.5$<br>r = 0.878 Ω | C1<br><br>C1<br>A1 |
| | | | **2.** | If the resistance R is too high, the pd across the PQ will be too low.<br>If the p.d. across PQ is lower than the e.m.f. of $E_2$, there will be no balance point. | B1<br><br>B1 |



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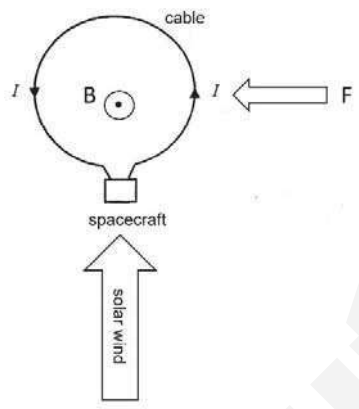
| **5** | **(a)** | The current in the magsail sets up a magnetic field (which is out of the page). A charge moving in a magnetic field experiences a force, thus getting deflected.<br>By Newton's third law, there is an equal and opposite force by the deflected charges on the magsail, thus propelling it. | | B1<br><br>B1 |
| | **(b)** | Photons do not have charge. | | B1 |
| | **(c)** | **(i)** |  | |
| | | **(ii)** | EK = ½ $mv^2$<br>500 x $10^3$ x 1.60 x $10^{-19}$ = ½ (1.67 x $10^{-27}$) $v^2$<br>v = 9.79 x $10^6$ m $s^{-1}$ | C1<br>A1 |
| | | **(iii)** | $B = \frac{\mu_o NI}{2r}$<br>$B = \frac{4\pi \times 10^{-7}\,(1)3000}{2(64)}$<br>$= 29.5\ \mu T$ | C1<br>A1 |
| | | **(iv)** | F = Bqv = 29.5 x $10^{-6}$ x (1.6 x $10^{-19}$) x (9.79 x $10^6$)<br>= 4.62 x $10^{-17}$ N | C1<br>A1 |

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| 6 | (a) | $\Phi = NBA = 400 \times 5 \times 10^{-5} \times \sin 60^\circ \times 25 \times 10^{-4}$<br>$= 4.33 \times 10^{-5}$ Wb | | C1<br>A1 |
| | (b) | (i) | $\Delta\Phi = \Phi_f - \Phi_i = \left[4.33 - \left(-4.33\right)\right] \times 10^{-5} = 8.66 \times 10^{-5}$ Wb | A1 |
| | | (ii) | Induced emf $E = \left\lvert\frac{d\Phi}{dt}\right\rvert = \frac{\Delta\Phi}{\Delta t}$<br>$= \frac{8.66 \times 10^{-5}}{2.5}$<br>$= 3.46 \times 10^{-5}$ V | C1<br>A1 |
| | (c) | Clockwise direction from the top view. | | A1 |
| | (d) | According to Lenz's Law, the induced current flows in a direction so as to oppose the change that produces it. This will result in a magnetic force that opposes the rotation of the coil.<br><br>Mechanical energy / kinetic energy is converted to electrical energy. | | B1<br><br>B1 |

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| 7 | (a) | Net force acting on the body and<br>the net torque acting on the body is zero . | | B1<br>B1 |
| | (b) | By considering moments about the left end of the rod:<br>**$0.25L \times 400 + 0.50L \times 120 = T_2 \cos 30^0 \times L$**<br>$T_2$ = 185 N<br>horizontally: **$185 \sin 30^0 = T_1 \sin 14.4^0$**<br>**$T_1 = 371$ N**<br><br>OR **$T_2 \cos 30^0 + T_1 \cos 14.4^0 = 400 + 120$**<br>**$T_1 = 371$ N**<br><br>OR Considering moments about right end of rod:<br>**$0.75L \times 400 + 0.50L \times 120 = T_1 \cos 14.4^0 \times L$**<br>$T_1$ = 372 N | | C1<br>A1<br>C1<br>A1 |
| | (c) | The frequency f of a body undergoing simple harmonic motion refers to the number of oscillation it undergoes per unit time and is measured in cycles per second.<br>The angular frequency ω is the angular velocity of the body in SHM measured in radians per second and ω = 2πf. | | B1<br><br>B1 |
| | (d) | (i) | When the spring is displaced by x, one of the springs (left) is compressed and the other spring (right) is extended. Both springs will exert a force of -2kx on the mass.<br>F = ma = -2kx<br>$a = -\frac{2kx}{m}$ | B1<br><br>B1 |



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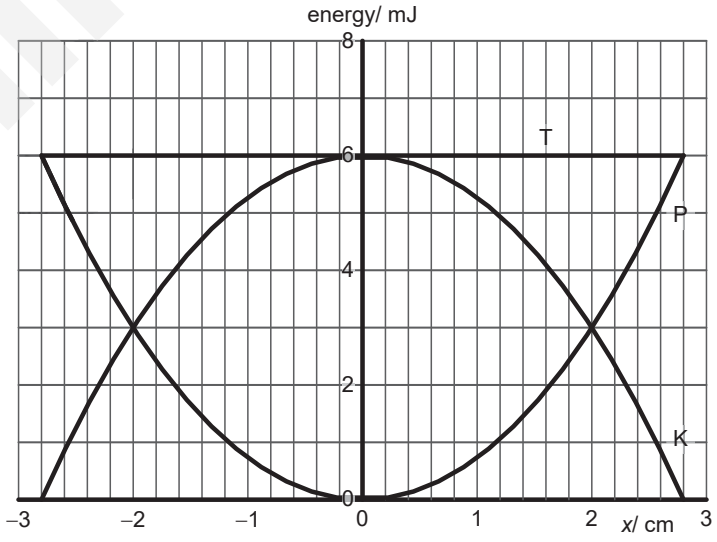
| | | **(ii)** | $E_T = \frac{1}{2}m\omega^2 x_0^2 = \frac{1}{2}\times 0.038\times(2\pi\times 3.2)^2\times 0.028^2$<br>$= 0.00602$ J $= 6.0$ mJ (2 sf) | M1<br>A1 |
| | | **(iii)** | When K.E. of ball is equal to P.E. of spring,<br>$E_P = \frac{1}{2}E_T$ OR $E_P = E_K$<br>$\frac{1}{2}m\omega^2 x^2 = \frac{1}{2}E_T$ $\frac{1}{2}m\omega^2 x^2 = \frac{1}{2}m\omega^2\left(x_o^{\,2} - x^2\right)$<br>$x = \sqrt{\frac{E_T}{m\omega^2}}$ $x = \frac{x_0}{\sqrt{2}}$<br>$= \sqrt{\frac{0.00602}{0.038\times(2\pi\times 3.2)^2}}$ $= \frac{2.8}{\sqrt{2}}$<br>$= 0.0198$ m $= 2.0$ cm<br>$= 1.98$ cm $= 2.0$ cm $= 0.020$ m<br><br>Note: Distance can only be positive. | C1<br><br>C1<br><br>A1 |
| | | **(iv)** |  <br>**Fig. 2.2**<br><br>T: Horizontal line at 6 mJ<br>K: max curve between 0 to 6 mJ | B1<br>B1<br>B1 |



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| | | | P: min curve between 0 to 6 mJ<br><br>Deduct 1m for (max 3m):<br>Any missing labels<br>K & P not intersecting at 3 mJ (not marking for 2.0 cm)<br>Any graphs not starting and ending at ± 2.8 cm. | |
| | **(e)** | In a vertical spring mass system, there is a change in gravitational potential energy.<br>At the highest position, EPE will be reduced.<br>or at the equilibrium position, the KE will be reduced. | | B1<br><br>B1 |

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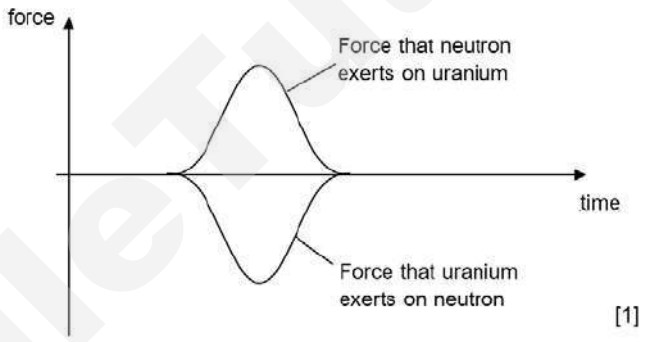
| **8** | **(a)** | The principle of conservation of momentum states that the total momentum of a system remains constant if no external resultant force acts on the system. | | | B1 |
| | **(b)** | **(i)** |  [1] | | A1 |
| | | **(ii)** | For each curve, the area under the graph is change in momentum of each body.<br>The graphs are mirror images of each other such that the gain in momentum of one is equal to the loss in momentum of the other, resulting in total momentum remaining constant. | | B1<br><br>B1 |
| | **(c)** | **(i)** | **1.** | Q = 1.2 MeV | A1 |
| | | | **2.** | $v = \sqrt{(E/( ½ m_e)}$<br>$= 6.5 \times 10^8$ ms$^{-1}$ | A1 |
| | | | **3.** | $m(Po) = m(Bi) - m_e - Q/c^2$<br>$= [(209.939u) - (9.11 \times 10^{-31}/1.66 \times 10^{-27}) - (\underline{1.2x10^6}x1.60x10^{-19}/c^2)]/(1.66 \times 10^{-27}$ kg)<br>= 209.937 u<br><br>Allow ecf from (c)(i)1. for Q value | C1<br>C1<br><br>A1 |



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| | | **(ii)** | Range of values accepted : 0.16 - 0.19 MeV | A1 |
| | | **(iii)** | For a stationary nucleus decaying into the beta particle and daughter nucleus, the conservation of linear momentum requires that $\underline{p_1} = -\underline{p_2}$.<br>The <u>sum of kinetic energies</u> will thus be $(p_1)^2/2m_1 + (p_2)^2/2m_2 =$ E, which <u>ought to equal the energy released in the reaction</u>, which, if equal to the increase in the total binding energy/decrease in total mass, ought to be constant.<br><br>The range of beta particle energies and thus the supposed energy released E, seem to suggest that the energy released was not constant, in contradiction to the principle of conservation of energy. | B1<br><br>B1 |
| | | **(iv)** | The existence of another undetected particle known as neutrino. | B1 |
| | **(d)** | **(i)** | The decay constant refers to the probability of decay of a radioactive nucleus in a time of one second. | B1 |
| | | **(ii)** | Using $A = A_o e^{-\lambda t}$,<br>$A = 375e^{-\left(\frac{\ln 2}{8.04} \text{ x } 2.5 \text{ x} 7\right)}$<br>**$A$ = 82. 9 Bq** | C1<br>C1<br>A1 |
| | | **(iii)** | $A = \lambda N$<br>$A = \left(\frac{\ln 2}{t_{\frac{1}{2}}}\right)\left(\frac{M}{M_m} N_A\right)$<br>$M = \frac{(375)(8.04\text{x}24\text{x}60\text{x}60)(131\text{x}10^{-3})}{(\ln 2)(6.02\text{x}10^{23})}$<br>**≈ 8. 2 x $10^{-17}$ kg** | C1<br><br><br>C1<br>A1 |

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## Mark Scheme for 2019 Prelim Paper 4

| | | | |
|---|---|---|---|
| **1 (a) (i)** | MMO | • Value of diameter d to correct precision of 0.001 cm using micro meter screw gauge<br>• Evidence of repeated measurement<br>• Expected Range: 0.16 to 0.20 mm | 1 |
| **(a) (ii)** | ACE | • Cross sectional area calculated correctly, with units, correct SF | 1 |
| **(a) (iii)** | ACE | • percentage uncertainty for the cross sectional area calculated using $2(\Delta d/d)$<br>• using $\Delta d >= 0.002$ cm | 1<br>1 |
| **(b)(iv)** | MMO | • Value of V given to 0.01 V<br>• Value of p given to correct precision of 0.1 cm<br>• Value of q given to correct precision of 0.1 cm<br>• p and q values are different<br>-1 mark for each error | 1<br>1 |
| **(c)** | MMO<br>PDO | • 6 sets of data without any assistance (deduct 1 mark for 5 sets)<br>• Headings with Units<br>• Recorded values for p, q are of appropriate DP<br>• Accuracy of calculated values (allow 1 slip)<br>• Calculated values are of appropriate SF | 1<br>1<br>1<br>1<br>1 |
| **(d)** | ACE | • **Linearisation** done correctly to $\frac{1}{q} = \frac{a}{p} + b$ or similar<br>• **Graph** scales are labelled with Qty and Unit. Scales must be chosen so that plotted points span at least half of the graph grid in both x and y directions<br>• Plotting of points accurate to half smallest square (check 3 plots)<br>• Line of Best fit shows balance of scatter (max +/- 5 smallest squares)<br>• Correct determination of Gradient, with gradient-triangle at least half graph paper. Read-offs must be accurate to half a small square.<br>• Correct calculation of a and b | 1<br>1<br>1<br>1<br>1<br>1 |
| **(e)** | ACE | • Correctly calculated **X** from given experssion using values of resistivity and area *A*<br>Percentage Diff between actual **X** = 10 Ω and the calculated value<br>OR similar approaches, e.g.<br>• Percentage Diff between constant b from gradient and calculated from substitution of values<br>• Comparison of this Perc Diff with Perc Uncertainty in area *A* to draw conclusion | 1<br>1 |

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| **(f)(i)** | ACE | E.g. of acceptable Sources of Error<br>• uncertainties in readings of p and q due to dimension of screw, clips thickness and parallax error<br>• not possible to adjust B for the two voltmeter readings to be exaclty same value V for each data<br>• Heating effect of wire if measurements take too long | Max 1 |
| **(f)(ii)** | ACE | • Use a thinner screw and thinners clips. Position eye consistently at the inner edges of the clips perpendicularly (use of a mirror under the wire)<br>• Instead of clips, use jockey with knife edge to determine q<br>• Take readings quickly, and off switch at short intervals to prevent heating effect of wire which will change resistance value | Max 1 |
| | | [total: 21 marks] | |

| | | | |
|---|---|---|---|
| **2 (a)(i)** | MMO<br>PDO<br><br>MMO | • Value of diameter d of spring to correct precision of 0.01 cm using vernier calliper<br>• Evidence of repeated measurement<br><br>• Value of N within Range = 29 to 31 | 1<br><br>1 |
| **(a)(ii)** | ACE | • Correct calculation of length L, with units, to correct SF | 1 |
| **(a)(iii)** | MMO | • length of unstretched spring *S* to correct precision of either 0,1 cm or 0.01 cm (using either ruler or vernier calliper)<br>• Evidence of repeated measurement<br><br>• Value of S within Range = 4.75 cm to 5.15 cm | 1 |
| **(b)(ii)** | MMO | • length of time *t* to correct precision of 0.1 s<br>• Evidence of repeated measurement<br><br>• Value of *t* within Range = 6.0 s to 8.0 s | 1 |
| **(c)(iii)** | MMO | • length of time *D* to correct precision of 0.1 cm<br>• Evidence of repeated measurement | 1 |
| **(d)** | ACE | • percentage uncertainty in D correctly calculated using $\Delta D >= 0.2$ cm | 1 |
| **(e)** | ACE | • Value of *k* correctly calculated, to appropriate number of significant figures | 1 |

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| | | | |
|---|---|---|---|
| **(f) (i)** | **P** | • **Varables = 1 Mark**<br>Identifying IV as *n*, DV as time *t*<br>AND stating CV of mass used to be same<br><br>• **Method of data collection = 1 Mark**<br>Brief description of varying *n*, measuring time *t* for 10 cycles with repeat, and calculation of average *t*<br><br>• **Valid Method of proving proportionality relationship = Max 1 Mark**<br><br>*0 mark if method of point testing:*<br>Hypothesize $t = kn$,<br>Obtain values of k by $k = t/n$ , mention of at least 2 values,<br>Check percentage difference in k and make conclusion by comparing with percentage uncertainty in *t*<br>(should use a Graphical Method)<br><br>*1 mark if method of graph plotting is:*<br>Hypothesize $t = kn$,<br>Plot *t* versus *n*<br>Inspection if BFL graph is a straight line passing through (or very near to Origin)<br><br>*1 mark if method of graph plotting is:*<br>Hypothesize $t = kn^x$,<br>Linearise to log $t = \log k + x \log n$<br>Plot log *t* versus log *n*<br>Obtain straight BFL<br>Method to deterimine gradient<br>Gradient = x and<br>if x is close to value of 1, the suggested relationship is valid<br><br>• **Might not have enough results = 1 mark**<br>if the connected springs become too long and touch bench surface<br>(does not allow for oscillation) | Max 4 |
| **(f) (ii)** | **P** | • Make the loops on the springs smaller so that n can be of larger range of values as more springs can be used on the retort stand<br>• Use shorter springs on a taller retort stand so that more springs can be used and range of n is big | 1 |
| | | [total: 13 mark] | |

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| | | | |
|---|---|---|---|
| **3 (a) (i)** | MMO | • Temperature to precision of 0.5 degree | 1 |
| **(ii)** | MMO | • Mass of cup and contents to 0.01 g | 1 |
| **(v)** | MMO | • Temperature diff *R* correctly calculated, to precision of 1 degree (allow to 0.5 deg)<br>• Mass diff *M* correctly calculated, to correct precision of 0.01 g (ECF on (a)(ii) ) | 1 |
| **(vi)** | ACE | • percentage uncertainty of *R* correctly calculated, using uncertainty >= 1 deg<br>• percentage uncertainty of *M* correctly calculated, using uncertainty >= 0.02 g | 1 |
| **(b)** | MMO | • New Temperature diff *R* obtained, to precision of 1 degree (allow to 0.5 deg)<br>New Mass diff *M* obtained, to correct precision of 0.1 g (ECF on (a)(ii) ) | 1 |
| **(c)(i)** | ACE | • Correct calculation of X/Y using simultaneous equation mtd or similar<br>• appropriate number of significant figures and using unit of g or kg | 1<br>1 |
| **(ii)** | ACE | • Calculation of percentage diff between X/Y and M<br>• Statement of validity by comapring the percentage diff with that in **(a)(ii) and a(vi)** | 1 |
| **(iii)** | ACE | Either of<br>• Graphical method is better as validity of relationship can be verified if a linear BFL is obtained using more data points<br>• Drawing of BFL using more data points allows for balancing of random errors (scatters) about the BFL, and so more accurate determination of the constants from values of gradient and Y-intercept | 1 |
| | | [total: 9 marks] | |

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**Q4**

**Diagram**

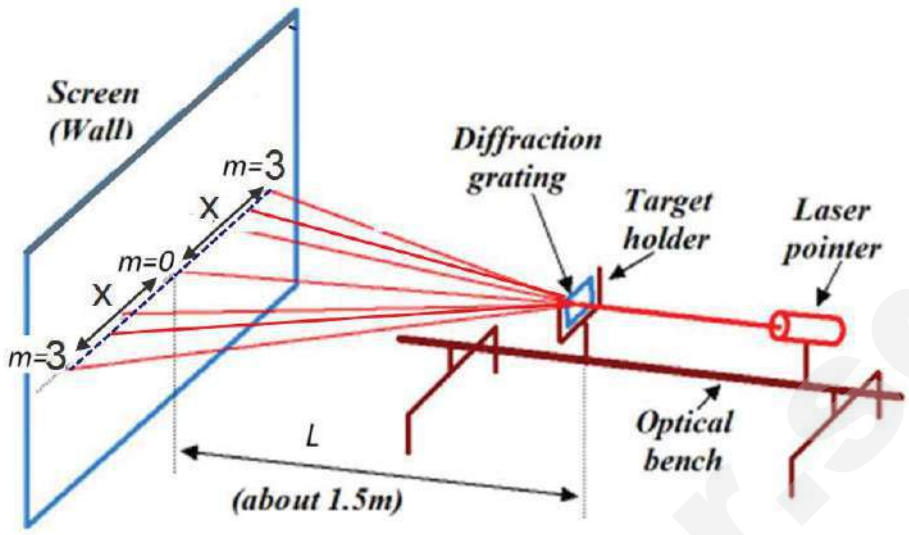


***Diagram of workable procedure***

| ***(All Diagram marks not awarded if grating is not shown in between screen and laser pointer)*** | **Max 2** |
|---|---|
| Diagram showing grating in between screen and laser , with use of retort stand and clamps to hold them | D1 |
| Diagram showing labelling of screen distance L and spot separation (x) for the 3rd spot | D2 |

***Variables / Basic Procedures***

| | |
|---|---|
| IV #1 is frequency f of light source, to be varied using the different lasers provided<br>IV #2 is number of lines on grating, N, to be varied by using different gratings<br>DV is θ, to be measured<br>using a protractor or<br>by calculation methods (tan θ or Pythagoras on sin θ ) | V1 |
| Keeping one of the IV constant, vary the other one and measure for p.<br>Then, keep the other IV constant now, and vary the first one to measure for θ<br><br>Control Variables –<br>keep Distance L between the screen and grating constant | V2 |

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***Procesures***

| | |
|---|---|
| Measure for length of L using measuring tape<br><br>Measure for distance x between middle bright spot and 3rd bright spot using a ruler | M1 |
| IV#1 - frequency f of light source<br>Use one of the grating throughout this part of the experiment, to keep N constant<br>Use different laser pointers with diff freq behind the grating<br>Measure for distance middle bright spot and 3rd bright spot using a ruler<br>Record values of f, L, x in Table A. | M2 |
| IV#2 - number of lines on grating, N<br>Use one of the laser throughout this part of the experiment, to keep f constant<br>Use different gratings with diff N<br>Measure for distance middle bright spot and 3rd bright spot using a ruler<br>record values of N, L, x in Table B. | M3 |

***Analysis (ALL details are required for the mark)***

| | |
|---|---|
| Calculate $\tan\theta = x/L$ in tables A and B<br>(or, use Pythagoras )<br>From Table A, Plot graph of $\lg(\tan\theta)$ versus $\lg(f)$.<br>Gradient = b<br>Y-intercept = $\lg(3kN^a)$ | A1 |
| From Table B, Plot graph of $\log(\sin\theta)$ versus $\log(N)$.<br>Gradient = a<br>Y-intercept = $\lg(3kf^b)$ | A2 |

***Steps for Accuracy: max 2***

| | |
|---|---|
| Do preliminary Measurements to determine optimum screen distance L (> 1 m) for spot separation to be large enough (> a few cm) | SA1 |
| Ensured measuring tape for L is straight , positioned along mid-point of grating and perpendicular to screen, fixed by being taped down to the table surface | SA2 |
| Measure for 2x between 3rd bright spots on either side, to divide by 2,<br>to reduce uncertainty in x | |
| Use of set square etc to ensure alignment of grating is perpendicular to screen | |
| Conduct in darkened room to see bright spots clearly | |
| Other credible details | |

***Safety considerations***

| | |
|---|---|
| Do not direct laser into eyes / always stand behind the laser beam | S1 |

Total: 12

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H

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| CLASS | | TUTOR'S NAME | |
| CENTRE NUMBER | S | INDEX NUMBER | |

# PHYSICS 9749/01

Paper 1 Multiple Choice **24 September 2019**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class, Centre number and index number in the spaces at the top of this page.

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

**Read the instructions on the Answer Sheet very carefully.**

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

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**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 | $\phi = -Gm / r$ |
| temperature | $T / \mathrm{K} = T / ^\circ\mathrm{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t$ |
| | $= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** Estimate the maximum number of passengers that can board a six-cabin Singapore Mass Rapid Transit train consisting of only standing cabins.

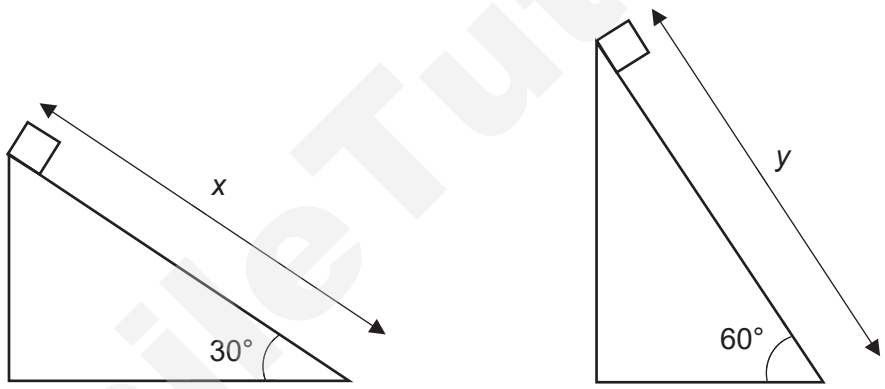
**A** 500 **B** 2000 **C** 10 000 **D** 100 000

**2** The Rayleigh-Jeans Law is an approximation to the spectral radiance of electromagnetic radiation as a function of wavelength from a black body at a given temperature through classical arguments. For wavelength $\lambda$, its spectral radiance is: $B = \frac{2ckT}{\lambda^4}$, where *c* is the speed of light, *k* is the Boltzmann constant and *T* is the thermodynamic temperature.

What is the unit of *B*, expressed in SI base units?

**A** $m^{-3}\ s^{-1}\ K$ **B** $m^{2}\ s^{-3}\ kg$ **C** $m^{-3}\ s^{-3}\ kg$ **D** $m^{-1}\ s^{-3}\ kg$

**3** Two identical blocks are released from rest from the top of two ramps as shown below.




Ignoring friction, what must be the ratio of *y*/*x* so that both blocks arrive at the end of the ramps at the same time?

**A** $\frac{1}{\sqrt{3}}$ **B** $\sqrt{2}$ **C** $\sqrt{3}$ **D** 3

**4** At the top of a cliff of height 100 m, a boy threw a rock upwards with velocity of 15 m $s^{-1}$. How much time later should he drop a second rock from rest so that both rocks will arrive simultaneously at the bottom of the cliff?

**A** 1.8 s **B** 2.7 s **C** 4.5 s **D** 6.3 s

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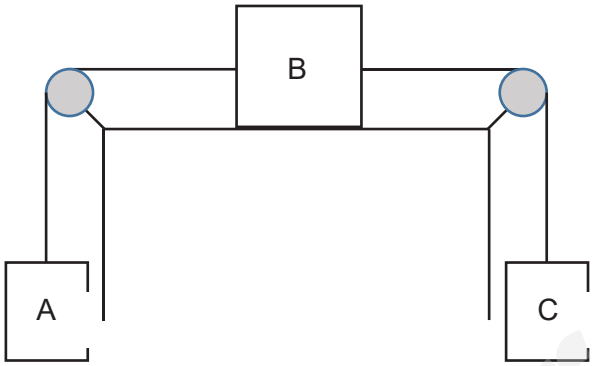
**5** Three bodies A, B and C with mass 15 kg, 45 kg and 25 kg are connected by light strings that pass over massless and smooth pulleys. The coefficient of friction, $\mu$, between B and the surface of the table is 0.15 and friction, $f$, is related to normal contact force, $N$, by the equation

$$f = \mu N.$$




What is the acceleration of the three bodies?

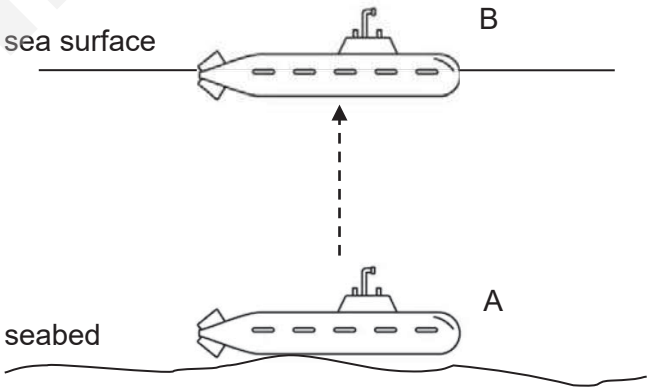
**A** 0 m s$^{-2}$ **B** 0.38 m s$^{-2}$ **C** 1.2 m s$^{-2}$ **D** 2.6 m s$^{-2}$

**6** Mary and Jane are standing at each end of an ice board 1.0 m in length. The ice board rests on frictionless ice. Mary throws a 5.0 kg ball horizontally to Jane who catches it.

Given that the mass of Mary, Jane and the ice board are 42 kg, 40 kg and 3.0 kg respectively, what is the distance travelled by the ice board before coming to rest again?

**A** 0.053 m **B** 0.056 m **C** 0.059 m **D** 0.063 m

**7** A submarine is initially at rest on the seabed at position A as shown in the diagram below. It then rises and floats on the sea surface at position B.




If the total weight of the submarine and its contents is $W$ and the upthrust on the submarine is $U$, by comparing the two positions A and B, which of the following is correct?

**A** $U$ has increased and $W$ has decreased.

**B** $U$ has decreased and $W$ remains the same.

**C** Both $U$ and $W$ have decreased.

**D** Both $U$ and $W$ have increased.

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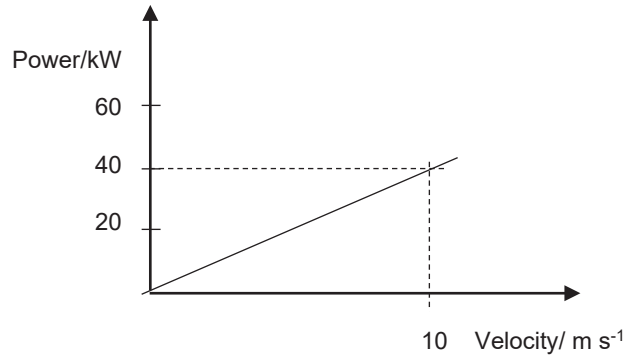
**8** The power of a motorcycle varies with its velocity as shown in the figure below.




If the total mass of the motorcycle and its rider is 500 kg, what is the acceleration of the motorcycle?

**A** 1.25 m $s^{-1}$ **B** 4.00 m $s^{-1}$ **C** 8.00 m $s^{-1}$ **D** 12.5 m $s^{-1}$

**9.** A piece of brass undergoes the following three processes involving a change of energy:

*P*: It is lifted vertically 2 m

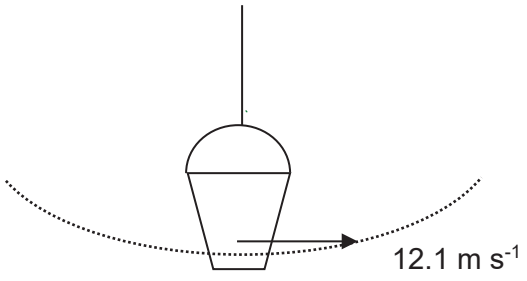
*Q*: it is heated from 15°C to 20°C

*R*: It is accelerated from rest to 10 m $s^{-1}$

The specific heat capacity of brass is 380 $J^{-1}$ $K^{-1}$ $kg^{-1}$.
These processes, arranged in order of increasing energy change are

**A** *P Q R* **B** *Q P R* **C** *Q R P* **D** *P R Q*

**10** A 1.2 kg bucket is held by a string and whirled in a vertical circle. The radius of the circle is 1.5 m. The speed of the bucket is 12.1 m $s^{-1}$ at the bottom of the loop and subsequently, the bucket reached the top of the circle.




At the bottom of the loop

What is the difference in the tension in the string at these two positions?

**A** 58 N **B** 71 N **C** 129 N **D** 187 N

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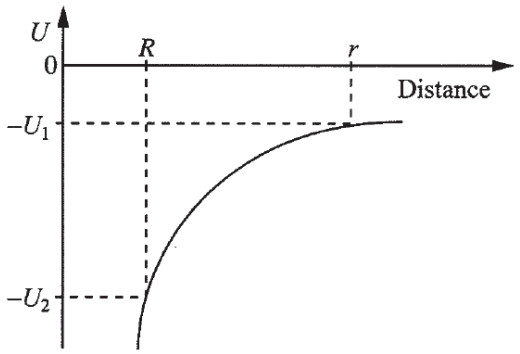
**11** The graph below shows the variation of the gravitational potential energy $U$ with the distance from the Earth's centre for a spacecraft. The radius of the earth is $R$.



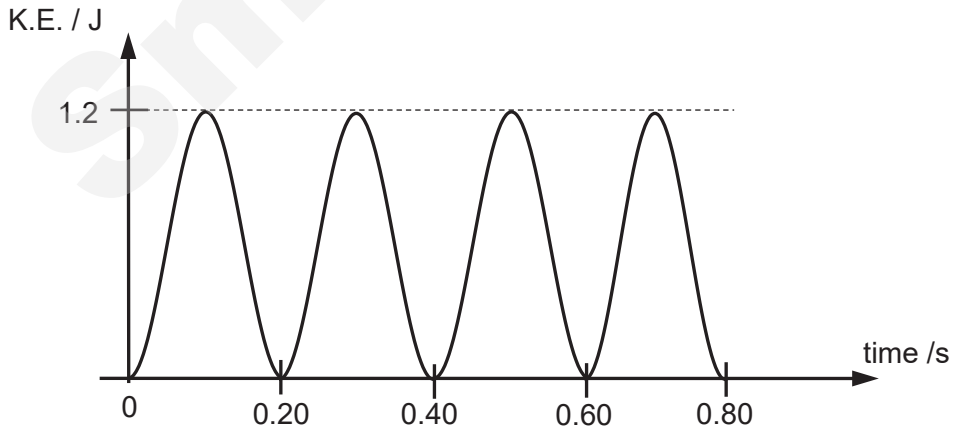

If the spacecraft is orbiting the earth in an orbit of radius $r$, the total energy of the spacecraft is

**A** $-\frac{1}{2}U_1$ **B** $-\frac{1}{2}U_2$ **C** $-2U_1$ **D** $-2U_2$

**12** A certain star of mass $M$ and radius $r$ rotates so rapidly that material at its equator only just remains on its surface. Given that the gravitational constant is $G$, the period of rotation is

**A** $2\pi\sqrt{\frac{r}{G}}$ **B** $2\pi\sqrt{\frac{G}{r}}$ **C** $2\pi\sqrt{\frac{r}{MG}}$ **D** $2\pi\sqrt{\frac{r^3}{MG}}$

**13** The graph below shows how the kinetic energy of a 50 g mass in simple harmonic motion varies with time.




What is the amplitude of the oscillation?

**A** 0.22 m **B** 0.44 m **C** 1.7 m **D** 2.8 m

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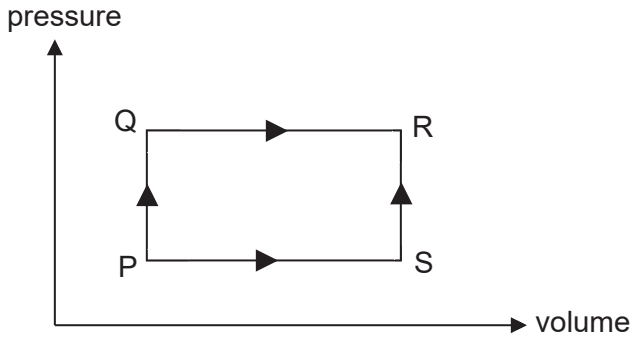
**14** A fixed mass of ideal gas undergoes changes of pressure and volume as shown below.




When the gas is taken from state P to state R by the stages PQ and QR, 8 J of heat are absorbed by it and 3 J of work are done by it. When the same resultant change is achieved by stages PS and SR, 1 J of work is done by the gas. In this case,

**A** 12 J of heat are liberated.

**B** 10 J of heat are absorbed.

**C** 8 J of heat are absorbed.

**D** 6 J of heat are absorbed.

**15** A beam of light goes through a polarising filter, followed by a sugar solution and then through a second polarising filter. The polarising axes of the two filters are initially aligned. The sugar solution has the effect of rotating the light's plane of polarization clockwise by 45°.

How should the second polarizing filter be rotated so that no light passes through?

**A** 45° clockwise

**B** 45° anti-clockwise

**C** 90° clockwise

**D** 90° anti-clockwise

**16** An interference pattern is formed on a screen by the superposition of two coherent light beams, one of which has four times the intensity of the other. The ratio of maximum to minimum intensity in the pattern is

**A** 1.7 **B** 3 **C** 4 **D** 9

**17** If a transparent glass block is placed in front of one of the slits of a Young's double slit experiment, which of the following observations of the fringe pattern will most likely occur?

**A** No fringe pattern will be observed on the screen.

**B** The fringe separation will become larger.

**C** The central maximum will be shifted from its original position.

**D** The bright fringe will become brighter.

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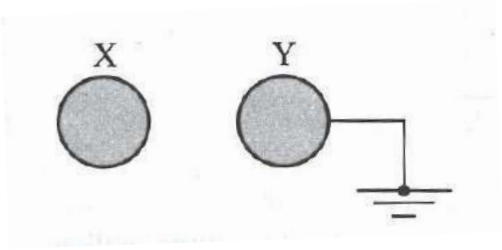
**18** The diagram below shows two metal spheres X and Y which are placed close to each other but not in contact. X is positively charged and Y is earthed.




Which of the following is correct for sphere Y?

| | electric potential on Y | charge on Y |
|---|---|---|
| **A** | Negative | Zero |
| **B** | Negative | Negative |
| **C** | Zero | Negative |
| **D** | Positive | Positive |

**19** Which one of the following statements about the electric potential at a point is true?

**A** The potential is given by the rate of change of electric field strength with distance.

**B** The potential is defined as the work done per unit positive charge in moving an electron from the point to infinity.

**C** The potential due to a system of point charges is given by the sum of the potentials due to the individual charges.

**D** Two points in an electric field are at the same potential when a unit positive charge placed anywhere on the line joining them remains stationary.

**20** A bulb lights up almost immediately when the switch is closed although the drift velocity of the electrons in the circuit is low at the start. This occurs because

**A** the resistance of the wires is very low.

**B** the electrons take a very short time to reach the bulb.

**C** all free electrons drift simultaneously in the circuit.

**D** the number density of electrons is high.

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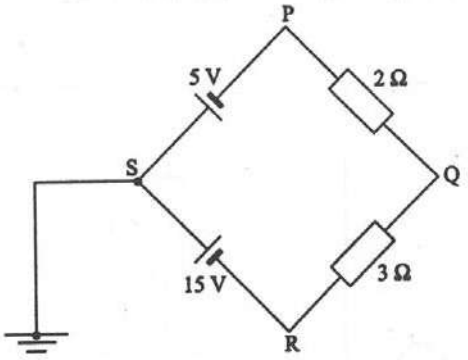
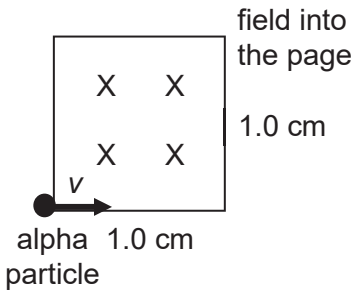
**21** In the circuit below, the point S is earthed.




The electric potential at the points **P**, **Q** and **R** respectively are

| | potential at **P** | potential at **Q** | potential at **R** |
|---|---|---|---|
| **A** | -5V | -15V | -10V |
| **B** | 10V | 1V | -15V |
| **C** | -5V | -9V | -15V |
| **D** | 5V | -1V | 10V |

**22** An alpha particle initially at rest is accelerated across a potential difference 250 V before entering a magnetic field. It enters the square uniform magnetic field of sides 1.0 cm with magnetic flux density 0.25 T at right angles from the corner of the field as shown below.




What is the angle of deflection of the velocity of the alpha particle?

**A** 0° **B** 33° **C** 51° **D** 180°

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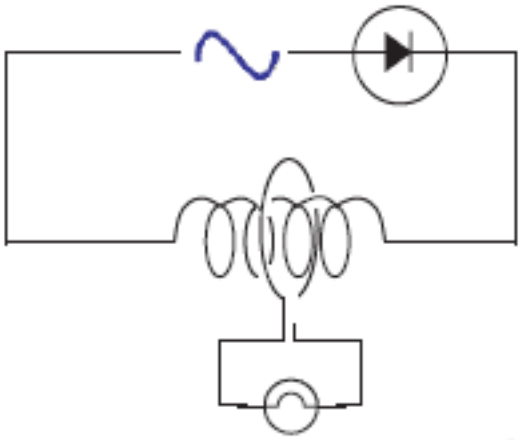
23 A circuit containing a circular loop of wire connected to a low power light bulb is positioned around a solenoid connected to a sinusoidal AC source and a diode as shown in the diagram below.



Which of the following statements is true?

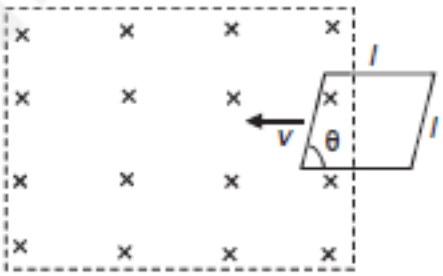
A The light bulb does not light up at all because the diode prevents current from flowing and does not produce any magnetic flux in the solenoid.

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

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

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

24 A wire frame in the shape of a parallelogram of sides $l$ enters a magnetic field with flux density $B$ as shown in the figure.




If the total resistance of the wire frame is $R$, what is the value of the induced current in the wire frame at the instant shown?

A 0 B $\frac{Blv}{R}$ C $\frac{Blv\sin\theta}{R}$ D $\frac{4Blv\sin\theta}{R}$

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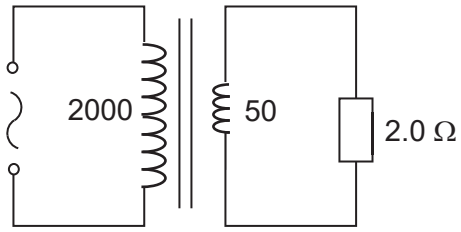
**25** In the circuit shown, the **average** power dissipated across a 2.0 Ω resistor is 50 W. The turns ratio of the primary coil to secondary coil of the ideal transformer in the circuit is 2000 : 50.




What is the peak potential difference across the primary coil of the ideal transformer?

**A** 20 V **B** 40 V **C** 400 V **D** 564 V

**26** A source emits monochromatic light of frequency $5.0 \times 10^{14}$ Hz at a rate of 0.10 W. The photons fall on the cathode of a photocell which gives a current of 80.0 μA in an external circuit. You may assume that this current consists of all the photoelectrons emitted.

What is the percentage of the photons falling on the cathode which produces photoelectrons?

**A** 0.017% **B** 0.17% **C** 1.7% **D** 100%

**27** In a X-ray tube, electrons of high energy *E* are incident on a target of tungsten. Which of the following statements is true?

**A** All the energy is converted to X-rays.

**B** The minimum X-ray wavelength obtained is *hc/E*.

**C** The wavelengths of the characteristic lines in the X-ray spectrum is dependent on *E*.

**D** The intensity of the characteristic lines in the X-ray spectrum is independent on *E*.

**28** The rest-masses of deuteron ${}^{2}_{1}\mathrm{H}$, proton and neutron are 2.0150 u, 1.0086 u and 1.0097 u respectively. A deuteron may disintegrate to a proton and neutron if it

**A** emits a photon of energy 2 MeV

**B** emits a photon of energy 3 MeV

**C** captures a photon of energy 2 MeV

**D** captures a photon of energy 3 MeV

**29** A source in the laboratory has a half-life of 10 days. The count rate was measured to be 100 Bq initially. 25 days later, the count rate was found to be 31 Bq. What is the count rate in the laboratory without the source?

**A** 8 **B** 13 **C** 16 **D** 19

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**30** A radioactive decay series, starting with Thorium $^{232}_{90}\text{Th}$, involves the emission of the following in order: alpha, beta, beta, gamma, alpha, gamma. Which of the following isotopes will not be a product of this series of decays?

**A** $^{228}_{89}\text{Ac}$ **B** $^{224}_{89}\text{Fr}$ **C** $^{224}_{88}\text{Ra}$ **D** $^{228}_{88}\text{Ra}$

**End of Paper**

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JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

# PHYSICS 9749/02

Paper 2 Structured Questions **4 September 2019**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, 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 | / 6 |
| 3 | / 7 |
| 4 | / 7 |
| 5 | / 9 |
| 6 | / 9 |
| 7 | / 7 |
| 8 | / 7 |
| 9 | / 20 |
| Total | / 80 |

This document consists of **19** printed pages.



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**Data**

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

**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$ |
| | $v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -Gm / r$ |
| temperature | $T / \mathrm{K} = T / ^\circ\mathrm{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t$ |
| | $= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** A 3.8 kg block on a plane inclined at 15° has initial speed of 5.0 m $s^{-1}$ when a horizontal force *F* of magnitude 25 N acts on it as shown in Fig. 1.1.

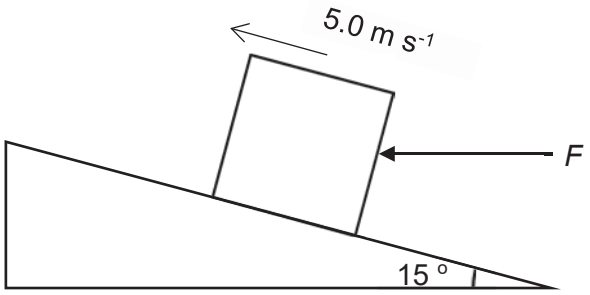


**Fig. 1.1**

**(a)** Determine the normal contact force exerted by the plane on the block.

normal contact force = ..... N [2]

**(b)** The coefficient of kinetic friction, $\mu$, is 0.40 and the kinetic friction, *f*, is related to the normal contact force, *N*, by the equation

$$f = \mu N .$$

**(i)** Calculate the magnitude of the acceleration of the block.

acceleration = ..... m $s^{-2}$ [2]


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**(ii)** Determine the distance travelled by the block before it comes to rest.

distance = ..... m [2]

**(iii)** Static friction is a force that acts on an object when it is at rest. It must be overcome before the object can start moving.

Considering that the maximum possible static friction between the object and the plane is equal to the value of the kinetic friction, *f*, state and explain, whether the block will slide down the plane after coming to rest if force *F* continues to act on the block.

.....

.....

.....

..... [2]

[Total: 8]

**2** **(a)** State an example of how the motion of an object can be undergoing the following situations:

**(i)** A body is instantaneously at rest but has a non-zero acceleration.

.....

..... [1]

**(ii)** A body is moving with a constant speed but has a non-zero acceleration.

.....

..... [1]

**(b)** A toy car, initially at rest, can be made to propel forward by attaching a bottle filled with baking soda and vinegar. When the bottle cap is removed, the gas released from the reaction will cause the toy car to move forward. Fig. 2.1 shows how the acceleration, *a*, of the toy car changes with time *t*.

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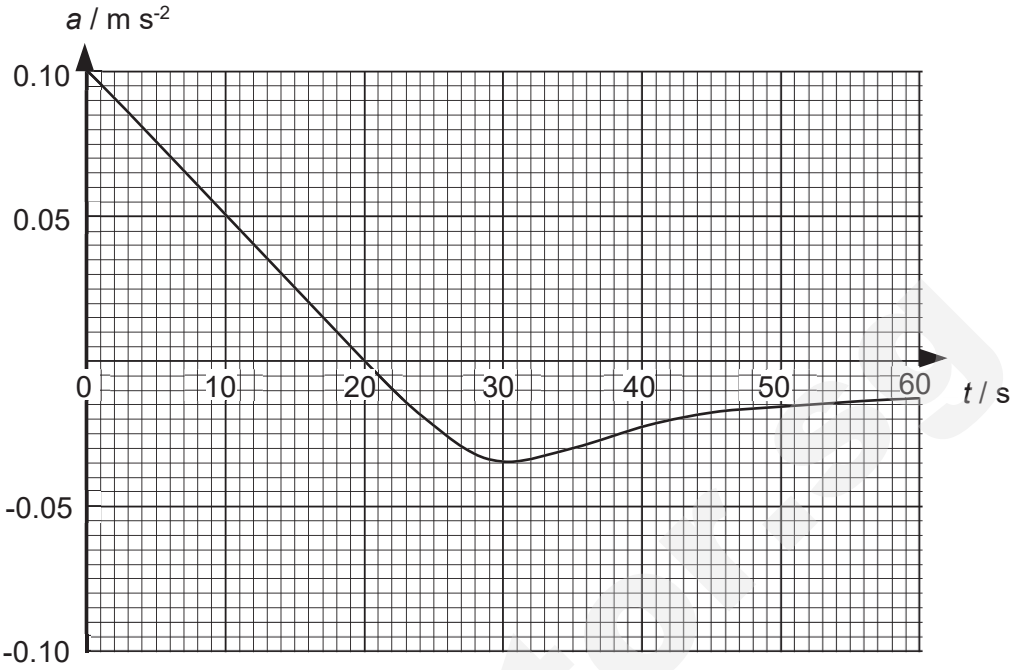


**Fig. 2.1**

**(i)** With reference to Fig. 2.1, determine the maximum speed of the toy car.

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

**(ii)** Hence, sketch a graph on Fig. 2.2 to show how the velocity, *v*, of the toy car changes with time *t*.

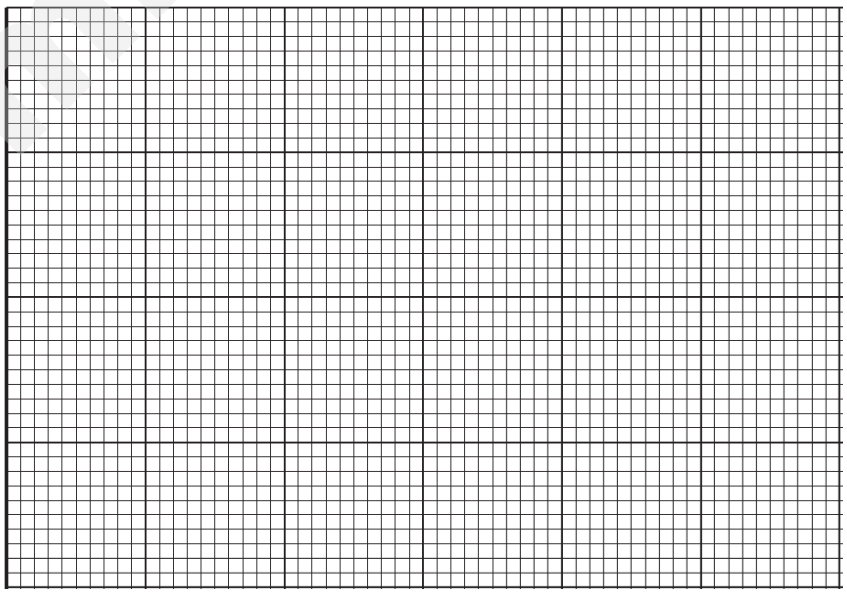

**Fig. 2.2**

[3]

[Total: 6]


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**3** In a system called the positronium, an electron and positron move in a circular orbit as shown in Fig. 3.1. A positron has a positive elementary charge *e* and a mass identical to that of an electron. The positron and electron are separated by a distance of $1.30 \times 10^{-10}$ m.

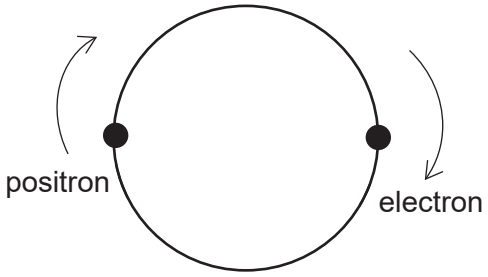


**Fig. 3.1**

**(a)** Explain why the centripetal forces on the electron and positron are equal in magnitude.

.....

.....

..... [1]

**(b)** Determine

**(i)** the magnitude of each centripetal force,

centripetal force = ..... N [2]

**(ii)** the time taken for one revolution of the electron.

time taken = ..... s [2]

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**(c)** State and explain whether there would be any difference to the circular orbit if it were a proton in place of the positron.

.....

.....

.....

.....

..... [2]

[Total: 7]

**4** **(a)** State two conditions necessary for the formation of stationary waves.

.....

.....

..... [2]

**(b)** With the aid of a labelled diagram, describe a laboratory experiment to demonstrate stationary waves in an air column.

.....

.....

.....

.....

.....

.....

..... [3]


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**(c)** Fig. 4.1 shows an arrangement used to determine the speed of microwaves in the laboratory.

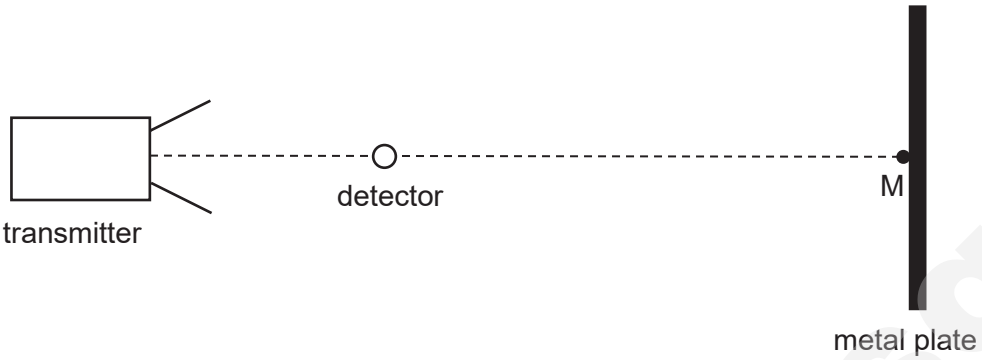


**Fig. 4.1**

A stationary wave is formed between the transmitter and the metal plate. As the detector is moved along the line between the transmitter and the point M, it registers a series of high intensity signals. The positions of these high intensity signals along an axis are marked by crosses on the x axis of the graph in Fig. 4.2.

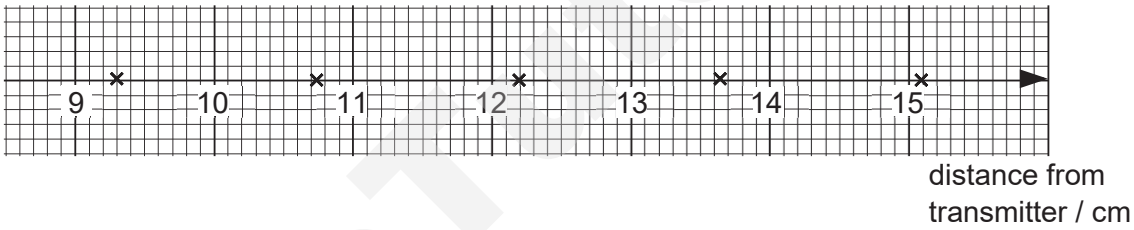


**Fig. 4.2**

The transmitter emits microwaves of frequency $1.0 \times 10^{10}$ Hz. Use Fig. 4.2 to deduce an experimental value for the speed of the microwaves.

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

[Total: 7]

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**5** **(a)** Explain what is meant by *electric field strength*.

.....

.....

..... [2]

**(b)** In a crystal of sodium chloride, a sodium ion has a positive charge of $+e$. It is separated from its closest chlorine ion by a distance of $2.8 \times 10^{-10}$ m. The chlorine ion has a charge of $-e$.

Assume that the ions are point charges.

**(i)** Calculate the magnitude of the electric field strength at the sodium ion due to its closest chlorine ion.

electric field strength = ..... N $C^{-1}$ [2]

**(ii)** Calculate the attractive force between the two ions.

force = ..... N [1]

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**(c)** The force calculated in **(b)(ii)** would result in the two ions accelerating towards each other. This does not happen because of the presence of other ions.

**(i)** Fig. 5.1 represents a plane of sodium and chlorine ions.

On Fig. 5.1, draw arrows to show the forces acting on the central sodium ion. Label the arrows to indicate whether these are forces of attraction (A) or repulsion (R). The length of the arrows should reflect the relative magnitudes of the forces.



[2]

**Fig. 5.1**

**(ii)** State the resultant force on the central sodium ion.

resultant force = ..... N [1]

**(iii)** When the central sodium ion is displaced out of position, describe the effect of the resultant force on the ion.

.....

..... [1]

[Total: 9]

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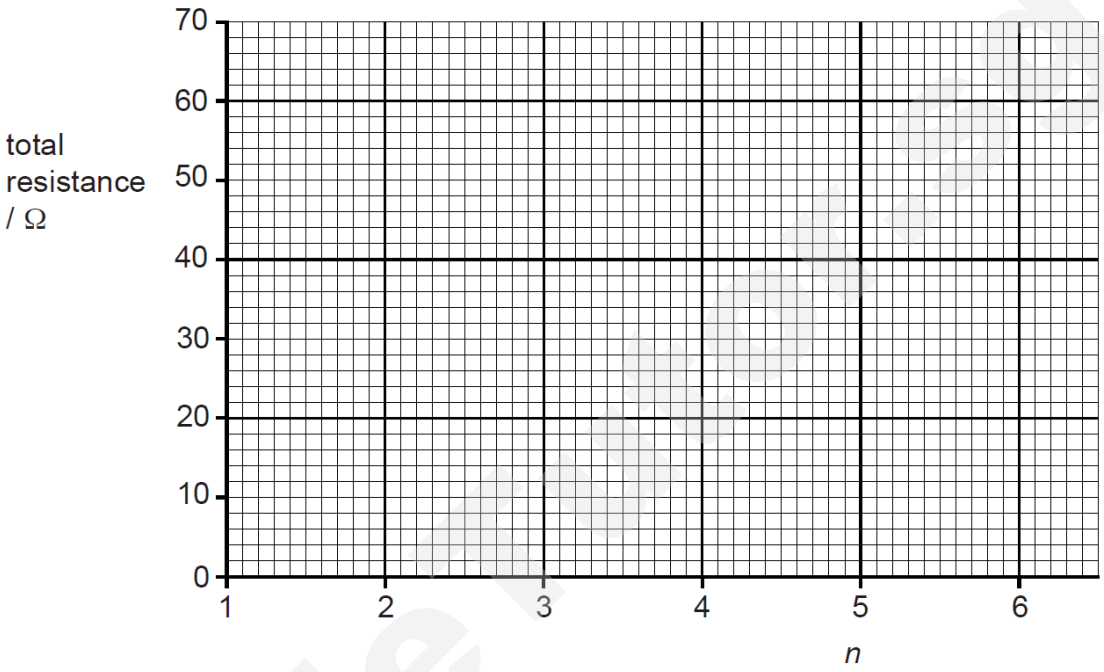
6 (a) (i) 1. Give an expression for the total resistance of $n$ resistors, each of resistance 10 Ω, connected in **series**, where $n$ is the number of resistors.

resistance = ..... Ω [1]

2. On Fig. 6.1, plot a graph showing the values of the total resistance for $n$ = 1, 2, 3, 4, 5 and 6. Label the line S.




[2]

**Fig. 6.1**

(ii) 1. Give an expression for the total resistance of $n$ resistors, each of resistance 10 Ω, connected in **parallel**, where $n$ is the number of resistors.

resistance = ..... Ω [1]

2. On Fig. 6.1, plot a graph showing the values of the total resistance for $n$ = 1, 2, 3, 4, 5 and 6. Label the line P. [2]

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**(b)** **(i)** Fig. 6.2 shows a network of 16 resistors, each of resistance 10 Ω connected in four parallel lines of four resistors in series.

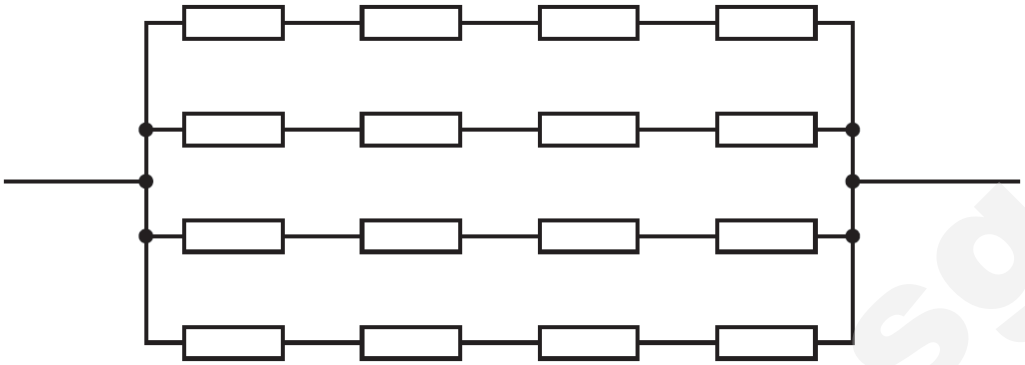

**Fig. 6.2**

Calculate the total resistance of the network.

total resistance = ..... Ω [1]

**(ii)** State the total resistance of a network of *n* parallel lines of *n* resistors in series where every resistor has a resistance of 10 Ω.

resistance = ..... Ω [1]

**(iii)** Explain one practical advantage of using many individual resistors in this way, rather than using a single resistor.

.....

..... [1]

[Total: 9]

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**7** **(a)** Define *magnetic flux density*.

.....

.....

..... [2]

**(b)** A rigid square single-wire coil PQRS of side 4.00 cm and mass 25.0 g hangs vertically in a uniform magnetic field with magnetic flux density of 0.0420 T acting vertically downwards, as shown in Fig. 7.1

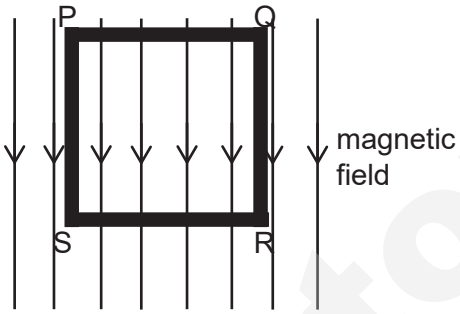


**Fig. 7.1**

This coil can rotate freely, pivoted along the top edge PQ. When a current of 7.50 A passes through the coil, it hangs at an angle of $\theta$ to the vertical as shown in the side view of the coil in Fig. 7.2.

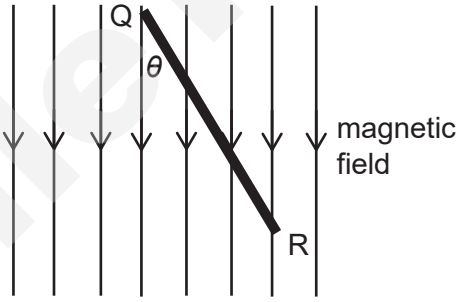


**Fig. 7.2**

**(i)** State the direction of current along the side RS.

direction =.....[1]

**(ii)** Explain how the answer in **(i)** was determined.

.....

..... [1]

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**(iii)** Calculate angle $\theta$ the coil makes with the magnetic field.

$\theta$ =.....[3]

[Total: 7]

**8** Fig. 8.1 shows a simplified circuit diagram of a laptop adaptor connected to the chargeable battery of a laptop. The adapter consists of a step-down transformer with a single diode.

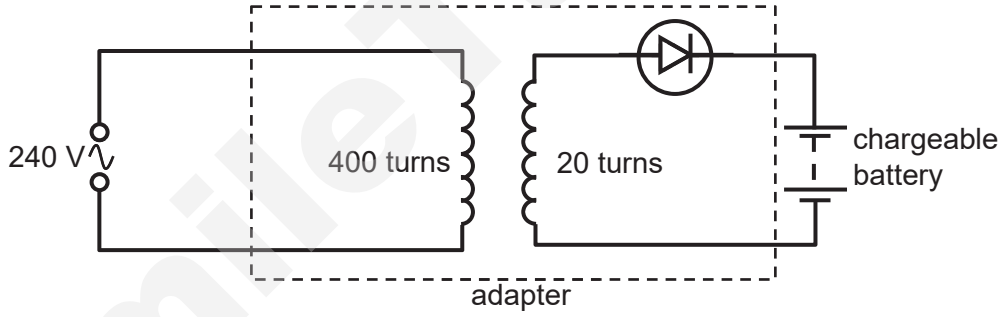


**Fig. 8.1**

**(a)** Calculate the peak voltage across the secondary coil and state one assumption made in performing the calculation.

peak voltage = ..... V [1]

Assumption: .....

..... [1]

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**(b)** Explain why, during the charging process, the power delivered to the secondary coil is twice the power delivered to the chargeable battery.

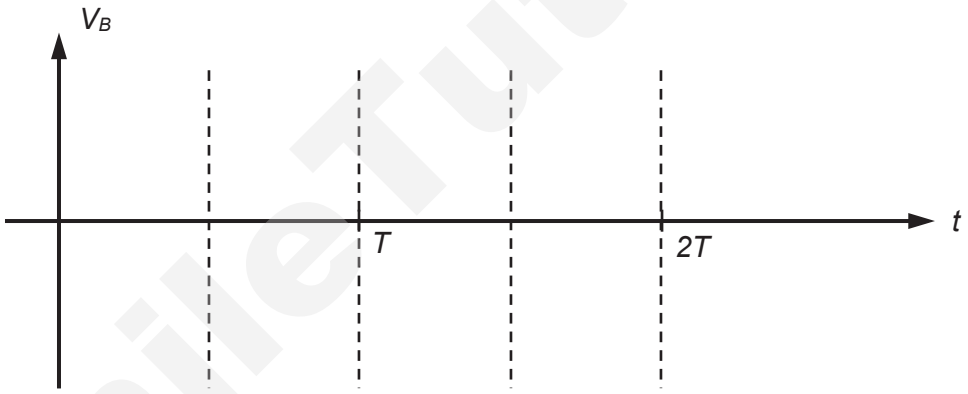
.....

..... [1]

**(c)** Hence show that the voltage rating of the chargeable battery is 8.5 V.

[1]

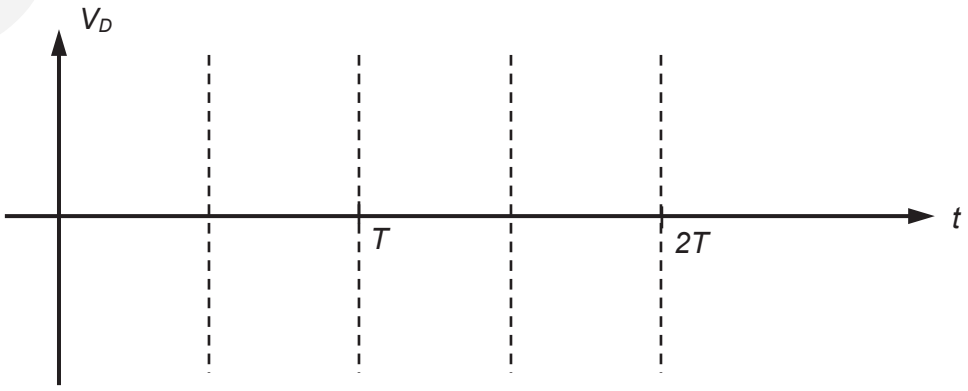
**(d)** Sketch on Fig. 8.2 the variation of potential difference $V_B$ across the chargeable battery with time $t$. It is given that $T$ is the period of the alternating current.




[1]

**Fig. 8.2**

**(d)** Hence sketch on Fig. 8.3 the variation of the potential difference across the diode $V_D$ with time $t$. Label appropriate values. It is given that $T$ is the period of the alternating current.




[2]

**Fig. 8.3**

[Total: 7]

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**9** On 11 March 2011, Japan suffered a Magnitude 9.0 Earthquake off the eastern coast of Japan. One of the consequences of the Earthquake was a tsunami that crippled the Fukushima Daiichi nuclear power plant, which subsequently released significant amounts of radioactive materials and by-products into the atmosphere and environment.

Tables 9.1 and 9.2 show the surface activities of several radionuclides measured on 31 March 2011 from soil samples at several locations in and around the Fukushima district, their half-lives and decay modes.

| | Surface Activity (Bq $m^{-2}$) | | | | | |
|---|---|---|---|---|---|---|
| Location | Tellurium-129m | Tellurium-132 / Iodine-132 | Iodine-131 | Caesium-134 | Caesium-137 | Barium-140 / Lanthanum-140 |
| A | 208 370 | 111 960 | 824 150 | 205 260 | 211 480 | 8 397 |
| B | 388 600 | 195 640 | 1 163 120 | 477 040 | 479 720 | 22 244 |
| C | 754 920 | 382 120 | 1 887 300 | 894 720 | 922 680 | 35 416 |
| D | 71 928 | 35 478 | 481 140 | 77 031 | 78 489 | 2 527 |

**Table 9.1 Surface Activities of Radionuclides**

| Radio-nuclide | Tellurium-129m | Tellurium-132 | Iodine-132 | Iodine-131 | Caesium-134 | Caesium-137 | Barium-140 | Lanthanum-140 |
|---|---|---|---|---|---|---|---|---|
| Half-life (Days) | 33.6 | 3.20 | 2.30 | 8.02 | 755 | 11 000 | 12.8 | 1.68 |
| Decay Constant ($s^{-1}$) | $2.39 \times 10^{-7}$ | $2.51 \times 10^{-6}$ | $3.49 \times 10^{-6}$ | | $1.06 \times 10^{-8}$ | $7.29 \times 10^{-10}$ | $6.27 \times 10^{-7}$ | $4.78 \times 10^{-6}$ |
| Decay Mode | $\gamma$ | $\beta^-$ | $\beta^-$ | $\beta^-$ | $\beta^-$ | $\beta^-$ | $\beta^-$ | $\beta^-$ |

**Table 9.2 Half-lives and Decay Modes of Radionuclides**

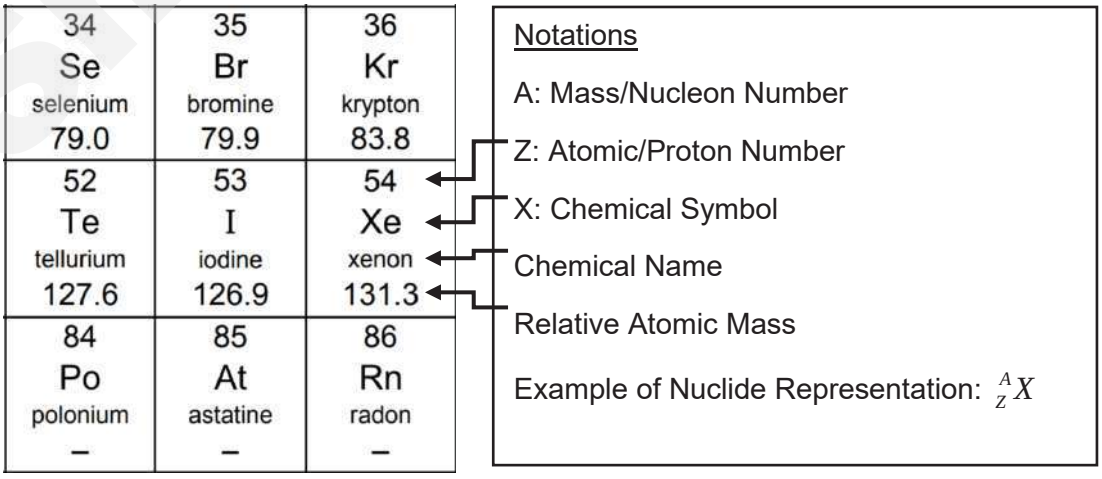


**Fig. 9.1 Elements Around Iodine on the Periodic Table**

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**(a)** Using the data from **Table 9.1**, **Table 9.2** and **Fig. 9.1**,

**(i)** calculate $A_\beta$, the total activity per $m^2$ due to beta decay, of the most contaminated location.

$A_\beta$ = ..... Bq $m^{-2}$ [1]

**(ii)** for the location C,

**1.** calculate the decay constant of Iodine-131,

decay constant = ..... $s^{-1}$ [1]

**2.** calculate $N_i$, the number of Iodine-131 nuclei present per $m^2$,

$N_i$ = ..... [2]

**3.** calculate $M_i$, the mass of Iodine-131 nuclei present per $m^2$,

$M_i$ = ..... kg [1]

**4.** calculate $A_{T,i}$, the total activity present due to Iodine-131 in 7.5 $km^2$ of the location.

$A_i$ = ..... Bq [1]


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**(v)** write down the decay equation for:

**1.** Tellurium-129m

.....[1]

**2.** Tellurium-132

.....[1]

**(b)** Explain why after 16.1 days, another sample taken at the same location had significantly more than a quarter of the original activity due to Iodine-131.

.....

.....

.....

.....

.....[2]

**(c)** Among the radioactive fallout, Iodine-131 and Caesium-137 are major concerns as both elements can be absorbed by the human body through inhalation as well as through the consumption of contaminated food and water.

**(i)** Even though the activity of Iodine-131 is significantly greater than that of Caesium-137 in all locations tested, Caesium-137 will present a greater hazard in the long term. Explain why this is so.

.....

.....

.....

.....

.....[2]

**(ii)** Iodine is absorbed by the body and accumulates in the thyroid. Explain why Iodine-131 is dangerous when ingested.

.....

.....

.....

.....

.....[2]

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**(iii)** Suggest why the consumption of potassium iodide pills before Iodine-131 exposure may help reduce the chances of irreparable damage to the thyroid or contracting thyroid cancer.

.....

.....

.....

.....

.....[2]

**(d)** Radioactive materials are often considered dangerous due to its high energy output with a relatively small mass and its hazardous nature to living things.

**(i)** By considering the decay constants of the radioactive materials listed that undergoes beta decay, suggest and explain which material could be the most dangerous.

.....

.....

.....

.....[2]

**(ii)** Suggest and explain another physical factor that contributes to the dangers of radioactive material.

.....

.....

.....[2]

[Total: 20]

**End of Paper**

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| CLASS | | TUTOR'S NAME | |
| CENTRE NUMBER | S | INDEX NUMBER | |

# PHYSICS 9749/03

Paper 3 Longer Structured Questions **20 September 2019**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your name, class, Centre number 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 a HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

**Section A**
Answer **all** questions.

**Section B**
Answer **one** question only.

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

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

| For Examiner's Use | |
|---|---|
| 1 | / 7 |
| 2 | / 8 |
| 3 | / 7 |
| 4 | / 7 |
| 5 | / 11 |
| 6 | / 8 |
| 7 | / 12 |
| 8 | / 20 |
| 9 | / 20 |
| Total | / 80 |

This document consists of **21** printed pages.

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**Data**

| | |
|---|---|
| speed of light in free space | $c = 3.00 \times 10^8$ m s$^{-1}$ |
| permeability of free space | $\mu_0 = 4\pi \times 10^{-7}$ 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 | $\phi = -Gm / r$ |
| temperature | $T / \mathrm{K} = T / ^\circ\mathrm{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t$ |
| | $= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

**1** The first atomic bomb explosion was during the Trinity Test in 1945. Based on a series of photographs of the explosion, along with a size scale and time stamps, British physicist Sir Geoffrey Ingram Taylor was able to estimate the power released by the explosion.

The radius $R$ of the fireball at time $t$ after the explosion was found to be related to the energy $E$ that was released and the density $\rho$ of the surrounding medium as follows:

$$R = E^{0.2} \rho^{-0.2} t^{\square}$$

where Z is a constant.

**(a)** Show that the value of Z is 0.4.

Z = ..... [2]

**(b)** Given that the radius $R$ is (80 ± 2) m at time $t$ being (0.006 ± 0.001) s with density of air being (1.2 ± 0.1) kg $m^{-3}$, determine the energy $E$ released by the bomb with its associated uncertainty.

$E \pm \Delta E$ = ..... J [3]

**(c)** Of all the data collected, state and explain which measurement you would improve to increase the precision of your answer in **(b)**.

.....

.....

..... [2]

[Total: 7]

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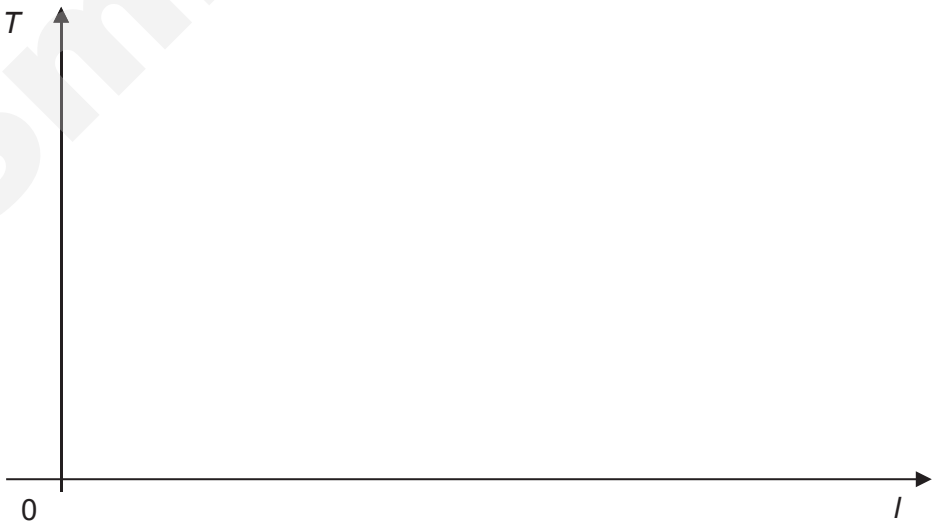
**2** Fig. 2.1 shows a person of mass 70 kg doing a bungee jump.



**Fig. 2.1**

The bungee rope has negligible mass and has an unstretched length of 50 m. This bungee rope may be assumed to obey Hooke's law. A force of 200 N extends the bungee rope by 2.5 m. The bungee rope is secured to the feet of the person. The person leans over a bridge above the river and drops vertically downwards towards the river below. You may assume that air resistance is negligible.

**(a)** Sketch a graph of the tension $T$ in the bungee rope against its total length $l$.




[2]

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**(b)** Show that the elastic potential energy in the bungee rope is directly proportional to the square of its extension *e*.

[2]

**(c)** Determine the elastic potential energy in the bungee rope when the person has reached the lowest point of his jump.

elastic potential energy = ..... J [3]

**(d)** Explain why it would be extremely dangerous to have a bungee rope that is much stiffer.

.....

.....

..... [1]

[Total: 8]

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**3** Modern gravity meters can measure *g*, the acceleration of free fall, to a high degree of accuracy. The principle on which they work is of measuring *t* the time of fall of an object through a known distance *h* in a vacuum.

**(a)** Assuming that the object starts from rest, deduce and expression for *g* in terms of *t* and *h*.

[1]

**(b)** State Newton's law of gravitation relating the force *F* between two point objects of masses *m* and *M*, their separation *r* and the gravitational constant *G*.

..... [1]

**(c)** Fig. 3.1 shows a standard kilogram mass at the surface of the Earth and a spherical region S of radius 2000 m with its centre 4000 m from the surface of the Earth.

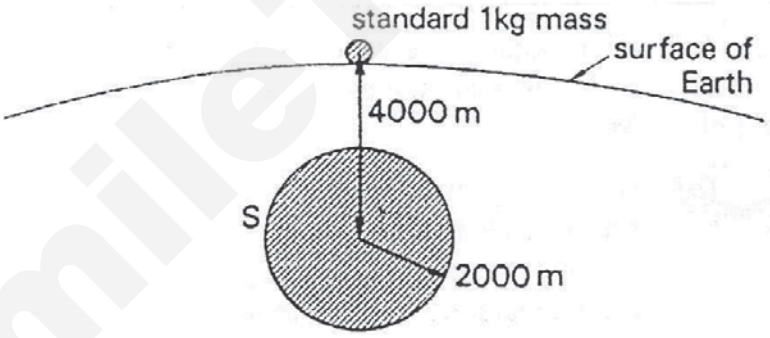


**Fig. 3.1 (Not to scale)**

Region S is made up of rocks with density 2800 kg $m^{-3}$. Calculate the force the matter in region S exerts on the standard mass.

force = ..... N [2]

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**(d)** Calculate the difference in the force on the standard mass, if region S consists of oil with density 900 kg $m^{-3}$ instead of rock.

difference in force = ..... N [2]

**(e)** In oil prospecting, the gravity meter is used to predict where deposits of oil are under the surface of Earth. Use your answers in **(d)** to suggest one necessary condition in using the gravity meter.

.....

.....

..... [1]

[Total: 7]

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**4** A student sets up the apparatus illustrated in Fig. 4.1 in order to investigate the oscillations of a 100 g metal cube suspended on a string.

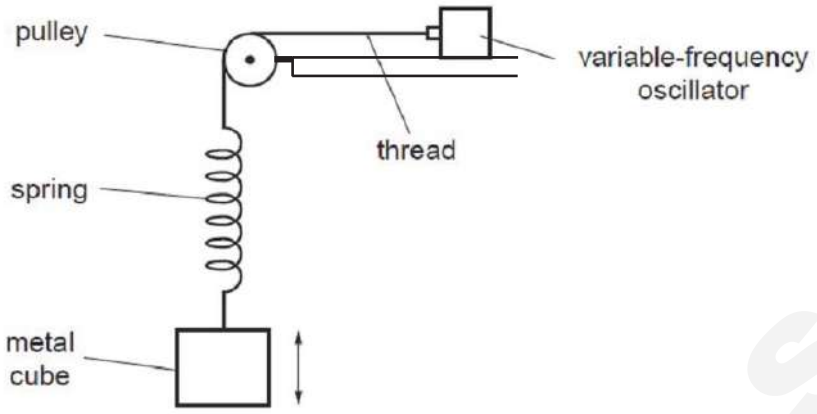


**Fig. 4.1**

Before switching on the variable-frequency oscillator, the metal cube was displaced by pulling it downwards and made to oscillate freely. A graph of its velocity against displacement is shown in Fig. 4.2.

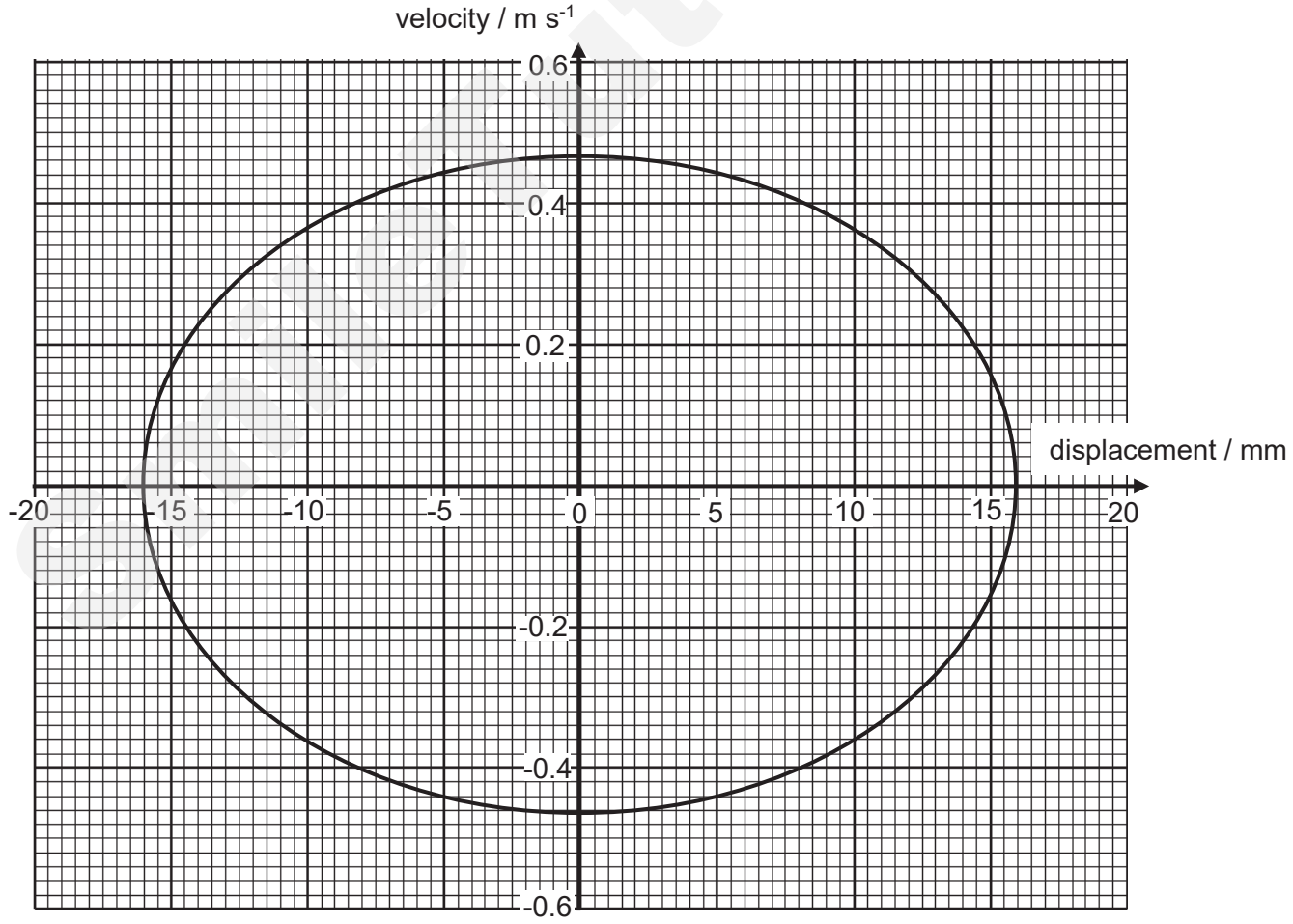


**Fig. 4.2**

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**(a)** Using Fig. 4.2, show that the natural frequency of the metal cube is 4.6 Hz.

[2]

**(b)** Hence, or otherwise, determine the maximum resultant force acting on the metal cube.

maximum resultant force = ..... N [2]

**(c)** The variable-frequency oscillator is now switched on so that the metal cube can undergo forced oscillation.

**(i)** State what is meant by *forced oscillation*.

.....

..... [1]

**(ii)** On Fig. 4.3, sketch the variation with frequency of the amplitude of the oscillations of the metal cube between 2 Hz to 8 Hz.

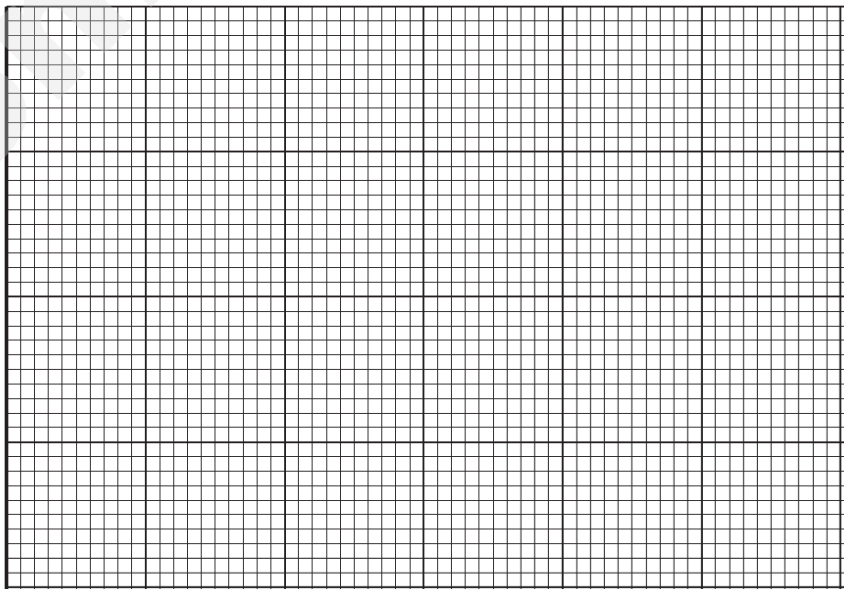

**Fig. 4.3**

[2]

[Total: 7]

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

.....

..... [2]

**(b)** An ideal gas, comprising single atoms, is contained in a cylinder and has a volume of $1.84 \times 10^{-2}$ $m^3$ at a pressure of $2.12 \times 10^7$ Pa. The mass of the gas in the cylinder is 3.20 kg.

**(i)** Determine the root-mean-square (r.m.s.) speed of the atoms of the gas.

root-mean-square speed = ..... $m\ s^{-1}$ [3]

**(ii)** The temperature of the gas in the cylinder is 22 °C.

Determine

**1.** the amount of gas,

amount = ..... mol [2]

**2.** the mass of one atom of the gas.

mass = ..... kg [2]

**(iii)** Use your answer in **(ii)2.** to determine the nucleon number A of an atom of the gas.

A = ..... [2]

[Total: 11]

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**6** Fig. 6.1 shows a long solenoid which has a small copper disc mounted at its centre.

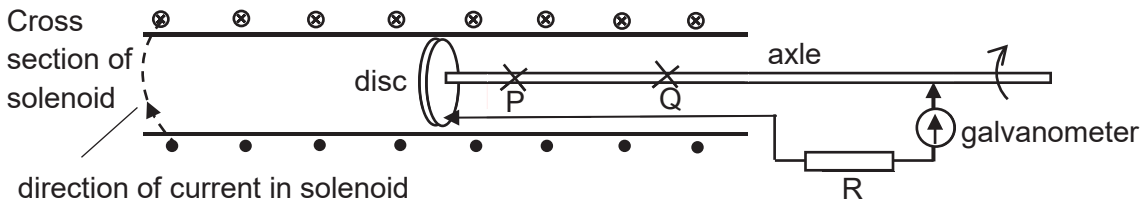


**Fig. 6.1**

The disc spins on a conducting axle which lies along the axis of the solenoid. The solenoid is connected in series with a d.c. supply and the direction of the current in the solenoid is as shown in Fig. 6.1. One end of the resistor is connected to the rim of the disc through brushes. The other end is connected to a galvanometer.

**(a)** **(i)** Indicate the direction of the induced current between point P and Q with an arrow on Fig. 6.1. [1]

**(ii)** Explain why an e.m.f. is generated between the axle and the rim of the disc when the disc rotates.

.....

.....

.....

.....

.....

.....

.....[3]

**(b)** State the effect on the galvanometer, if any, when

**(i)** the speed of the rotation of the disc is increased,

.....[1]

**(ii)** the direction of the rotation of the disc is changed.

.....[1]

**(c)** A voltmeter is now connected across the rim of the disc. Explain why there is no reading.

.....

.....

.....[2]

[Total: 8]

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**7** A beam of light consists of a continuous range of wavelengths from 430 to 600 nm. It passes through a cloud of cool hydrogen gas as shown in Fig. 7.1.

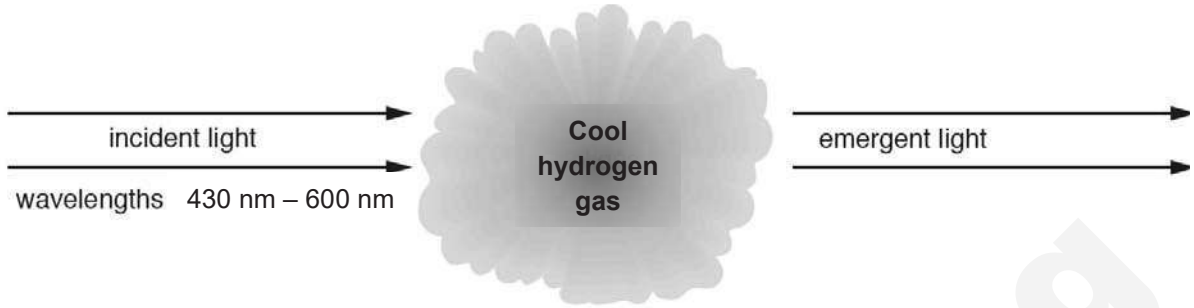


**Fig. 7.1**

**(a)** The spectrum of light emerging from the cloud of cool hydrogen gas is viewed with a spectrometer. Explain why this spectrum contains 2 dark lines.

.....

.....

.....

.....

.....

.....

..... [4]

**(b)** The measured wavelengths, $\lambda_m$ , of the selected lines in the hydrogen spectrum are given empirically by

$$\frac{1}{\lambda_m} = R\left(\frac{1}{4} - \frac{1}{m^2}\right)$$

where $R$ is a constant of value 1.097 x $10^7$ m $s^{-1}$ and $m$ is an integer taking the values 3, 4, 5… etc.

**(i)** Calculate the value of the wavelength when $m$ = 4.

wavelength = ..... m [2]

**(ii)** Determine the minimum wavelength given by the equation.

minimum wavelength = ..... m [2]

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**(iii)** Some of the electron energy levels of the hydrogen atom in the gas are represented in Fig. 7.2.

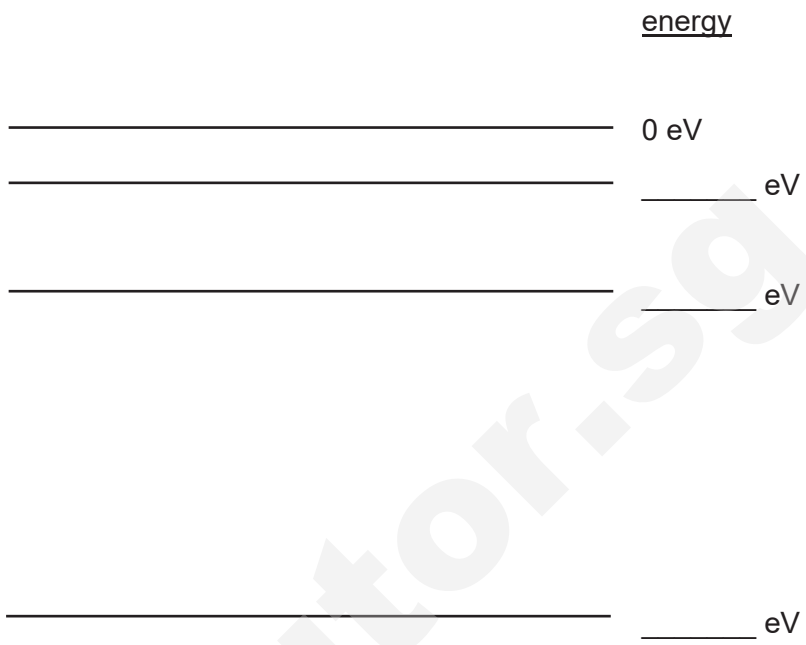


**Fig. 7.2**

**1.** Use your answers from **(b)(i)** and **(b)(ii)** to determine the energy of the 3 other electron energy levels in Fig. 7.2. Write your answer in the blanks in Fig. 7.2.

[2]

**2.** On Fig. 7.2, draw, and label with D, the transitions giving rise to the 2 darks lines from **(a)**. [2]

[Total: 12]

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## Section B

Answer **one** question from this Section in the spaces provided.

**8** **(a)** Explain what is meant by *diffraction* of wave.

.....

..... [1]

**(b)** A laser light of wavelength 633 nm is incident on a single slit of width *b*. A diffraction pattern is formed on a vertical screen 4.2 m away from the single slit.

A photograph of the single slit diffraction pattern is shown in Fig. 8.1.



**Fig. 8.1 (drawn to scale)**

**(i)** Determine *b*.

*b* = ..... m [3]

**(ii)** With reference to the concept of interference, suggest why the value of *b* cannot be less than the wavelength of the laser light.

.....

.....

..... [2]

**(c)** A second identical single slit is then placed beside the first slit at a horizontal distance of 0.320 mm away from the centre of the first slit. An interference pattern is then observed.

**(i)** Explain why an interference pattern is observed on the screen.

.....

.....

.....

..... [2]

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**(ii)** Calculate the fringe separation of the interference pattern.

fringe separation = ..... m [2]

**(iii)** **1.** State the changes to the fringe pattern when the width of both slits is reduced slightly, resulting in the intensity of the light coming out from both slits to be reduced.

.....

.....

.....

..... [3]

**2.** Suggest why the intensity of the light coming out from each slit will be reduced when the width of each slit is reduced.

.....

..... [1]

**(d)** A thin wedge of air is made by separating two thin glass plates by a spacer as shown in Fig. 8.2.

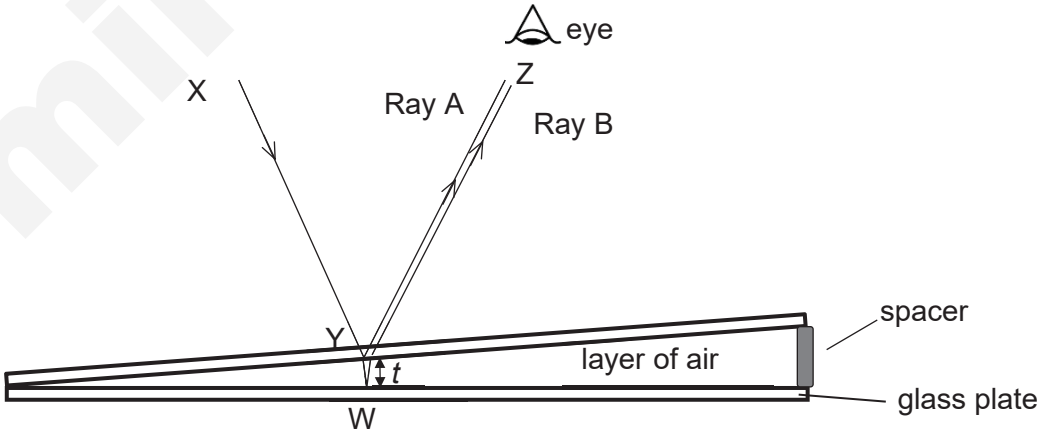


**Fig. 8.2**

There are two rays of light, Ray A and B, which are directly at the glass plates.

Ray A take the path X→Y→Z.

Ray B take the path X→Y→W→Z.

**(i)** State the path difference between Rays A and B in terms of *t* which is the thickness of the layer of air between the two glass plates.

path difference = ..... [1]

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**(ii)** When the observer moves his eyes across the layer of air, he observes dark and bright fringes that are uniformly spaced. The initial and final position of his eye is shown in Fig. 8.3. At the final position, he is looking at the fifth order dark fringe.

Given that the wavelength of the light directed at the glass plates is 550 nm, determine the thickness of air *t'* at this position.

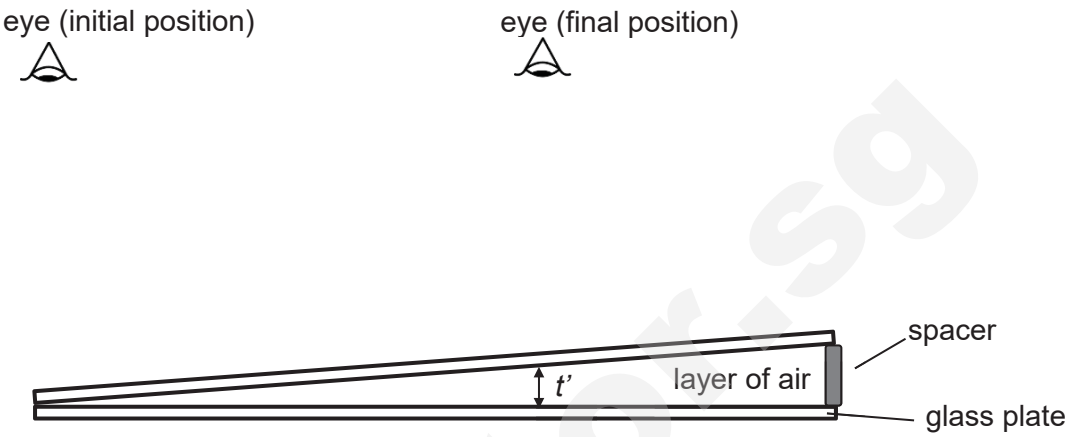


**Fig. 8.3**

thickness *t'* = ..... [2]

**(iii)** White light of wavelength ranging from 400 nm to 700 nm is now incident on the thin wedge of air. At a certain thickness, a violet colour is observed where violet colour is due to overlapping of red and blue colours.

Explain this observation.

.....

.....

..... [2]

**(iv)** In reality, Ray B will undergo a phase change of 180° when it is reflected but there is no phase change for Ray A.

Suggest why the thickness of air cannot be smaller than one quarter of the wavelength in order to observe a bright fringe.

.....

.....

..... [1]

[Total: 20]

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**9** **(a)** **(i)** Explain what is meant by the binding energy of a nucleus.

.....

..... [1]

The variation of the binding energy per nucleon with nucleon number of all the different nuclei is shown in Fig. 9.1.

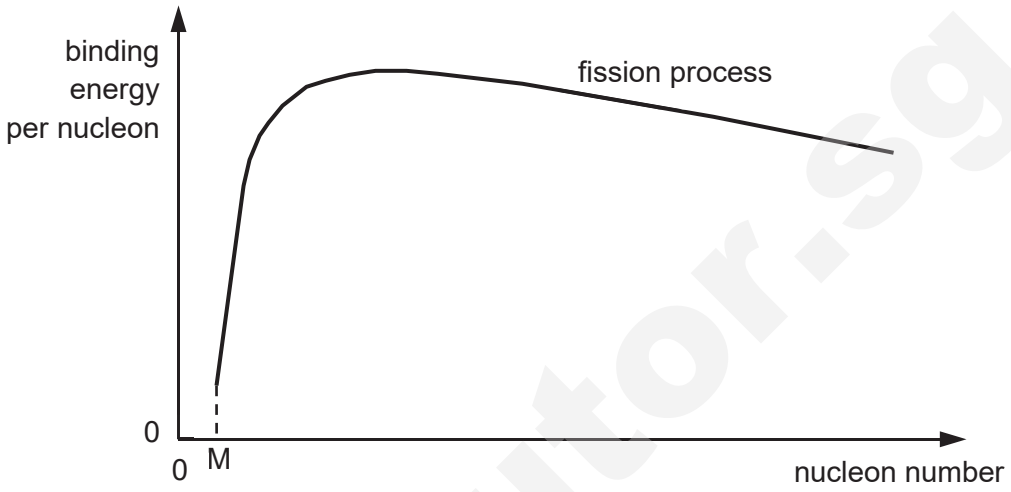


**Fig. 9.1**

**(ii)** State the value of M and explain your answer clearly.

.....

.....

..... [2]

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**(b)** In a fission process, a neutron with speed of $2.00 \times 10^3$ m s$^{-1}$ collides with a Uranium-235 nucleus and causes a nuclear reaction summarised in the following equation:

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{143}_{53}Xe + {}^{90}_{38}Sr + 3\,{}^{1}_{0}n + \text{energy}$$

**(i)** Using the data from Fig. 9.2, show that the binding energy per nucleon for Strontium-90 is 8.73 MeV.

| | rest mass |
|---|---|
| Strontium, $^{90}_{38}Sr$ | 89.9077 u |
| Proton, $^{1}_{1}p$ | 1.0078 u |
| Neutron, $^{1}_{0}n$ | 1.0087 u |

**Fig. 9.2**

[3]

**(ii)** Data for binding energies per nucleon are shown in Fig. 9.3. Hence calculate the total energy released during the nuclear fission reaction.

| Isotope | binding energy per nucleon / MeV |
|---|---|
| Uranium-235 | 7.59 |
| Xenon-143 | 8.41 |

**Fig. 9.3**

energy released = ..... J [2]

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**(iii)** Explain quantitatively why the kinetic energy of the neutron directed at Uranium-235 is neglected.

.....

..... [1]

**(c)** Fig. 9.4 shows the possible directions of Strontium-90, Xenon-143, and neutrons when nuclear fission takes place. Assume that this is an isolated system.

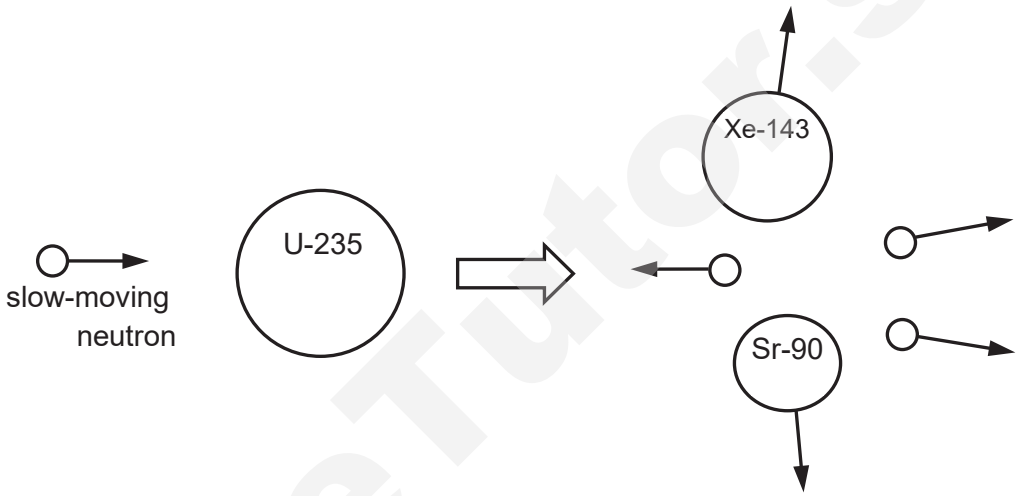


**Fig. 9.4**

**(i)** Explain why it is unlikely for the two fission products to move in the same direction after the fission process.

.....

.....

..... [1]

**(ii)** The total momentum of two fission products and neutrons after reaction is not zero even though the total momentum of Uranium-235 and slow moving neutron may be taken to be zero. Explain why this may be so.

.....

.....

..... [2]

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**(d)** Neutrons emitted from a nuclear fission may hit another Uranium-235 nucleus, causing a chain reaction.

**(i)** To control the reaction, neutrons emitted from a fission reaction may be slowed down by Carbon-12 nuclei, $^{12}_{6}C$. Show that when a neutron undergoes an elastic head-on collision with a Carbon-12 nucleus as shown in Fig. 9.5, the speed is reduced by about 15%.

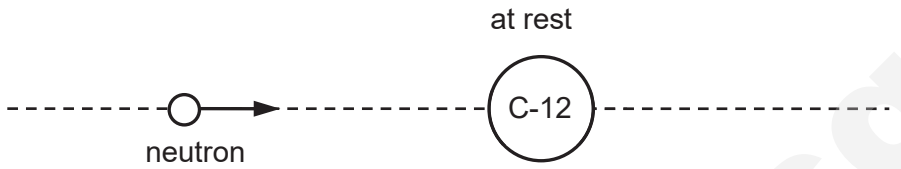


**Fig. 9.5**

[3]

**(ii)** On average, the neutron speed after each collision is 0.93 of its speed before the collision.

Suggest why this speed reduction is different from what is stated in **(ii)** for a nuclear reactor.

.....

.....

..... [1]

**(iii)** Suggest why a slow neutron has a higher chance of being captured by Uranium-235 to cause a fission reaction compared to a fast neutron.

.....

..... [1]

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**(e)** The fission products are usually radioactive and give rise to a series of radioactive decay products. Each decay product has its own half life, but eventually a stable nuclide is reached.

One such fission product and its decay products is shown here:

$$^{143}_{54}Xe \longrightarrow {}^{143}_{55}Cs \longrightarrow {}^{143}_{56}Ba$$

The half-lives of Xenon-143 and Caesium-143 are 0.511 s and 1.79 s respectively.

**(i)** Suggest how the number of Caesium-143 nuclei inside the nuclear reactor may remain constant even when it decays to form Barium-143.

.....

.....

..... [2]

**(ii)** Explain why a particular Xenon-143 nucleus produced earlier in the reaction may not necessarily decay before another Xenon-143 nucleus which was produced after it.

.....

.....

..... [1]

[Total: 20]

**End of Paper**

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| CLASS | | TUTOR'S NAME | |
| CENTRE NUMBER | S | INDEX NUMBER | |

# PHYSICS

**9749/04**

Paper 4 Practical Paper

**21 August 2019**

**2 hours 30 minutes**

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions.

**READ THESE INSTRUCTIONS FIRST**

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

Answer **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| Total | / 55 |



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**[Turn over**

**1** In this experiment, you will investigate how the deflection of a wooden strip depends on the distribution of the load on the strip.

**(a)** **(i)** Lay the wooden strip flat on the bench.
Place the ten slotted masses along the strip, as shown in Fig. 1.1.

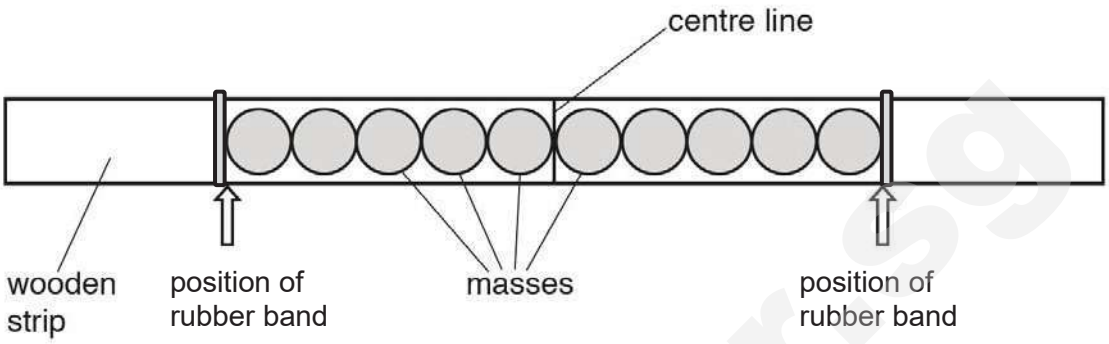


**Fig. 1.1**

**(ii)** Use a rubber band to mark the position of each end of the row of masses, as shown in Fig. 1.1.

**(iii)** Remove the masses.

**(iv)** Measure and record the distance *D* between the marks, as shown in Fig. 1.2.

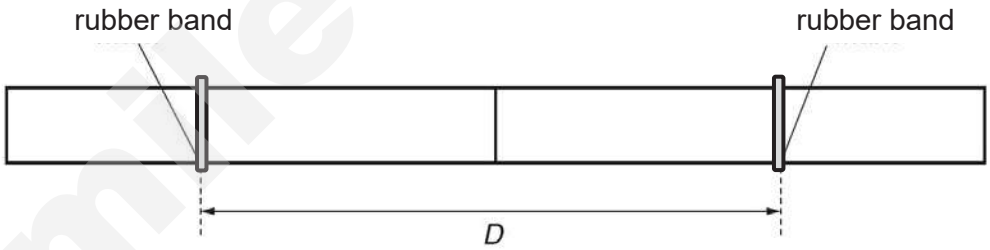


**Fig. 1.2**

*D* = ..... [1]

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**(b)** **(i)** Place the strip on the two wooden blocks with the inner edges of the blocks at the rubber bands, as shown in Fig.1.3.

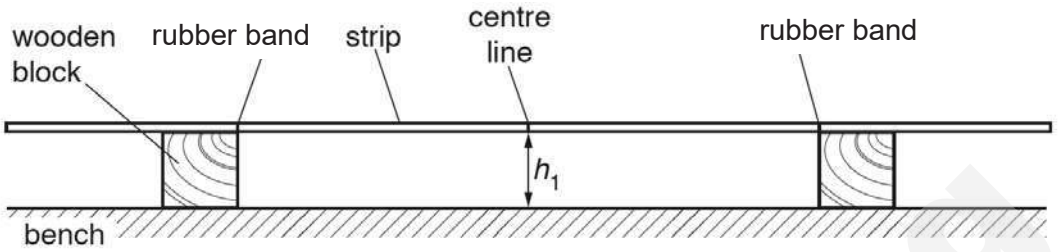


**Fig. 1.3**

**(ii)** Measure and record the height $h_1$ of the **bottom** of the strip at the centre line, as shown in Fig. 1.3.

$h_1$ = .....

**(c)** **(i)** Replace the masses on the strip and ensure the blocks are still positioned at the rubber bands. Measure and record the height $h_2$ of the bottom of the strip at the centre line, as shown in Fig. 1.4.

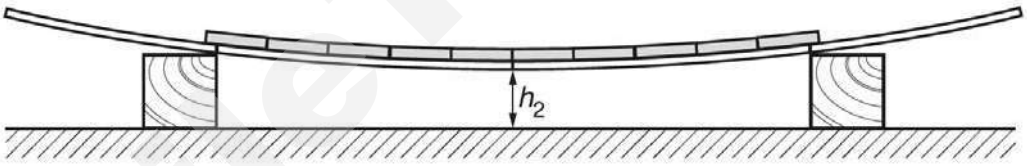


**Fig. 1.4**

$h_2$ = ..... [1]

**(ii)** Calculate $d$, where $d = h_1 - h_2$.

$d$ = ..... [1]

**(d)** Estimate the percentage uncertainty in your value of $d$.

percentage uncertainty = ..... [1]

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**(e)** **(i)** Remove the masses from the strip.

**(ii)** Ensure the blocks are still positioned at the rubber bands. Measure and record the height $h_3$ of the bottom of the strip at the centre line.

$h_3$ = .....

**(iii)** Place all the masses at the centre line, as shown in Fig. 1.5.

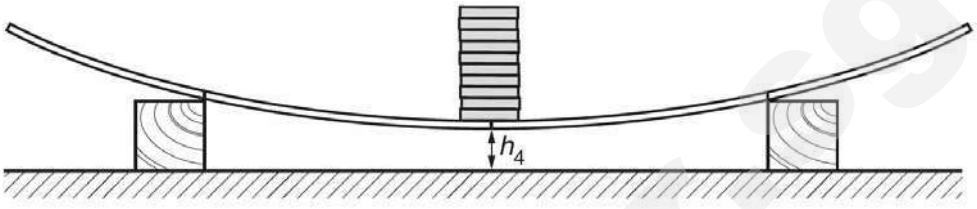


**Fig. 1.5**

**(iv)** Ensure the blocks are still positioned at the rubber bands, then measure and record the height $h_4$ of the bottom of the strip at the centre line.

$h_4$ = .....

**(v)** Calculate $p$, where $p = h_3 - h_4$.

$p$ = ..... [1]

**(f)** Estimate the percentage uncertainty in your value of $p$.

percentage uncertainty = ..... [1]

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**(g)** **(i)** Remove the masses.

**(ii)** Measure the thickness *t* and the width *w* of the strip, as shown in Fig. 1.6.

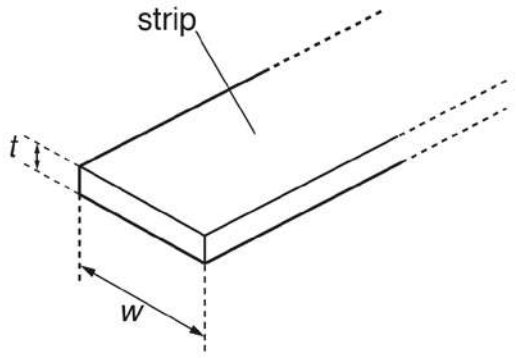


**Fig. 1.6**

*t* = .....

*w* = .....
[1]

**(iii)** Calculate the Young modulus *E* for the material of the strip using

$$E = \frac{FD^3}{4pwt^3}$$

where *F* = 10.0 N.

*E* = ..... [1]

**(h)** Repeat **(a)**, **(b)**, **(c)** and **(e)** using **eight** masses.

*D* = .....

$h_1$ = .....

$h_2$ = .....

*d* = .....

$h_3$ = .....

$h_4$ = .....

*p* = .....
[2]

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**(i)** It is suggested that the relationship between $d$ and $p$ is

$$d = k\,p$$

where $k$ is a constant.

**(i)** Using your data, calculate two values of $k$.

first value of $k$ = .....

second value of $k$ = .....
[2]

**(ii)** Justify the number of significant figures you have given for your values of $k$.

.....

.....

..... [1]

**(iii)** State whether the results of your experiment support the suggested relationship.

Justify your conclusion by referring to your values in **(d)** and **(f).**

.....

.....

.....

..... [2]

[Total: 15]

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**2** In this experiment, you will investigate stationary wave patterns.

**(a)** You are provided with a piece of string. The piece of string has a 10 g mass attached to one end.

Using the string, assemble the apparatus as shown in Fig. 2.1.

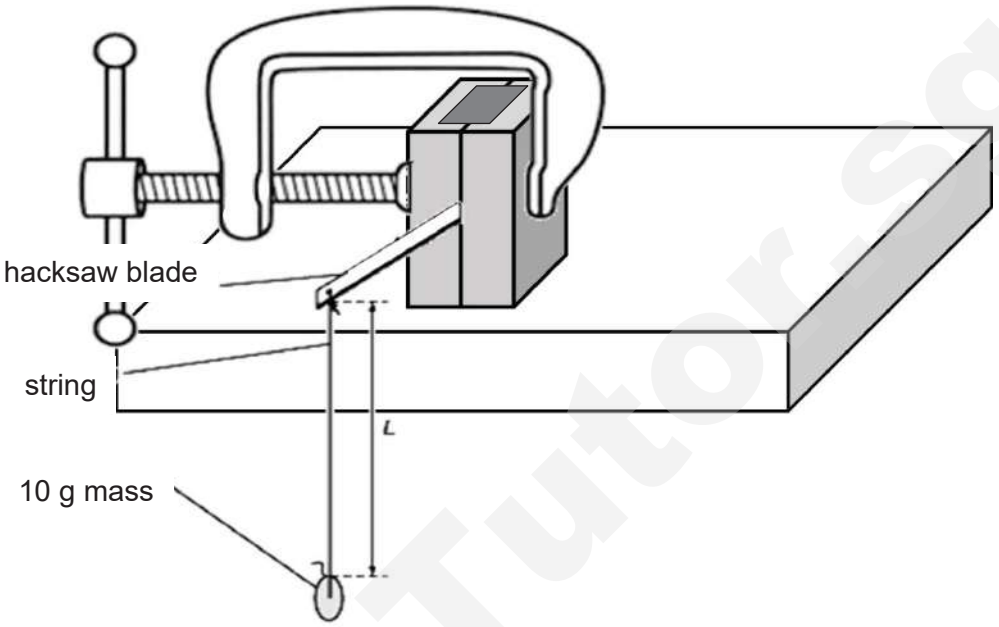


**Fig. 2.1**

The length of string between the hacksaw blade and the 10 g mass is *L*, as shown in Fig. 2.1. Measure and record *L*.

*L* = ..... [1]

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**(b)** The length of hacksaw blade outside the blocks is *x*, as shown in Fig. 2.2.

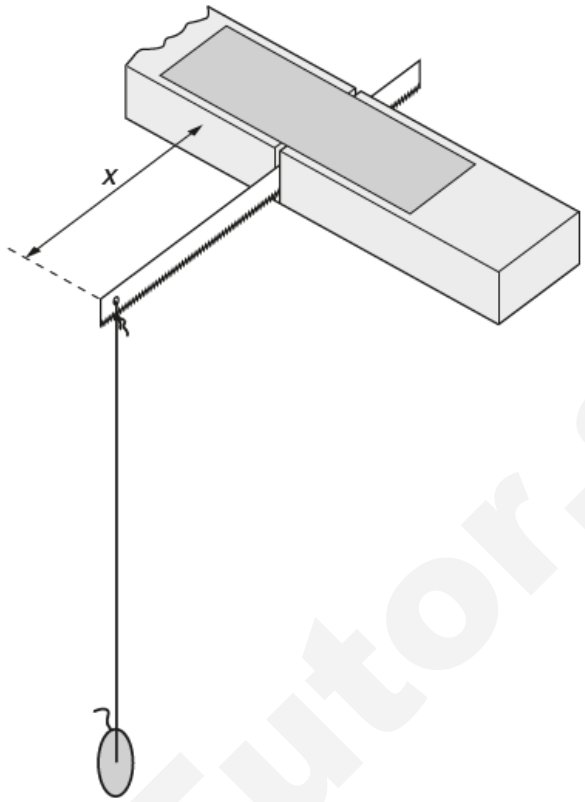
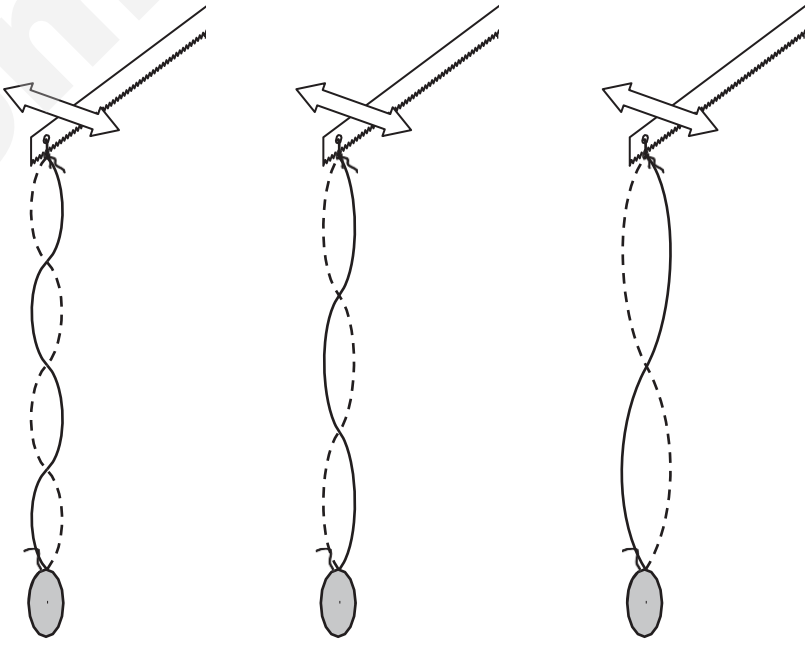



**Fig. 2.2**

When the end of the hacksaw blade is moved a small distance to one side and released, the string vibrates.

For certain values of *x*, the string vibrates in stationary wave patterns. Examples of these patterns are shown in Fig. 2.3.



A B C

**Fig. 2.3**

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**(ii)** Press down on the clamp so that the blocks rest on the tabletop as shown in Fig. 2.1. Move the end of the hacksaw blade a small distance to one side and release it.

**(iii)** Change $x$ in small steps. Keep changing $x$, testing for a pattern at each step, **until the pattern B with three loops is clearly produced**.

Measure and record $x$.

$x$ = ..... [2]

**(iii)** Estimate the percentage uncertainty in your value of $x$.

percentage uncertainty = ..... [1]

**(c)** Calculate the value of $\lambda$ in metres, using

$$\lambda = \frac{2}{n}L$$

where n is the number of loops observed.

$\lambda$ = ..... m [1]

**(d)** Justify the number of significant figures you have given for your value of $\lambda$.

.....

.....

..... [1]

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**(e)** You are provided with a card stating the mass per unit length $\mu$ of the string.

**(j)** Record the value of $\mu$ from the card.

$\mu$ = ..... kg $m^{-1}$

**(ii)** Calculate the frequency $f$ of the vibrations, using

$$f = \frac{1}{\lambda}\sqrt{\frac{mg}{\mu}}$$

where $m$ = 0.010 kg and $g$ = 9.81 m $s^{-2}$.

$f$ = ..... Hz [1]

[Total: 7]

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**3** Many electrical components have to function properly in conditions of extreme temperature and moisture content. In this experiment you will maintain a diode at five degrees Celsius and investigate how the current in it varies as the potential difference across it is changed.

**(a)** Set up the circuit shown in Fig. 3.1. The 10 Ω resistor is to prevent current overload in the diode.

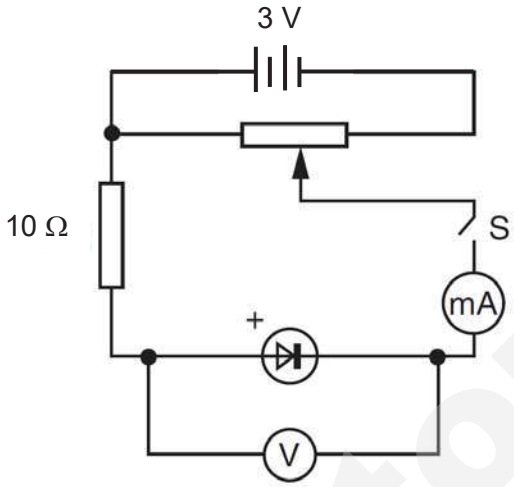


**Fig. 3.1**

**(b)** Close switch S.

Put 50 ml of water into the beaker. Place the diode in the water.

Close switch S. Measure and record the current *I* when the potential difference *V* across the diode is 0.50 V.

*I* = .....

**(c)** Add a quantity of ice to the water in the beaker.

Stir the ice/water mixture gently using the thermometer until the temperature is at, or close to, 5 °C.

**(i)** Record the temperature. You are to maintain the temperature for the rest of the experiment to be within 2 °C of your recorded temperature.

temperature of ice/water mixture = ..... [1]

**(ii)** Measure and record the current *I* when the potential difference *V* across the diode is 1.0 V.

*I* = ..... [1]

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**(d)** Vary the resistance of the rheostat and repeat **(c)(ii)** until you have five more sets of readings for $V$ and $I$. You should keep the range of $V$ between 1.0 V and 2.0 V.

[6]

**(e)** A simplified expression relating the current $I$ in the diode to the potential difference $V$ is

$$I = I_o e^{\frac{aV}{kT}}$$

where $k$ is the Boltzmann constant of $1.38 \times 10^{-23}$ J $K^{-1}$, $a$ is a constant, $T$ is the temperature of diode in kelvin, and $I_o$ is a constant.

Plot a suitable graph to determine the values of $a$ and $I_o$.

$a$ = .....

$I_o$ = .....

[3]

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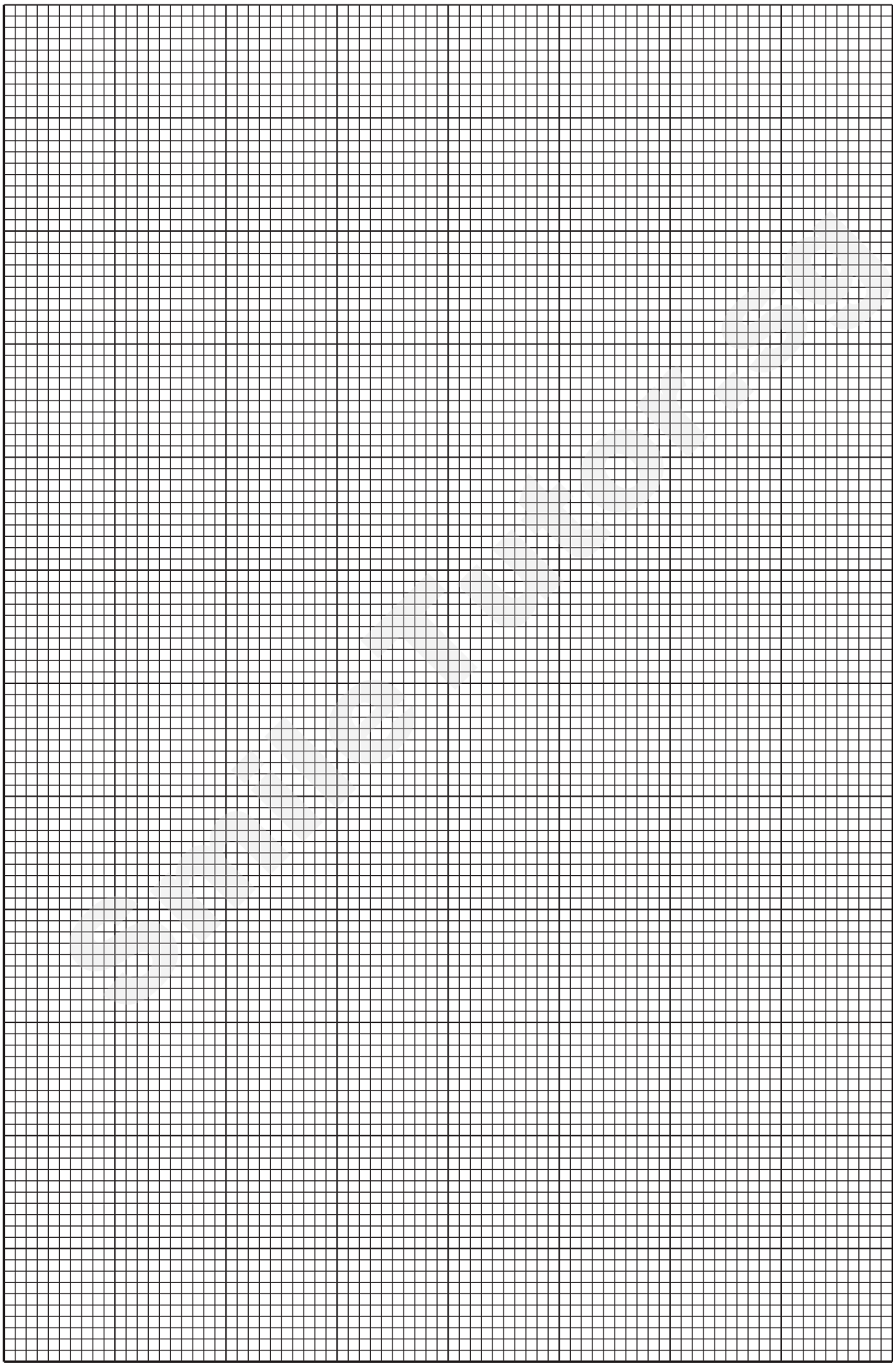

[3]

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**(f)** Using the expression in **(e)**, calculate the current in the diode if it were placed in boiling water with a potential difference of 1.0 V applied across it.

*I* = ..... [1]

**(g)** **(i)** Suggest one significant source of error in this experiment.

.....

.....

..... [1]

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

.....

.....

..... [1]

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**(h)** A manufacturer wishes to put this diode in their product where the operating temperature is between room temperature and 300 °C.

The simplified expression in **(e)** is only valid for temperatures less than a critical value.

Plan an investigation to determine the critical temperature of the diode.

Your account should include:

- your experimental procedure
- control of variables
- how you would determine the critical temperature.

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.....[4]

[Total: 21]

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**4** A student is investigating how the intensity of the reflection of sound from a wall depends on the thickness of foam attached to the wall and the frequency of the sound, as shown in Fig. 4.1.

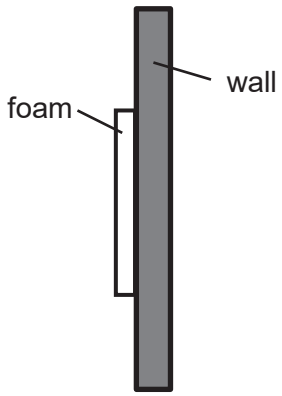


**Fig. 4.1**

It is suggested that the intensity $I$ of the reflected sound is related to the thickness $t$ of the foam and frequency $f$ by the relationship

$$I = At^x f^y$$

where $A$, $x$ and $y$ are constants.

You are provided with a number of pieces of foam of different thickness. You may also use any other equipment usually found in the physics laboratory.

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

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

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

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**Diagram**

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[12]

[Total: 12]

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H2 P1 Answer Key

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

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H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME **SOLUTION**

CLASS

TUTOR'S NAME

# PHYSICS 9749/02

Paper 2 Structured Questions **4 September 2019**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, 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 | / 6 |
| 3 | / 7 |
| 4 | / 7 |
| 5 | / 9 |
| 6 | / 9 |
| 7 | / 7 |
| 8 | / 7 |
| 9 | / 20 |
| Total | / 80 |

This document consists of **19** printed pages.



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**Data**

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

**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$ |
| | $v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -Gm / r$ |
| temperature | $T / \mathrm{K} = T / ^\circ\mathrm{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t$ |
| | $= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** A 3.8 kg block on a plane inclined at 15° has initial speed of 5.0 m $s^{-1}$ when a horizontal force $F$ of magnitude 25 N acts on it as shown in Fig. 1.1.

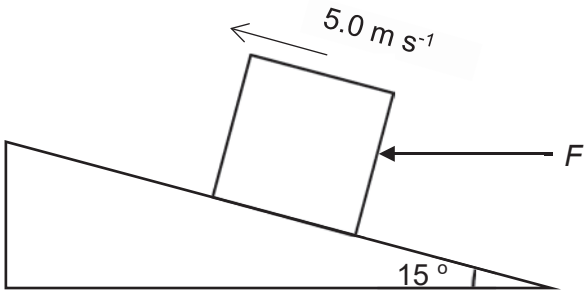


**Fig. 1.1**

**(a)** Determine the normal contact force exerted by the plane on the block.

Considering forces acting in the direction perpendicular to plane,

$$F_{net} = 0$$

$$N = F\sin\theta + mg\cos\theta$$

$$= 25\sin 15° + 3.8(9.81)\cos 15°$$

$$= 42 \text{ N}$$

normal contact force = ..... N [2]

**(b)** The coefficient of kinetic friction, $\mu$, is 0.40 and the kinetic friction, $f$, is related to the normal contact force, $N$, by the equation

$$f = \mu N .$$

**(i)** Calculate the magnitude of the acceleration of the block.

By Newton's second law of motion, taking downslope as positive,

$$F_{net} = ma$$

$$mg\sin\theta + f - F\cos\theta = ma$$

$$mg\sin\theta + \mu N - F\cos\theta = ma$$

$$a = g\sin\theta + \frac{\mu N - F\cos\theta}{m}$$

$$= 9.81\sin 15° + \frac{0.40(42) - 25\cos 15°}{3.8}$$

$$= 0.66 \text{ m s}^{-2}$$

acceleration = ..... m $s^{-2}$ [2]

**(ii)** Determine the distance travelled by the block before it comes to rest.


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$$v^2 = u^2 + 2as$$
$$s = -\frac{u^2}{2a}$$
$$= -\frac{5.0^2}{2(-0.66)}$$
$$= 19 \text{ m}$$

distance = ..... m [2]

**(iii)** Static friction is a force that acts on an object when it is at rest. It must be overcome before the object can start moving.

Considering that the maximum possible static friction between the object and the plane is equal to the value of the kinetic friction, *f*, state and explain, whether the block will slide down the plane after coming to rest if force *F* continues to act on the block.

component of *F* parallel to plane, $F_{//} = F\cos\theta$
$= 25\cos 15°$
$= 24 \text{ N}$

component of weight parallel to plane, $W_{//} = mg\sin\theta$
$= 3.8(9.81)\sin 15°$
$= 9.6 \text{ N}$

Since the component of *F* parallel to plane is greater than the component of weight parallel to plane, the block has tendency to slide up. However, as there is friction between the block and surface of plane and the maximum static friction, *f*,

$f = \mu N$
$= 0.40(42)$
$= 17 \text{ N}$

Hence friction acts parallel to plane down the slope and the amount of friction required, *f'*,

$F_{net} = 0$
$F_{//} = W_{//} + f'$
$f' = F_{//} - W_{//}$
$= 24 - 9.6$
$= 14 \text{ N} < f$

Therefore block remains at rest with static friction of 14 N acting on it.

.....

.....

.....

..... [2]

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[Total: 8]

**2** **(a)** State an example of how the motion of an object can be undergoing the following situations:

**(i)** A body is instantaneously at rest but has a non-zero acceleration.

An object at its highest point when thrown vertically upwards on Earth or an object at the position of maximum displacement in a simple harmonic motion or any reasonable example. [1]

**(ii)** A body is moving with a constant speed but has a non-zero acceleration.

Any reasonable example of an object undergoing uniform circular motion. [1]

**(b)** A toy car, initially at rest, can be made to propel forward by attaching a bottle filled with baking soda and vinegar. When the bottle cap is removed, the gas released from the reaction will cause the toy car to move forward. Fig. 2.1 shows how the acceleration, $a$, of the toy car changes with time $t$.

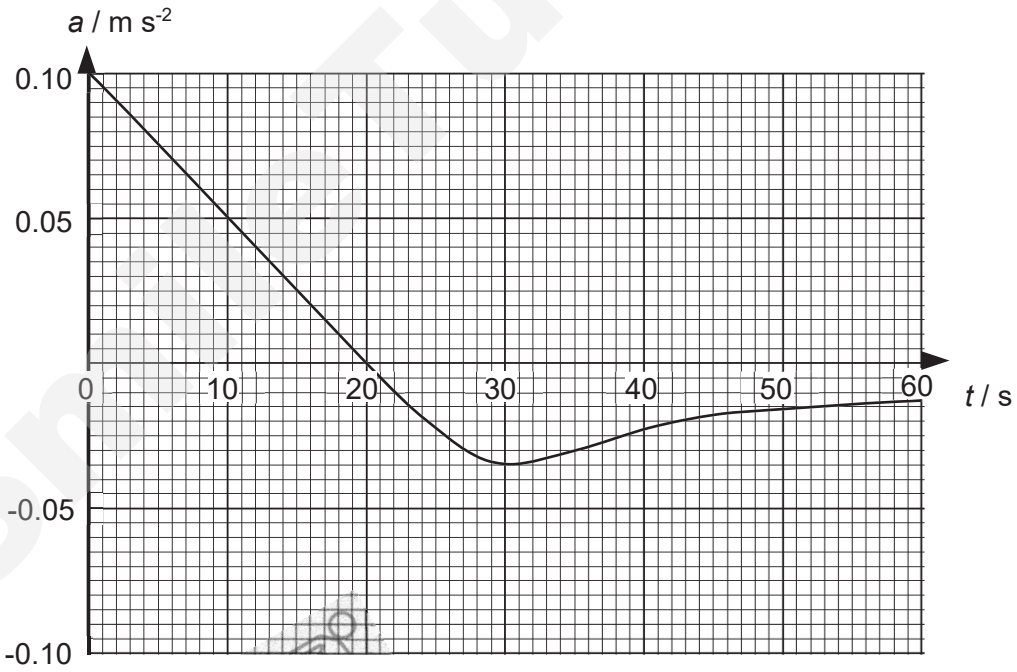


**Fig. 2.1**

**(i)** With reference to Fig. 2.1, determine the maximum speed of the toy car.

Maximum speed occur at 20.0 s.

Maximum speed = Area under graph from 0 – 20.0 s

= ½ (0.100)(20.0)

= 1.00 m $s^{-1}$ [1]


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**(ii)** Hence, sketch a graph on Fig. 2.2 to show how the velocity, *v*, of the toy car changes with time *t*.

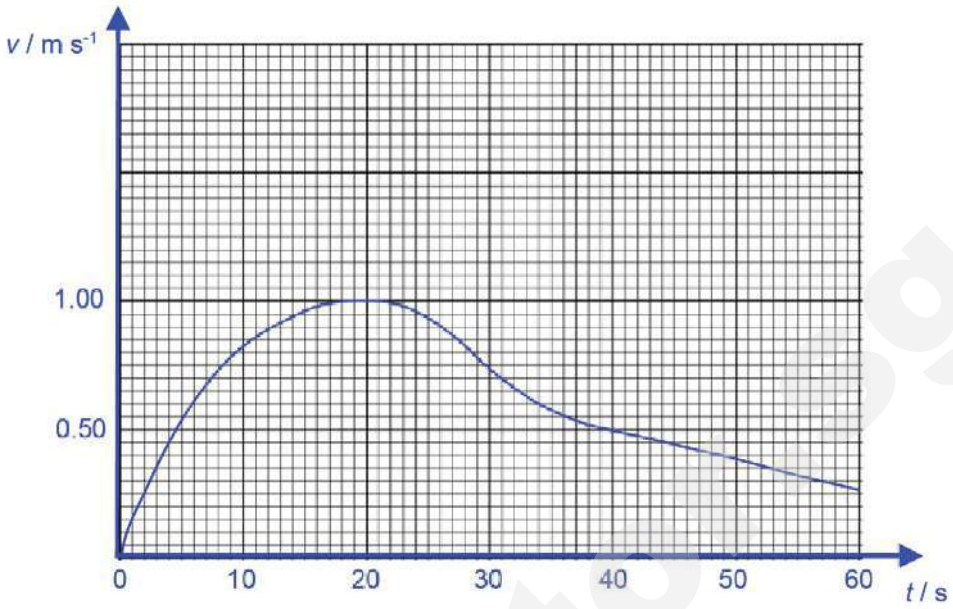


**Fig. 2.2**

[3]

[Total: 6]

**3** In a system called the positronium, an electron and positron move in a circular orbit as shown in Fig. 3.1. A positron has a positive elementary charge *e* and a mass identical to that of an electron. The positron and electron are separated by a distance of $1.30 \times 10^{-10}$ m.

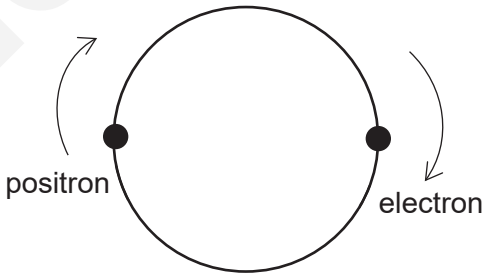


**Fig. 3.1**

**(a)** Explain why the centripetal forces on the electron and positron are equal in magnitude.

The force that exist between the 2 charges is the electric force and by newton's 3'rd law, they have the same magnitude. Since the only force that is exerted on the positron or electron is the electric force and this provides the centripetal force, the 2 centripetal forces have the same magnitude. (Gravitational force between the 2 masses is very small and thus negligible.) [1]

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**(b)** Determine

**(i)** the magnitude of each centripetal force,

The electric force provides the centripetal force,

$$F = \frac{q_1 q_2}{4\pi\varepsilon r^2}$$
$$= \frac{(1.60x10^{-19})(1.60x10^{-19})}{4\pi(8.85x10^{-12})(1.30x10^{-10})^2}$$
$$= 1.36x10^{-8} N$$

centripetal force = ..... N [2]

**(ii)** the time taken for one revolution of the electron.

$$F = mr\omega^2$$
$$1.36x10^{-8} = (9.11x10^{-31})(\frac{1.30x10^{-10}}{2})(\frac{2\pi}{T})^2$$
$$T = 4.15x10^{-16} s$$

time taken = ..... s [2]

**(c)** State and explain whether there would be any difference to the circular orbit if it were a proton in place of the positron.

When the positron is replaced by a proton, the electric force remained unchanged (centripetal force is also unchanged) but the mass of the proton is much higher (2000 times) than the electron, thus, the radius of the orbit for the proton will be much smaller than that of the electron. The result will be the proton seems to be stationary while the electron will orbit around the proton.

..... [2]

[Total: 7]

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4 **(a)** State two conditions necessary for the formation of stationary waves.

The two waves must have the same frequency, same wavelength and same speed (state at least 2 of the 3).

The two waves must meet in opposite direction.

[2]

**(b)** With the aid of a labelled diagram, describe a laboratory experiment to demonstrate stationary waves in an air column.

Detailed diagram of air column partially submerged in water-filled glass cylinder/ loudspeaker facing closed tube.

Use of tuning fork and varying unsubmerged length of air column/ use of varying frequency sound source projected on closed tube.

Observing successive loud and soft sound as unsubmerged length is varied/ use of microphone with c.r.o. to observe high and low amplitude within the closed tube.

[3]

**(c)** Fig. 4.1 shows an arrangement used to determine the speed of microwaves in the laboratory.

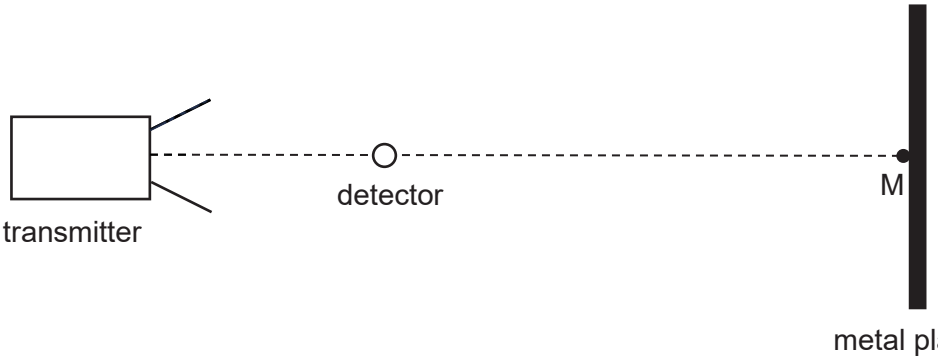


**Fig. 4.1**

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A stationary wave is formed between the transmitter and the metal plate. As the detector is moved along the line between the transmitter and the point M, it registers a series of high intensity signals. The positions of these high intensity signals along an axis are marked by crosses on the x axis of the graph in Fig. 4.2.

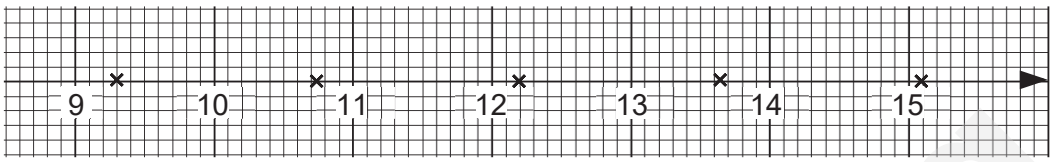


**Fig. 4.2**

The transmitter emits microwaves of frequency $1.0 \times 10^{10}$ Hz. Use Fig. 4.2 to deduce an experimental value for the speed of the microwaves.

From Fig. 4.2, wavelength = (15.10 – 9.30) /2 = 2.90 cm

Speed = $f\lambda = 1.0 \times 10^{10} (2.90 \times 10^{-2}) = 2.9 \times 10^{8}$ m s$^{-1}$

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

[Total: 7]

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5 **(a)** Explain what is meant by *electric field strength*.

Electric field strength at a point in an electric field is the **electric force per unit positive charge** on a **small test charge placed at that point**.

[2]

**(b)** In a crystal of sodium chloride, a sodium ion has a positive charge of $+e$. It is separated from its closest chlorine ion by a distance of $2.8 \times 10^{-10}$ m. The chlorine ion has a charge of $-e$.

Assume that the ions are point charges.

**(i)** Calculate the magnitude of the electric field strength at the sodium ion due to its closest chlorine ion.

$$E = \frac{Q}{4\pi\varepsilon_o r^2}$$

$$= \frac{1.6\times10^{-19}}{4\pi\varepsilon_o(2.8\times10^{-10})^2}$$

$$= 1.8\times10^{10} \text{ N C}^{-1}$$

electric field strength = ..... N $C^{-1}$ [2]

**(ii)** Calculate the attractive force between the two ions.

$$F = qE$$

$$= 1.6 \times10^{-19}(1.8\times10^{10})$$

$$= 2.9 \times10^{-9} \text{ N}$$

force = ..... N [1]

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**(c)** The force calculated in **(b)(ii)** would result in the two ions accelerating towards each other. This does not happen because of the presence of other ions.

**(i)** Fig. 5.1 represents a plane of sodium and chlorine ions.

On Fig. 5.1, draw arrows to show the forces acting on the central sodium ion. Label the arrows to indicate whether these are forces of attraction (A) or repulsion (R). The length of the arrows should reflect the relative magnitudes of the forces.

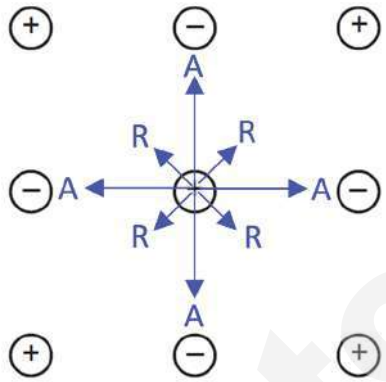


**Fig. 5.1**

[2]

**(ii)** State the resultant force on the central sodium ion.

resultant force = zero N [1]

**(iii)** When the central sodium ion is displaced out of position, describe the effect of the resultant force on the ion.

The forces are unbalanced, the resultant force will tend to bring it back to the equilibrium position

[1]

[Total: 9]

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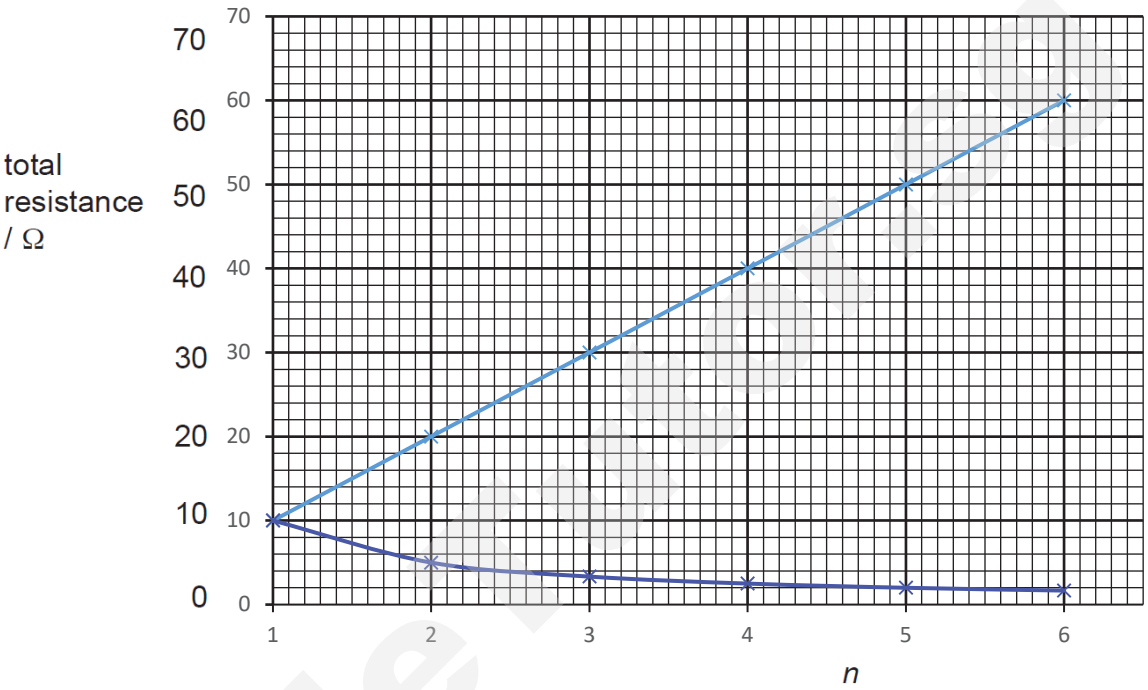
6 (a) (i) 1. Give an expression for the total resistance of $n$ resistors, each of resistance 10 Ω, connected in **series**, where $n$ is the number of resistors.

resistance = 10n Ω [1]

2. On Fig. 6.1, plot a graph showing the values of the total resistance for $n$ = 1, 2, 3, 4, 5 and 6. Label the line S.




[2]

**Fig. 6.1**

(ii) 1. Give an expression for the total resistance of $n$ resistors, each of resistance 10 Ω, connected in **parallel**, where $n$ is the number of resistors.

resistance = 10/n Ω [1]

2. On Fig. 6.1, plot a graph showing the values of the total resistance for $n$ = 1, 2, 3, 4, 5 and 6. Label the line P. [2]

(b) (i) Fig. 6.2 shows a network of 16 resistors, each of resistance 10 Ω connected in four parallel lines of four resistors in series.

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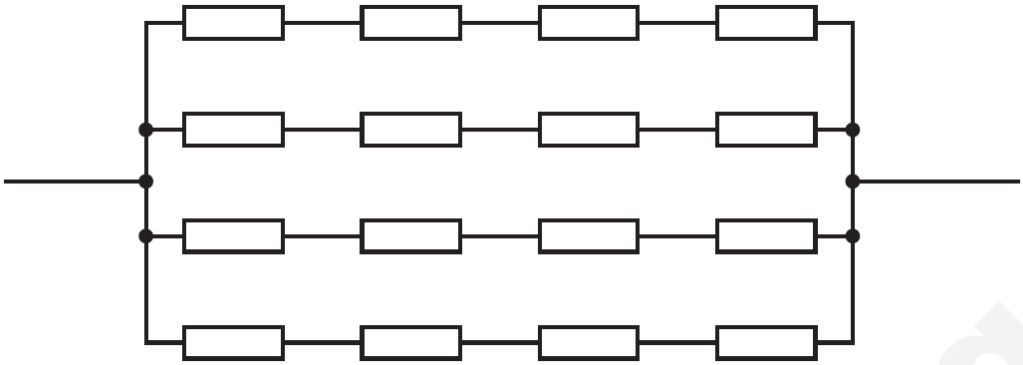

**Fig. 6.2**

Calculate the total resistance of the network.

$R_{tot} = \frac{40}{4} = 10\ \Omega$

total resistance = 10 Ω [1]

**(ii)** State the total resistance of a network of *n* parallel lines of *n* resistors in series where every resistor has a resistance of 10 Ω.

$R_{tot} = \frac{10n}{n} = 10\ \Omega$

resistance = ..... Ω [1]

**(iii)** Explain one practical advantage of using many individual resistors in this way, rather than using a single resistor.

If one resistor is faulty or inaccurate, the total resistance of the array is close to 10 Ω, and so it's the array continues to function as it should. [1]

The current through each resistor in the array would be smaller than the current through a single resistor. The resistors in the array would be less likely to reach the maximum power rating of the resistor.

[Total: 9]

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7 **(a)** Define *magnetic flux density*.

Magnetic flux density is (numerically equal to) the force per unit length on straight conductor carrying unit current normal to the field. [2]

**(b)** A rigid square single-wire coil PQRS of side 4.00 cm and mass 25.0 g hangs vertically in a uniform magnetic field with magnetic flux density of 0.0420 T acting vertically downwards, as shown in Fig. 7.1

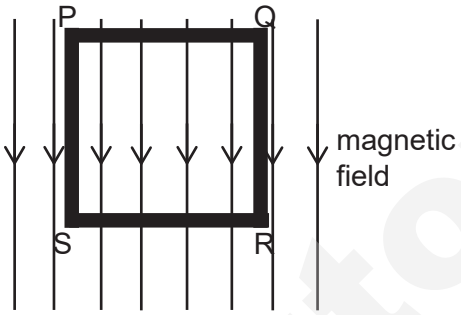


**Fig. 7.1**

This coil can rotate freely, pivoted along the top edge PQ. When a current of 7.50 A passes through the coil, it hangs at an angle of $\theta$ to the vertical as shown in the side view of the coil in Fig. 7.2.

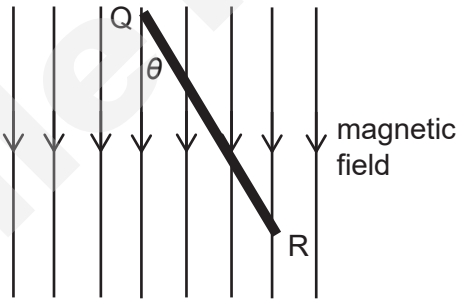


**Fig. 7.2**

**(i)** State the direction of current along the side RS.

direction = from S to R [1]

**(ii)** Explain how the answer in **(i)** was determined.

[1]

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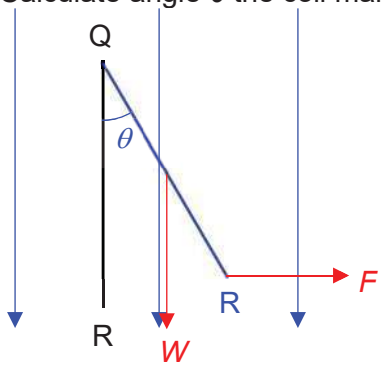
**(iii)** Calculate angle $\theta$ the coil makes with the magnetic field.




side view

By principle of moments,

$$\tau_{net} = 0$$

$$F(L\cos\theta) = W\left(\frac{L}{2}\sin\theta\right)$$

$$2BIL = mg\tan\theta$$

$$\tan\theta = \frac{2BIL}{mg}$$

$$\theta = \tan^{-1}\frac{2BIL}{mg}$$

$$= \tan^{-1}\left[\frac{2(0.0420)(7.50)(4.00\times10^{-2})}{(25.0\times10^{-3})(9.81)}\right]$$

$$= 5.87°$$

$\theta$ =.....[3]

[Total: 7]

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**8** Fig. 8.1 shows a simplified circuit diagram of a laptop adaptor connected to the chargeable battery of a laptop. The adapter consists of a step-down transformer with a single diode.

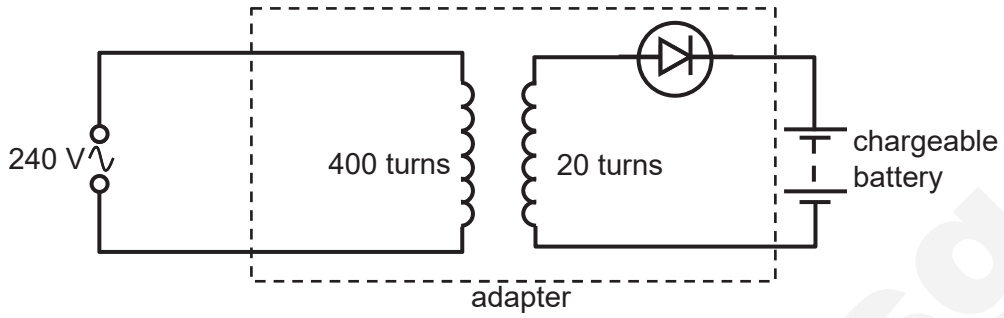


**Fig. 8.1**

**(a)** Calculate the peak voltage across the secondary coil and state one assumption made in performing the calculation.

$$\frac{Ns}{Np} = \frac{Vs}{Vp}$$

Vs = 20/400 (240 ) = 12 V

Hence $V_o = \sqrt{2} \times 12 = 17$ V

peak voltage = ..... V [1]

Assumption: ... the transformer is ideal/100% efficiency. .....

..... [1]

**(b)** Explain why, during the charging process, the power delivered to the secondary coil is twice the power delivered to the chargeable battery.

The voltage step down to the secondary coil is sinusoidal but with the diode in place, .....

the voltage across the battery is half wave rectified . This imply that the time that the ..... [1]

battery get charged is only half of the time voltage is step down across the secondary

coil. Hence the energy received by the battery is reduced by half.

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**(c)** Hence show that the voltage rating of the chargeable battery is 8.5 V.

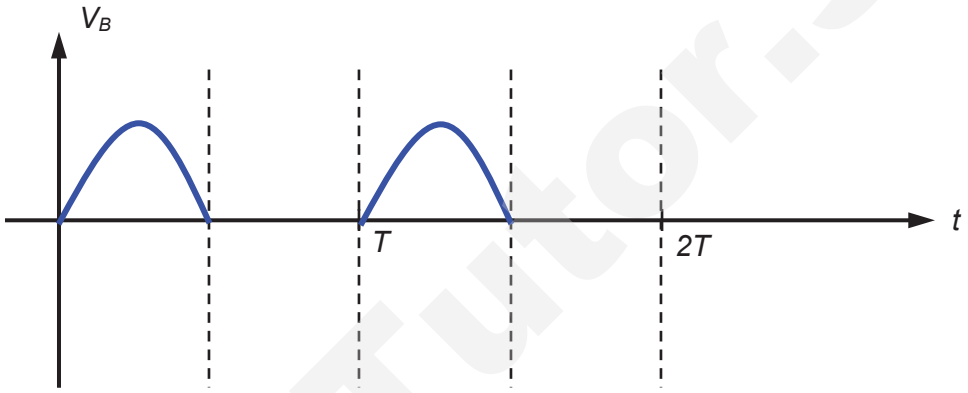
Without diode , assume power is P and $P = (12)^2/R$

With diode , power delivered = $P/2 = V_{rms}^2/R$

Hence $V_{rms}$ $\sqrt{(144/2)} = 8.5$ V

[1]

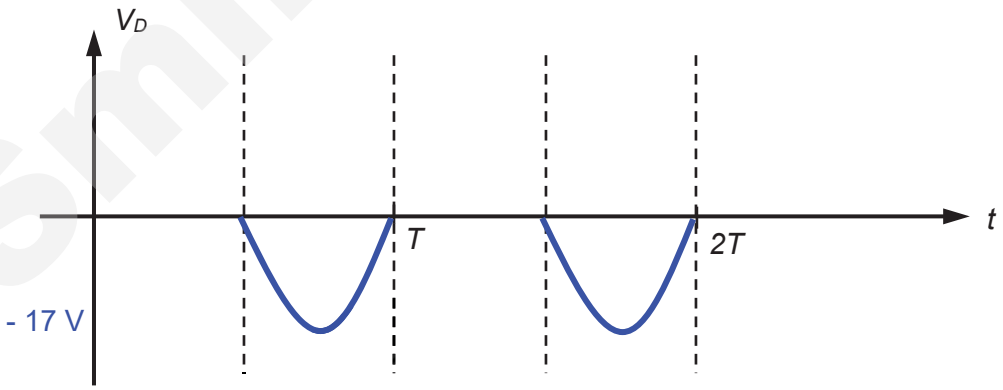
**(d)** Sketch on Fig. 8.2 the variation of potential difference $V_B$ across the chargeable battery with time $t$. It is given that $T$ is the period of the alternating current.




[1]

**Fig. 8.2**

**(d)** Hence sketch on Fig. 8.3 the variation of the potential difference across the diode $V_D$ with time $t$. Label appropriate values. It is given that $T$ is the period of the alternating current.




[2]

**Fig. 8.3**

[Total: 7]

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**9** On 11 March 2011, Japan suffered a Magnitude 9.0 Earthquake off the eastern coast of Japan. One of the consequences of the Earthquake was a tsunami that crippled the Fukushima Daiichi nuclear power plant, which subsequently released significant amounts of radioactive materials and by-products into the atmosphere and environment.

Tables 9.1 and 9.2 show the surface activities of several radionuclides measured on 31 March 2011 from soil samples at several locations in and around the Fukushima district, their half-lives and decay modes.

| | Surface Activity (Bq $m^{-2}$) | | | | | |
|---|---|---|---|---|---|---|
| Location | Tellurium-129m | Tellurium-132 / Iodine-132 | Iodine-131 | Caesium-134 | Caesium-137 | Barium-140 / Lanthanum-140 |
| A | 208 370 | 111 960 | 824 150 | 205 260 | 211 480 | 8 397 |
| B | 388 600 | 195 640 | 1 163 120 | 477 040 | 479 720 | 22 244 |
| C | 754 920 | 382 120 | 1 887 300 | 894 720 | 922 680 | 35 416 |
| D | 71 928 | 35 478 | 481 140 | 77 031 | 78 489 | 2 527 |

**Table 9.1 Surface Activities of Radionuclides**

| Radio-nuclide | Tellurium-129m | Tellurium-132 | Iodine-132 | Iodine-131 | Caesium-134 | Caesium-137 | Barium-140 | Lanthanum-140 |
|---|---|---|---|---|---|---|---|---|
| Half-life (Days) | 33.6 | 3.20 | 2.30 | 8.02 | 755 | 11 000 | 12.8 | 1.68 |
| Decay Constant ($s^{-1}$) | $2.39 \times 10^{-7}$ | $2.51 \times 10^{-6}$ | $3.49 \times 10^{-6}$ | | $1.06 \times 10^{-8}$ | $7.29 \times 10^{-10}$ | $6.27 \times 10^{-7}$ | $4.78 \times 10^{-6}$ |
| Decay Mode | $\gamma$ | $\beta^-$ | $\beta^-$ | $\beta^-$ | $\beta^-$ | $\beta^-$ | $\beta^-$ | $\beta^-$ |

**Table 9.2 Half-lives and Decay Modes of Radionuclides**

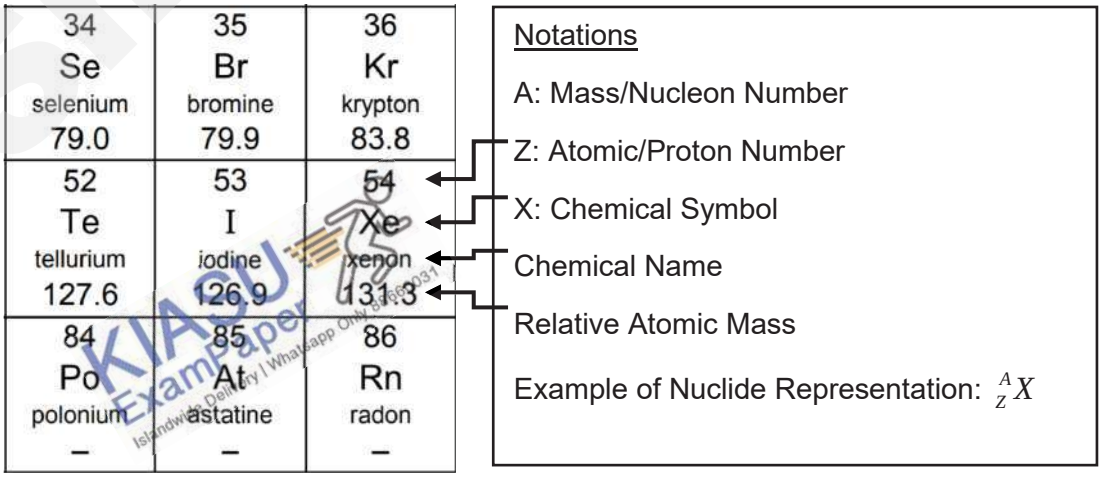


**Fig. 9.1 Elements Around Iodine on the Periodic Table**

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**(a)** Using the data from **Table 9.1**, **Table 9.2** and **Fig. 9.1**,

**(i)** calculate $A_\beta$, the total activity per $m^2$ due to beta decay, of the most contaminated location.

$$A_\beta = 382120 + 1887300 + 894720 + 922680 + 35416 \quad [1]$$
$$= 4.1222 \times 10^6 \ Bq\ m^{-2} \quad [1]$$

$A_\beta$ = ..... Bq $m^{-2}$ [1]

**(ii)** for the location C,

**1.** calculate the decay constant of Iodine-131,

$$\lambda_i = \frac{t_{\frac{1}{2}}}{\ln 2}$$
$$\lambda_i = \frac{8.02 \times 24 \times 3600}{\ln 2} \quad [1]$$
$$\lambda_i = 1.00 \times 10^{-6}$$

decay constant = ..... $s^{-1}$ [1]

**2.** calculate $N_i$, the number of Iodine-131 nuclei present per $m^2$,

$$A_i = \lambda_i N_i$$
$$N_i = \frac{1887300}{1.00 \times 10^{-6}} \quad [1]$$
$$N_i = 1.89 \times 10^{12} \quad [1]$$

$N_i$ = ..... [2]

**3.** calculate $M_i$, the mass of Iodine-131 nuclei present per $m^2$,

$$M_i = 1.887 \times 10^{12} \times 131 \times 1.66 \times 10^{-27}$$
$$M_i = 4.10 \times 10^{-13} \ kg \quad [1]$$

$M_i$ = ..... kg [1]

**4.** calculate $A_{T,i}$, the total activity present due to Iodine-131 in 7.5 $km^2$ of the location.

$$A_{T,i} = 1887300 \times 7500000$$
$$A_{T,i} = 1.42 \times 10^{13} \ Bq$$

$A_i$ = ..... Bq [1]

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**(v)** write down the decay equation for:

**1.** Tellurium-129m

$^{129}_{52}Te^{*} \rightarrow {}^{129}_{52}Te + \gamma$ .....[1]

**2.** Tellurium-132

$^{132}_{52}Te \rightarrow {}^{131}_{53}I + {}^{0}_{-1}e$ .....[1]

**(b)** Explain why after 16.1 days, another sample taken at the same location had significantly more than a quarter of the original activity due to Iodine-131.

25% of the original activity assumes that 2 half-lives has occurred for iodine-131 that is not replenished / with a fixed mass. [1] However, as iodine-131 decays to another nuclide, there could be other radioactive nuclide which also decays to iodine-131 but with a shorter half-live, hence significantly increasing the mass of iodine-131 present. [1] .....[2]

**(c)** Among the radioactive fallout, Iodine-131 and Caesium-137 are major concerns as both elements can be absorbed by the human body through inhalation as well as through the consumption of contaminated food and water.

**(i)** Even though the activity of Iodine-131 is significantly greater than that of Caesium-137 in all locations tested, Caesium-137 will present a greater hazard in the long term. Explain why this is so.

The half-life of iodine-131 at only 8.02 days is short while the half-life of cesium-137 at 11000 days is significantly longer. In the long term, the activity due to iodine-131 would have reduced to a relatively insignificant level while the activity of cesium-137 would remain significant. .....[2]

**(ii)** Iodine is absorbed by the body and accumulates in the thyroid. Explain why Iodine-131 is dangerous when ingested.

Iodine-131 emits beta particles which is an ionising radiation which can damage and kill living cells. As it is accumulated in the thypoid after ingestion, it can cause severe and irreparable damage to the surrounding cells over a long period of time and significantly increase the chance of contracting cancer.

.....[2]

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**(iii)** Suggest why the consumption of potassium iodide pills before Iodine-131 exposure may help reduce the chances of irreparable damage to the thyroid or contracting thyroid cancer.

The consumption of potassium iodide pills before exposure could saturate the thyroid with non-radioactive iodine. This reduces the accumulation of radioactive iodine in the thyroid, hence reducing the time it spends in the thyroid. [2]

**(d)** Radioactive materials are often considered dangerous due to its high energy output with a relatively small mass and its hazardous nature to living things.

**(i)** By considering the decay constants of the radioactive materials listed that undergoes beta decay, suggest and explain which material could be the most dangerous.

As Lanthanum-140 has the largest decay constant of $4.78 \times 10^{-6}$ $s^{-1}$, this suggests that the material has the highest percentage of nuclide undergoing radioactive decay. [1] This means that for the same mass and exposure duration, Lanthanum-140 produces the most ionising particles (beta) and could be releasing the highest amount of energy per unit time. [1] [2]

**(ii)** Suggest and explain another physical factor that contributes to the dangers of radioactive material.

Type of radiation: alpha and beta particles are more ionising than gamma rays.

Half-life: longer half-life means longer periods of radioactivity

Activity: higher activity means higher energy output [2]

Binding energy per nucleon: higher BE/N = higher energy output per decay [Total: 20]

**End of Paper**

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INDEX NUMBER

# PHYSICS 9749/03

Paper 3 Longer Structured Questions **20 September 2019**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your name, class, Centre number 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 a HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

**Section A**
Answer **all** questions.

**Section B**
Answer **one** question only.

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

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

| For Examiner's Use | |
|---|---|
| 1 | / 7 |
| 2 | / 8 |
| 3 | / 7 |
| 4 | / 7 |
| 5 | / 11 |
| 6 | / 8 |
| 7 | / 12 |
| 8 | / 20 |
| 9 | / 20 |
| Total | / 80 |

This document consists of **21** printed pages.

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**Data**

| | |
|---|---|
| speed of light in free space | $c = 3.00 \times 10^8$ m s$^{-1}$ |
| permeability of free space | $\mu_0 = 4\pi \times 10^{-7}$ 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 | $\phi = -Gm / r$ |
| temperature | $T / \text{K} = T / ^\circ\text{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t$ |
| | $= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

**1** The first atomic bomb explosion was during the Trinity Test in 1945. Based on a series of photographs of the explosion, along with a size scale and time stamps, British physicist Sir Geoffrey Ingram Taylor was able to estimate the power released by the explosion.

The radius $R$ of the fireball at time $t$ after the explosion was found to be related to the energy $E$ that was released and the density $\rho$ of the surrounding medium as follows:

$$R = E^{0.2}\rho^{-0.2}t^{Z}$$

where Z is a constant.

**(a)** Show that the value of Z is 0.4.

$[R] = \left[E^{0.2}\rho^{-0.2}t^{Z}\right]$ [1]

$m = kg^{0.2}m^{0.4}s^{-0.4}kg^{-0.2}m^{0.6}s^{Z}$ [1]

$Z = 0.4$

Z = ..... [2]

**(b)** Given that the radius $R$ is (80 ± 2) m at time $t$ being (0.006 ± 0.001) s with density of air being (1.2 ± 0.1) kg m$^{-3}$, determine the energy $E$ released by the bomb with its associated uncertainty.

$R = E^{0.2}\rho^{-0.2}t^{0.4}$

$E = R^{5}\rho t^{-2}$

$E = (80)^{5}(1.2)(0.006)^{-2}$

$E = 1.09\times10^{14}$ [1]

$E \pm \Delta E = (1.1 \pm 0.6)\times10^{14}$ [1]

$\frac{\Delta E}{E} = 5\frac{\Delta R}{R} + \frac{\Delta\rho}{\rho} + 2\frac{\Delta t}{t}$ [1]

$\Delta E = (1.092\times10^{14})\left[5\left(\frac{2}{80}\right) + \frac{0.1}{1.2} + 2\left(\frac{0.001}{0.006}\right)\right]$

$\Delta E = 5.92\times10^{13}$ [1]

$E \pm \Delta E$ = ..... J [3]

**(c)** Of all the data collected, state and explain which measurement you would improve to increase the precision of your answer in **(b)**.

$5\left(\frac{2}{80}\right) = 0.125$ $\frac{0.1}{1.2} = 0.08$ $2\left(\frac{0.001}{0.006}\right) = 0.33$ [1]

Improve $t$ to increase precision of $E$.

Due to its large percentage uncertainty and factor 2 in the calculation of uncertainty of $E$, it contributes to the majority of uncertainty of $E$. [1] ..... [2]

[Total: 7]

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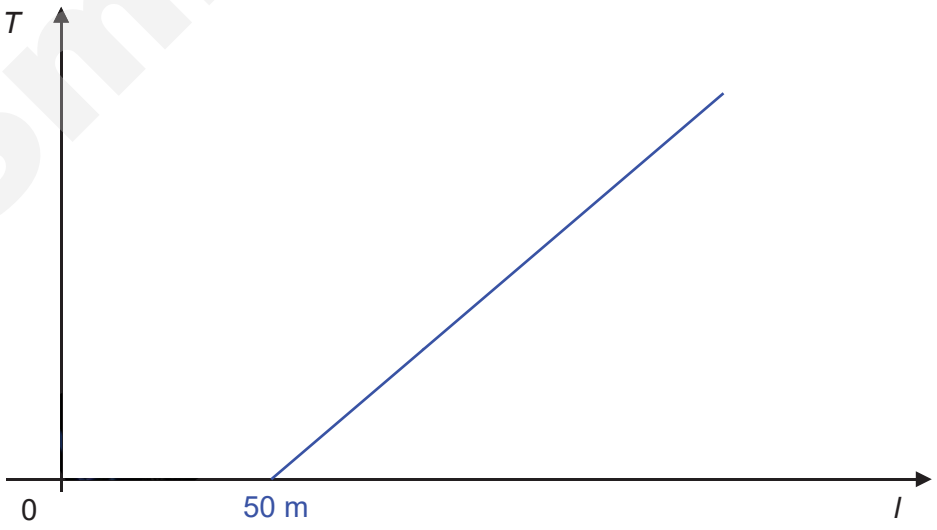
**2** Fig. 2.1 shows a person of mass 70 kg doing a bungee jump.



**Fig. 2.1**

The bungee rope has negligible mass and has an unstretched length of 50 m. This bungee rope may be assumed to obey Hooke's law. A force of 200 N extends the bungee rope by 2.5 m. The bungee rope is secured to the feet of the person. The person leans over a bridge above the river and drops vertically downwards towards the river below. You may assume that air resistance is negligible.

**(a)** Sketch a graph of the tension *T* in the bungee rope against its total length *l*.




[2]

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**(b)** Show that the elastic potential energy in the bungee rope is directly proportional to the square of its extension $e$.

Elastic potential energy = Area under Force-extension graph

$= \frac{1}{2} T e$

$= \frac{1}{2} ke\,(e)$ since $T = ke$ by Hooke's Law

$= \frac{1}{2} ke^2$

Hence, elastic potential energy $\alpha\ e^2$ [shown]

[2]

**(c)** Determine the elastic potential energy in the bungee rope when the person has reached the lowest point of his jump.

At lowest point, by Conservation of Energy,

Loss in GPE = Gain in Elastic PE

$mg(l_0 + e) = \frac{1}{2} ke^2$

$70(9.81)(50 + e) = \frac{1}{2}(200 / 2.5)e^2$

$40\ e^2 - 70(9.81)\ e - 70(9.81)(50) = 0$

$e = 39.11$ m

Hence, elastic potential energy $= \frac{1}{2} ke^2$

$= \frac{1}{2}(200/2.5)(39.11)^2$

$= 6.1 \times 10^4$ J

elastic potential energy = ..... J [3]

**(d)** Explain why it would be extremely dangerous to have a bungee rope that is much stiffer.

If the bungee rope is stiffer, the extension and hence, the time taken $\Delta t$ for the jumper to change his momentum from a high value to zero (at the lowest point) will be shorter. Therefore, the rate of change of momentum experienced by the jumper will be higher and this will result in a larger force acting on the jumper which may injure the jumper.

[1]

[Total: 8]

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**3** Modern gravity meters can measure *g*, the acceleration of free fall, to a high degree of accuracy. The principle on which they work is of measuring *t* the time of fall of an object through a known distance *h* in a vacuum.

**(a)** Assuming that the object starts from rest, deduce and expression for *g* in terms of *t* and *h*.

$s = u\,t + 1/2\,a\,t^2$

$h = 0 + 1/2\,g\,t^2$

$g = 2h/t^2$

[1]

**(b)** State Newton's law of gravitation relating the force *F* between two point objects of masses *m* and *M*, their separation *r* and the gravitational constant *G*.

$F = \frac{GMm}{r^2}$

$= \frac{(6.67\times10^{-11})\left(\frac{4}{3}\pi(2000)^3(2800)\right)(1)}{4000^2}$

$= 3.91\times10^{-4}$ N

Newton's Law of Gravitation states that one point object will attract the other point object with a gravitational force that is directly proportional to the product of the masses of the particles and inversely proportional to the square of the distance between them, where G is the constant of proportionality..

..... [1]

**(c)** Fig. 3.1 shows a standard kilogram mass at the surface of the Earth and a spherical region S of radius 2000 m with its centre 4000 m from the surface of the Earth.

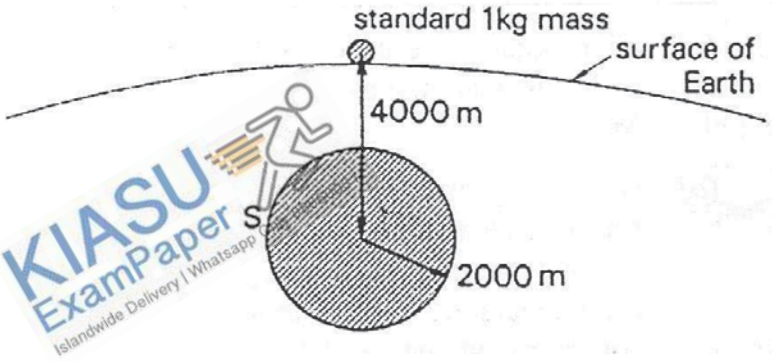


**Fig. 3.1 (Not to scale)**

Region S is made up of rocks with density 2800 kg $m^{-3}$. Calculate the force the matter in region S exerts on the standard mass.

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$$F = \frac{GMm}{r^2}$$

$$= \frac{(6.67\times10^{-11})\left(\frac{4}{3}\pi(2000)^3(2800)\right)(1)}{4000^2}$$

$$= 3.91\times10^{-4}\ \text{N}$$

force = ..... N [2]

**(d)** Calculate the difference in the force on the standard mass, if region S consists of oil with density 900 kg $m^{-3}$ instead of rock.

The difference between the values of the forces in (c) and (d) is due to the density of S.

$$F_{oil} = \frac{900}{2800}3.91\times10^{-4}\ \text{N}$$

$$= 1.26\times10^{-4}\ \text{N}$$

*Or any other correct means of calculation*

$$\Delta F = 3.91\times10^{-4} - 1.26\times10^{-4}$$

$$= 2.65\times10^{-4}\ \text{N}$$

difference in force = ..... N [2]

**(e)** In oil prospecting, the gravity meter is used to predict where deposits of oil are under the surface of Earth. Use your answers in **(d)** to suggest one necessary condition in using the gravity meter.

The gravity meter has to be precise to 5 significant figures to detect the difference in forces.

..... [1]

[Total: 7]

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**4** A student sets up the apparatus illustrated in Fig. 4.1 in order to investigate the oscillations of a 100 g metal cube suspended on a string.

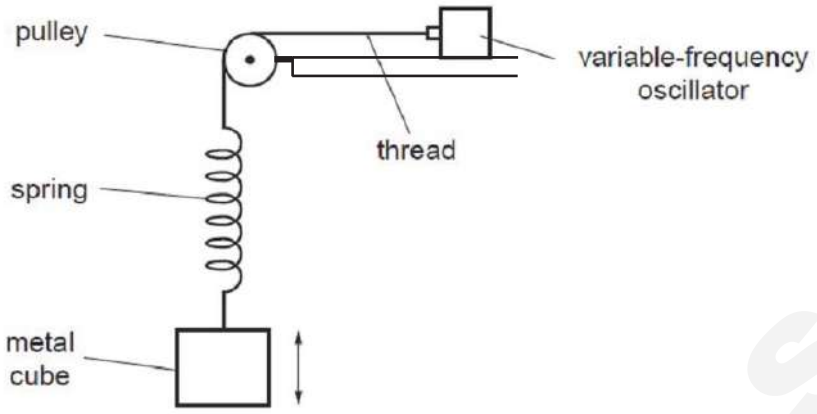


**Fig. 4.1**

Before switching on the variable-frequency oscillator, the metal cube was displaced by pulling it downwards and made to oscillate freely. A graph of its velocity against displacement is shown in Fig. 4.2.

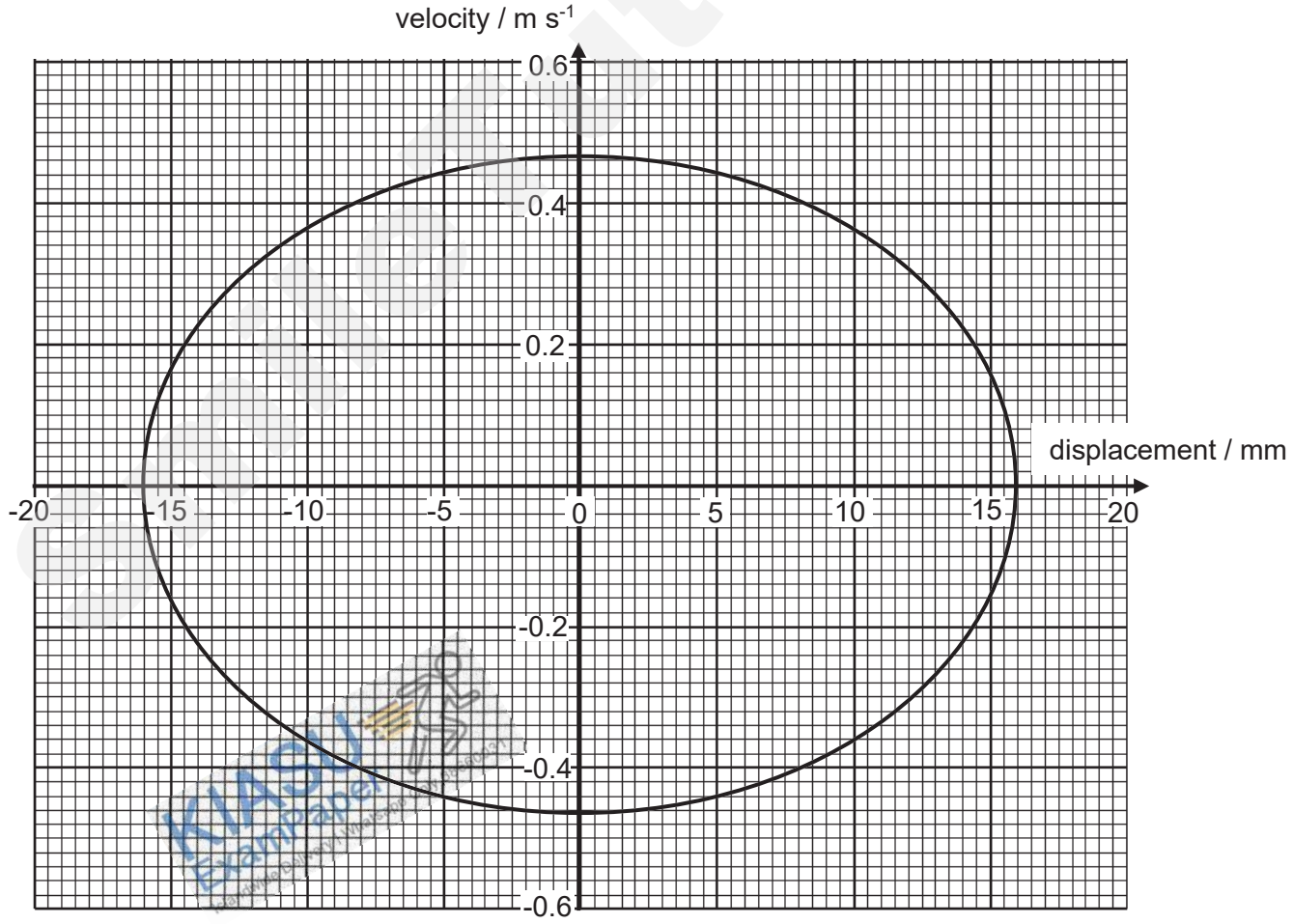


**Fig. 4.2**

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**(a)** Using Fig. 4.2, show that the natural frequency of the metal cube is 4.6 Hz.

From graph, $v_0 = 0.46$ m s$^{-1}$ and $x_0 = 16.0$ mm.

$v_0 = \omega x_0$

$v_0 = 2\pi f x_0$

$0.46 = 2\pi f\,(16.0 \times 10^{-3})$

$f = 4.6$ Hz [shown]

[2]

**(b)** Hence, or otherwise, determine the maximum resultant force acting on the metal cube.

$a_0 = \omega^2 x_0 = (2\pi f)^2 x_0 = [2\pi(4.6)]^2(16.0 \times 10^{-3}) = 13.37$ m s$^{-2}$

By Newton's 2nd Law of motion,

$\sum F = ma$

$\sum F_0 = ma_0 = 0.100\,(13.37) = 1.3$ N

maximum resultant force = ..... N [2]

**(c)** The variable-frequency oscillator is now switched on so that the metal cube can undergo forced oscillation.

**(i)** State what is meant by *forced oscillation*.

Forced oscillation is an oscillatory system which is driven by an external periodic force.

[1]

**(ii)** On Fig. 4.3, sketch the variation with frequency of the amplitude of the oscillations of the metal cube between 2 Hz to 8 Hz.

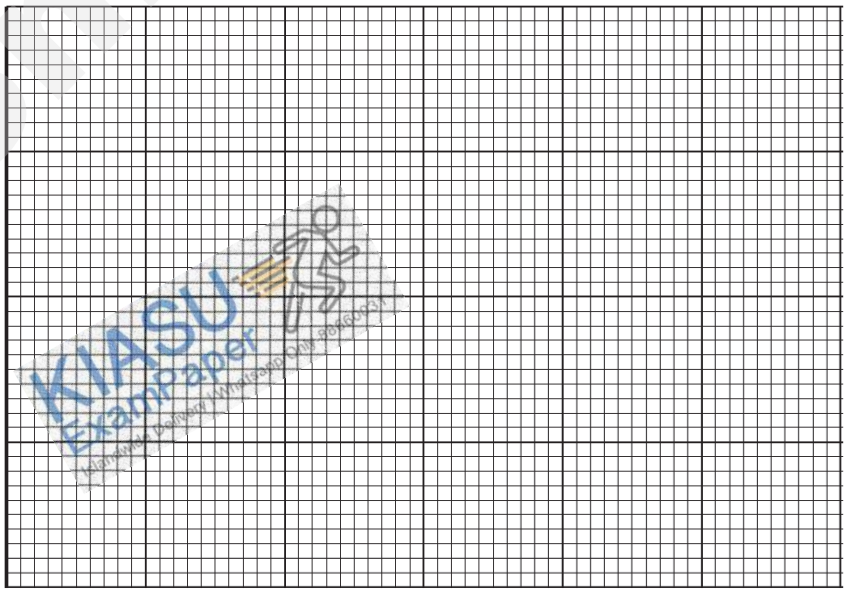

**Fig. 4.3**

A resonance graph with the correct shape with peak at 4.6 Hz.

[2]

[Total: 7]

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

A hypothetical gas whose molecules occupy negligible space and have no interactions, and which obeys the gas laws exactly at all pressure, volume and temperature. [2]

**(b)** An ideal gas, comprising single atoms, is contained in a cylinder and has a volume of $1.84 \times 10^{-2}$ m$^3$ at a pressure of $2.12 \times 10^7$ Pa. The mass of the gas in the cylinder is 3.20 kg.

**(i)** Determine the root-mean-square (r.m.s.) speed of the atoms of the gas.

From kinetic theory of gas,

$$KE = \frac{3}{2}nRT$$

From ideal gas equation,

$$pV = nRT$$

$$\frac{1}{2}mv_{rms}^2 = \frac{3}{2}pV \quad [1]$$

$$v_{rms} = \sqrt{\frac{3\left(2.12\times10^{7}\right)\left(1.84\times10^{-2}\right)}{3.2}} \quad [1]$$

$$v_{rms} = 605\ m\ s^{-1} \quad [1]$$

root-mean-square speed = ..... m s$^{-1}$ [3]

**(ii)** The temperature of the gas in the cylinder is 22 °C.

Determine

**1.** the amount of gas,

Using ideal gas equation,

$$pV = nRT$$

$$n = \frac{\left(2.12\times10^{7}\right)\left(1.84\times10^{-2}\right)}{8.31\left(22+273\right)} \quad [1]$$

$$n = 159 \quad [1]$$

amount = ..... mol [2]

**2.** the mass of one atom of the gas.

mass of gas = number of atom × mass of atom
3.2 = 159 × 6.02 × $10^{-23}$ × mass of atom [1]
mass of atom = 3.34 × $10^{-26}$ kg [1]

mass = ..... kg [2]

**(iii)** Use your answer in **(ii)2.** to determine the nucleon number A of an atom of the gas.

mass of atom = nucleon number × unified atomic mass
nucleon number = 3.34 × $10^{-26}$ / 1.66 × $10^{-27}$
nucleon number = 20 [1]

A = ..... [2]

[Total: 11]

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**6** Fig. 6.1 shows a long solenoid which has a small copper disc mounted at its centre.

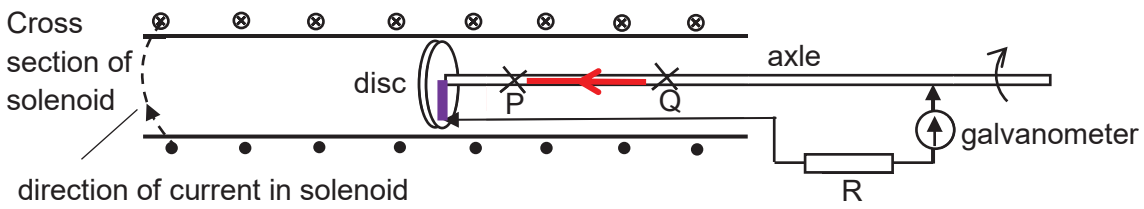


**Fig. 6.1**

The disc spins on a conducting axle which lies along the axis of the solenoid. The solenoid is connected in series with a d.c. supply and the direction of the current in the solenoid is as shown in Fig. 6.1. One end of the resistor is connected to the rim of the disc through brushes. The other end is connected to a galvanometer.

**(a)** **(i)** Indicate the direction of the induced current between point P and Q with an arrow on Fig. 6.1. [1]

**(ii)** Explain why an e.m.f. is generated between the axle and the rim of the disc when the disc rotates.

The solenoid sets up a uniform magnetic field perpendicular to the plane of the disc. When the disc turns, there is a continuous flux cutting across the metal strip from centre of the disc to rim. By Faraday's law, this results in induced e.m.f. across this strip from centre of the disc to rim as drawn the diagram.

.....

.....

.....[3]

**(b)** State the effect on the galvanometer, if any, when

**(i)** the speed of the rotation of the disc is increased,

Larger angle of deflection.

.....[1]

**(ii)** the direction of the rotation of the disc is changed.

Same angle of deflection in the other direction.

.....[1]

**(c)** A voltmeter is now connected across the rim of the disc. Explain why there is no reading.

The rate of flux cutting is the same for any strip of conductor from the centre to the rim, thus, the rim will be at the same potential, the potential difference across 2 points of the rim will be zero and hence no reading.

.....[2]

[Total: 8]

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7 A beam of light consists of a continuous range of wavelengths from 430 to 600 nm. It passes through a cloud of cool hydrogen gas as shown in Fig. 7.1.

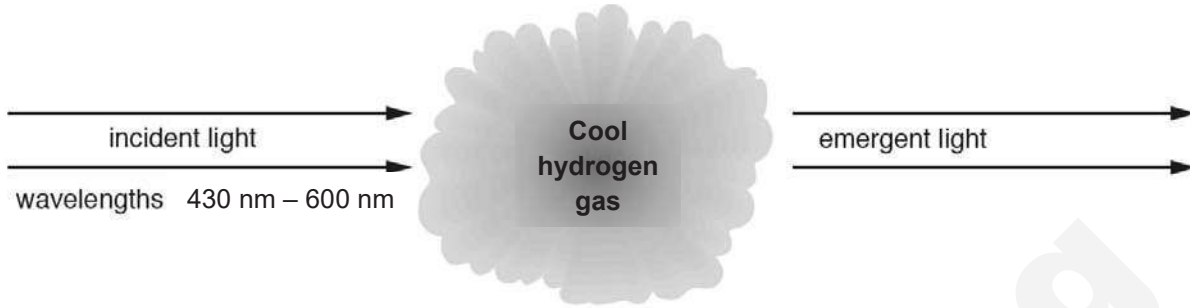


**Fig. 7.1**

**(a)** The spectrum of light emerging from the cloud of cool hydrogen gas is viewed with a spectrometer. Explain why this spectrum contains 2 dark lines.

The incident light consist of photons of different wavelengths and different energies. A photon can only be absorbed by the cool gas and excite electron of the hydrogen atom from a lower energy level to higher energy level when the difference between the 2 energy levels are exactly equal to the energy of the photon. There are 2 possible match to the energy level differences. These 2 photons are released when the hydrogen atom undergoes de-excitation, however, these photons will be released in all direction, intensity detected will be so low that the 2 wavelength or frequent appear to be dark line.

.....

..... [4]

**(b)** The measured wavelengths, $\lambda_m$ , of the selected lines in the hydrogen spectrum are given empirically by

$$\frac{1}{\lambda_m} = R\left(\frac{1}{4} - \frac{1}{m^2}\right)$$

where $R$ is a constant of value 1.097 x $10^7$ m $s^{-1}$ and $m$ is an integer taking the values 3, 4, 5… etc.

**(i)** Calculate the value of the wavelength when $m$ = 4.

$\frac{1}{\lambda_4} = (1.097x10^7)\left(\frac{1}{4} - \frac{1}{4^2}\right)$

$\lambda_4 = 4.86x10^{-7}\,m$

wavelength = ..... m [2]

**(ii)** Determine the minimum wavelength given by the equation.

For minimum wavelength, m → infinity, $\frac{1}{\lambda_{min}} = (1.097x10^7)\left(\frac{1}{4} - 0\right)$

$\lambda_{min} = 3.65x10^{-7}\,m$

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minimum wavelength = ..... m [2]

**(iii)** Some of the electron energy levels of the hydrogen atom in the gas are represented in Fig. 7.2.

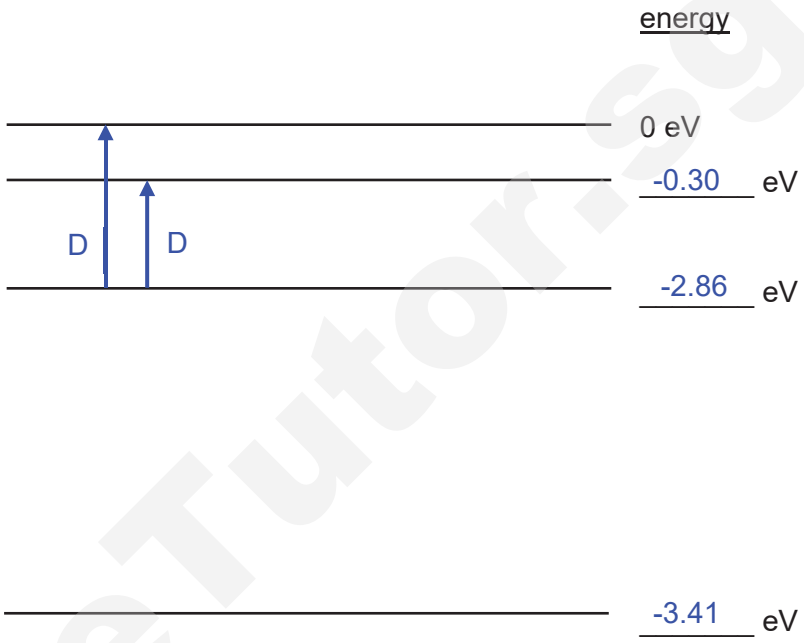


**Fig. 7.2**

**1.** Use your answers from **(b)(i)** and **(b)(ii)** to determine the energy of the 3 other electron energy levels in Fig. 7.2. Write your answer in the blanks in Fig. 7.2.

[2]

**2.** On Fig. 7.2, draw, and label with D, the transitions giving rise to the 2 darks lines from **(a)**. [2]

[Total: 12]

$E = h\frac{c}{\lambda_4}$

$E = (6.63x10^{-34})\frac{3.00x10^{8}}{4.86x10^{-7}}$

$\Delta E = 2.56eV$

$E = (6.63x10^{-34})\frac{3.00x10^{8}}{3.65x10^{-7}}$

$\Delta E = 3.41eV$

$\lambda_5 = 4.34x10^{-7}m$

$\Delta E = 2.86eV$

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## Section B

Answer **one** question from this Section in the spaces provided.

**8** **(a)** Explain what is meant by *diffraction* of wave.

**The spreading of waves when they pass through an opening or around an obstacle is known as diffraction.**

..... [1]

**(b)** A laser light of wavelength 633 nm is incident on a single slit of width *b*. A diffraction pattern is formed on a vertical screen 4.2 m away from the single slit.

A photograph of the single slit diffraction pattern is shown in Fig. 8.1.



**Fig. 8.1 (drawn to scale)**

**(i)** Determine *b*.

**1.5w = 8.2 cm**

**W = 5.5 cm**

$$\tan\theta = \frac{w/2}{D} \text{ and } \sin\theta = \frac{\lambda}{b}$$

**b = 9.7 x $10^{-5}$ m**

= ..... m [3]

**(ii)** With reference to the concept of interference, suggest why the value of *b* cannot be less than the wavelength of the laser light.

**The maximum path difference between two points within the slit width will be less than one wavelength. Hence a single slit diffraction pattern cannot be observed. obstacle is known as diffraction.**

..... [2]

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**(c)** A second identical single slit is then placed beside the first slit at a horizontal distance of 0.320 mm away from the centre of the first slit. An interference pattern is then observed.

**(i)** Explain why an interference pattern is observed on the screen.

**The two slits acts as two coherent sources of light . At any point along the screen, the path difference will changes periodically between nλ and (n+1/2)λ, resulting any two waves to meet in phase or anti-phase respectively .**

..... [2]

**(ii)** Calculate the fringe separation of the interference pattern.

$$x = \frac{\lambda D}{a} = = \frac{(633x10^{-9})(4.2)}{0.32x10^{-3}}$$

**= 0.0083 m**

fringe separation = ..... m [2]

**(iii)** **1.** State the changes to the fringe pattern when the width of both slits is reduced slightly, resulting in the intensity of the light coming out from both slits to be reduced.

- **Intensity of bright fringe will decrease.**
- **Intensity of dark fringe will increase**
- **The number of fringes will increase as overlapping region increase.**

..... [3]

**2.** Suggest why the intensity of the light coming out from each slit will be reduced when the width of each slit is reduced.

**When the width of each slit is reduced, the width of the central fringe from each slit will increase. Since the area spread will increase, the intensity will decrease.**

..... [1]

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**(d)** A thin wedge of air is made by separating two thin glass plates by a spacer as shown in Fig. 8.2.

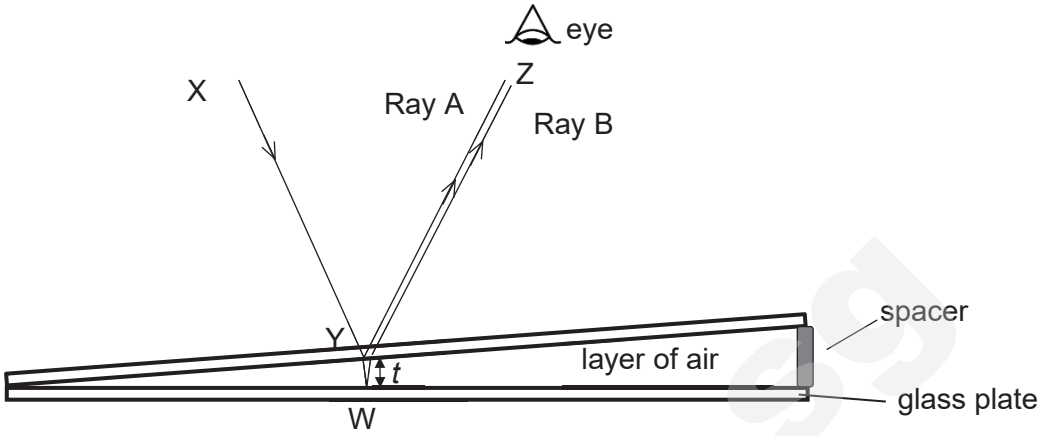


**Fig. 8.2**

There are two rays of light, Ray A and B, which are directly at the glass plates.

Ray A take the path X→Y→Z.

Ray B take the path X→Y→W→Z.

**(i)** State the path difference between Rays A and B in terms of *t* which is the thickness of the layer of air between the two glass plates.

path difference = **2t** [1]

**(ii)** When the observer moves his eyes across the layer of air, he observes dark and bright fringes that are uniformly spaced. The initial and final position of his eye is shown in Fig. 8.3. At the final position, he is looking at the fifth order dark fringe.

Given that the wavelength of the light directed at the glass plates is 550 nm, determine the thickness of air *t'* at this position.

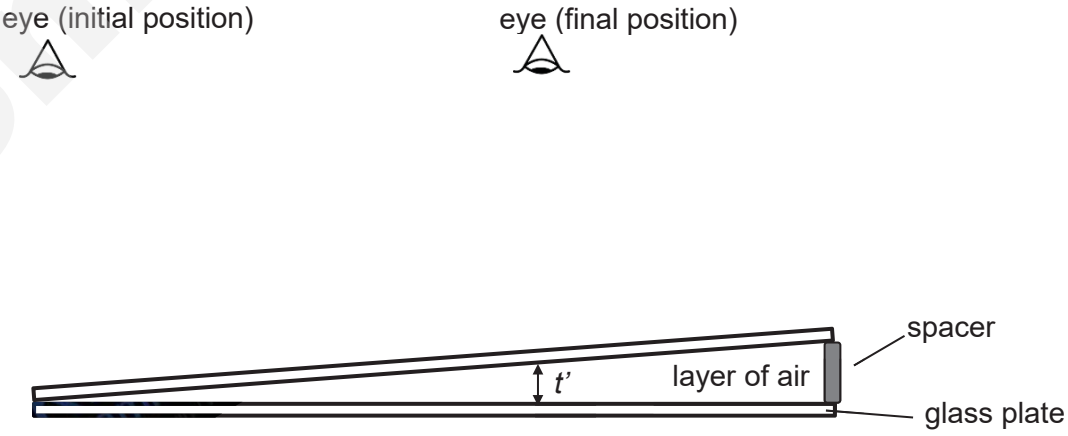


**Fig. 8.3**

**Path diff = 4.5λ =2t**

**t = 1.24 x $10^{-6}$ m**

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thickness $t'$ = ..... [2]

**(iii)** White light of wavelength ranging from 400 nm to 700 nm is now incident on the thin wedge of air. At a certain thickness, a violet colour is observed where violet colour is due to overlapping of red and blue colours.

Explain this observation.

**Red colour has a wavelength close = 700 nm and blue colour has a wavelength close to 400 nm. Hence 3(400) can be numerically close to 2(700). They can have the same physical path difference.**

..... [2]

**(iv)** In reality, Ray B will undergo a phase change of 180° when it is reflected but there is no phase change for Ray A.

Suggest why the thickness of air cannot be smaller than one quarter of the wavelength in order to observe a bright fringe.

**Minimum path diff will be 1/2λ to observe the bright fringe.**

**Since 2t = 1/2λ, min t = 1/4λ.**

..... [1]

[Total: 20]

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9 (a) (i) Explain what is meant by the binding energy of a nucleus.

**It is the energy required to separate the nucleons in a nucleus to infinity.** [1]

The variation of the binding energy per nucleon with nucleon number of all the different nuclei is shown in Fig. 9.1.

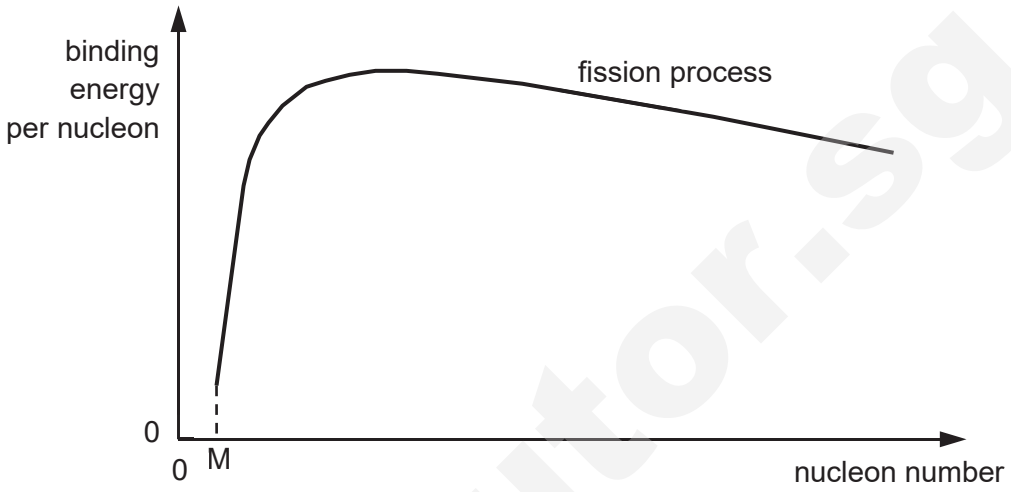


**Fig. 9.1**

(ii) State the value of M and explain your answer clearly.

Value of M is 2. If the nucleon number is only 1, it cannot be separated further. Hence the minimum number of nucleons needed to form a nucleus is 2. [2]

(b) In a fission process, a neutron with speed of $2.00 \times 10^3$ m $s^{-1}$ collides with a Uranium-235 nucleus and causes a nuclear reaction summarised in the following equation.

$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{143}_{54}Xe + {}^{90}_{38}Sr + 3\,{}^{1}_{0}n + \text{energy} $$

(i) Using the data from Fig. 9.2, show that the binding energy per nucleon for Strontium-90 is 8.73 MeV.

| | rest mass |
|---|---|
| Strontium, $^{90}_{38}Sr$ | 89.9077 u |
| Proton, $^{1}_{1}p$ | 1.0078 u |
| Neutron, $^{1}_{0}n$ | 1.0087 u |

**Fig. 9.2**

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Mass defect = $(38m_p + 52m_n) - m_{nucleus}$

= (38)(1.0078u) + (90-38)(1.0087u) – 89.9077 u = 0.8411 u.

BE = mass defect × $c^2$ = $(0.8411 \times 1.66 \times 10^{-27})(3.00 \times 10^8)^2(1/1.60 \times 10^{-19})$ eV

= 785 MeV

Hence BE per nucleon = BE/n = 8.73 MeV

[3]

**(ii)** Hence calculate the total energy released during the nuclear fission reaction. Data for binding energies per nucleon are shown in Fig. 9.3.

| Isotope | binding energy per nucleon / MeV |
|---|---|
| Uranium-235 | 7.59 |
| Xenon-143 | 8.41 |

Energy released = $(\text{total B.E.})_{products} - (\text{total B.E.})_{reactants}$

= $[(90)(8.73) + (143)(8.41) - (235)(7.59)] \times 10^6 \times 1.60 \times 10^{-19}$ J

= $3.27 \times 10^{-11}$ J

energy released = ..... J [2]

**(iii)** Explain quantitatively why the kinetic energy of the neutron directed at Uranium-235 is neglected.

KE of neutron = $(1/2mv^2) = (1/2)(1.0087 \times 1.66 \times 10^{-27})(2.00 \times 10^3)^2$

= $3.35 \times 10^{-21}$ J

Since KE of neutron << energy released, it is neglected.

..... [1]

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**(c)** Fig. 9.4 shows the possible directions of Strontium-90, Xenon-143, and neutrons when nuclear fission takes place. Assume that this is an isolated system.

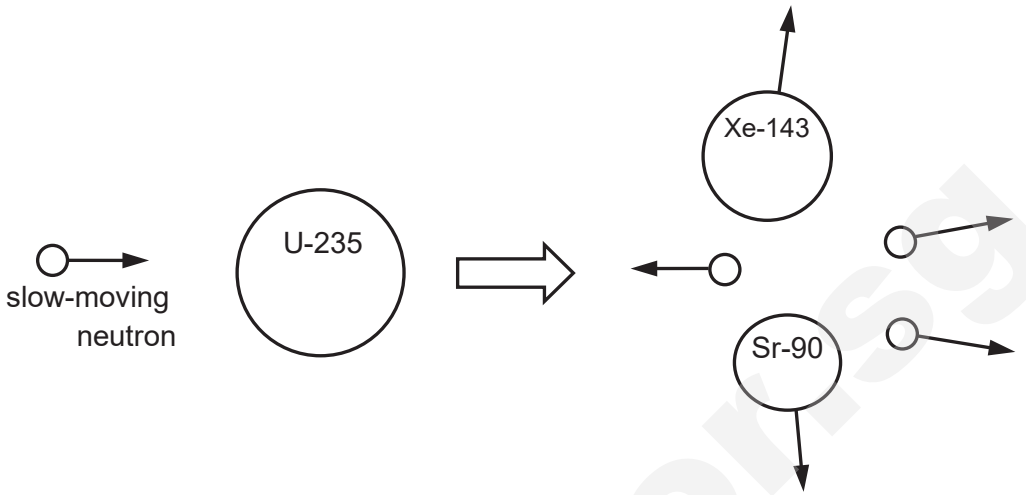


**Fig. 9.4**

**(i)** Explain why it is unlikely for the two fission products to move in the same direction after the fission process.

The total initial momentum of the reactants is close to zero as the neutron is slow moving. By principle of conservation of linear momentum, the total momentum of the products should be close to zero as well. Since the two fission products are much more massive than the neutrons released, the neutrons will have to travel approximately in the opposite direction of the two fission products with speeds much larger than them such that the total momentum is approximately zero. This may not be energetically possible and it is unlikely for the two fission products to move in the same direction. [1]

**(ii)** The total momentum of two fission products and neutrons after reaction is not zero even though the total momentum of Uranium-235 and slow moving neutron may be taken to be zero. Explain why this may be so.

Part of the energy released may be due to photon such as gamma radiation. The momentum of photon may need to be taken into consideration since here is a emission of gamma photon. The photon will move off in a direction such that the vector sum of the total final momentum will be zero. [2]

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**(d)** Neutrons emitted from a nuclear fission may hit another Uranium-235 nucleus, causing a chain reaction.

**(i)** To control the reaction, neutrons emitted from a fission reaction may be slowed down by Carbon-12 nuclei, $^{12}_{6}C$. Show that when a neutron undergoes an elastic head-on collision with a Carbon-12 nucleus as shown in Fig. 9.5, the speed is reduced by about 15%.

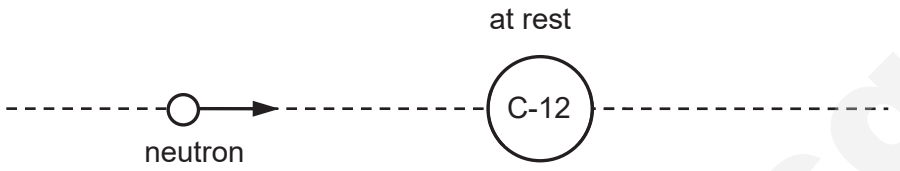


**Fig. 9.5**

$\Sigma p_{inital} = \Sigma p_{final}$

$(m)(u) = m(v_1) + (12m)(v_2)$

apply relative speed equation

$v_2 - v_1 = u$

Solving

$v_1 = -0.85\ u$

[3]

**(ii)** On average, the neutron speed after each collision is 0.93 of its speed before the collision.

Suggest why this speed reduction is different from what is stated in **(ii)** for a nuclear reactor.

The collision is unlikely to be always head-on and hence the kinetic energy transferred to C-12 will be less. Hence the speed reduction will be lesser.

[1]

**(iii)** Suggest why a slow neutron has a higher chance of being captured by U-235 to cause a fission reaction compared to a fast neutron.

The probability that fission will occur is described by the neutron cross-section. The fission cross-section increases greatly when the speed reduces making the likelihood of interaction with U-235 greater.

[1]

**(e)** The fission products are usually radioactive and give rise to a series of radioactive decay products. Each decay product has its own half life, but eventually a stable nuclide is reached.

One such fission product and its decay products is shown here:

$$^{143}_{54}Xe \longrightarrow ^{143}_{55}Cs \longrightarrow ^{143}_{56}Ba$$

The half-life of Xe-143 and Cs-143 are 0.511 s and 1.79 s respectively.

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**(i)** Suggest how the number of Cs-143 nuclei inside the nuclear reactor may remain constant even when it decays to form Ba-143.

Cs-143 is continuously formed from the decay of Xe-142. The number of Cs-143 may remain constant if the rate of decay of Xe is equal to the rate of decay of Cs.

[2]

**(ii)** Explain why a particular Xenon-143 nucleus produced earlier in the reaction may not necessarily decay before another Xenon-143 nucleus which was produced after it.

Due to the **random** nature of radioactivity decay, the probability of decay of a nucleus (per unit time) is constant (and the same for all radioactive Xe-143 nuclei). Hence, there is possibility that Xenon produced at a later time may decay first.

[1]

[Total: 20]

**End of Paper**

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H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME **SOLUTION**

CLASS | TUTOR'S NAME

CENTRE NUMBER S | INDEX NUMBER

# PHYSICS

**9749/04**

Paper 4 Practical Paper

**21 August 2019**

**2 hours 30 minutes**

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions.

**READ THESE INSTRUCTIONS FIRST**

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

Answer **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| Total | / 55 |



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1 In this experiment, you will investigate how the deflection of a wooden strip depends on the distribution of the load on the strip.

**(a)** **(i)** Lay the wooden strip flat on the bench.
Place the ten slotted masses along the strip, as shown in Fig. 1.1.

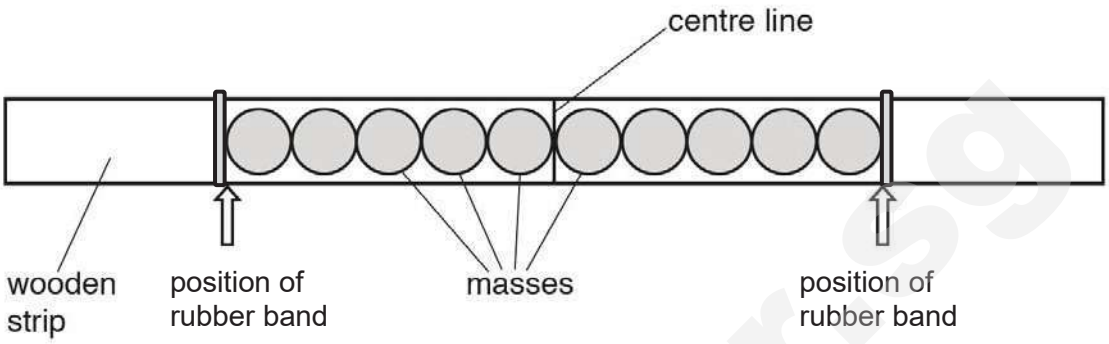


**Fig. 1.1**

**(ii)** Use a rubber band to mark the position of each end of the row of masses, as shown in Fig. 1.1.

**(iii)** Remove the masses.

**(iv)** Measure and record the distance *D* between the marks, as shown in Fig. 1.2.

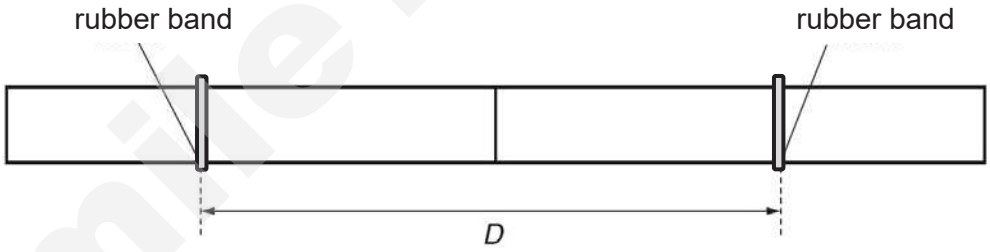


**Fig. 1.2**

*D* = .....39.9 cm..... [1]

**(b)** **(i)** Place the strip on the two wooden blocks with the inner edges of the blocks at the rubber bands, as shown in Fig.1.3.

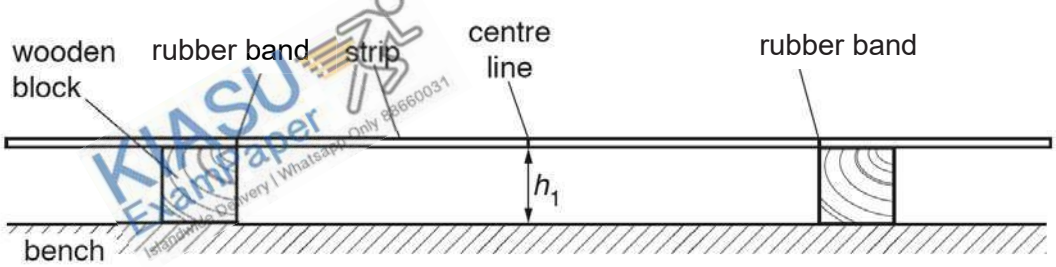


**Fig. 1.3**

**(ii)** Measure and record the height $h_1$ of the **bottom** of the strip at the centre line, as shown in Fig. 1.3.

$h_1$ = .....6.9 cm.....

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**(c)** **(i)** Replace the masses on the strip and ensure the blocks are still positioned at the rubber bands. Measure and record the height $h_2$ of the bottom of the strip at the centre line, as shown in Fig. 1.4.

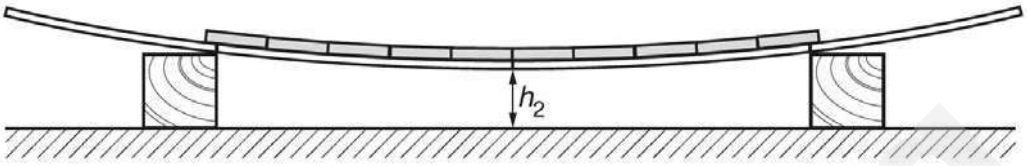


**Fig. 1.4**

$h_2$ = .....5.7 cm..... [1]

**(ii)** Calculate $d$, where $d = h_1 - h_2$.

$d$ = .....1.2 cm..... [1]

**(d)** Estimate the percentage uncertainty in your value of $d$.

$$\text{percentage uncertainty} = \frac{0.2}{1.2} \times 100\%$$
$$= 17\%$$

percentage uncertainty = .....17%..... [1]

**(e)** **(i)** Remove the masses from the strip.

**(ii)** Ensure the blocks are still positioned at the rubber bands. Measure and record the height $h_3$ of the bottom of the strip at the centre line.

$h_3$ = .....6.8 cm.....

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**(iii)** Place all the masses at the centre line, as shown in Fig. 1.5.

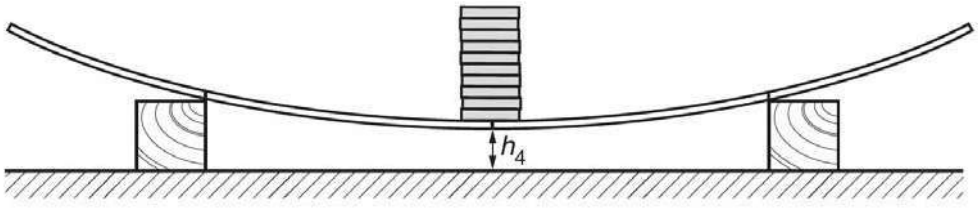


**Fig. 1.5**

**(iv)** Ensure the blocks are still positioned at the rubber bands, then measure and record the height $h_4$ of the bottom of the strip at the centre line.

$h_4$ = .....5.0 cm.....

**(v)** Calculate $p$, where $p = h_3 - h_4$.

$p = 6.8 - 5.0$

$= 1.8$ cm

$p$ = .....1.8 cm..... [1]

**(f)** Estimate the percentage uncertainty in your value of $p$.

$$\text{percentage uncertainty} = \frac{0.2}{1.8} \times 100\%$$

$$= 11\%$$

percentage uncertainty = ..... 11%..... [1]

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**(g)** **(i)** Remove the masses.

**(ii)** Measure the thickness $t$ and the width $w$ of the strip, as shown in Fig. 1.6.

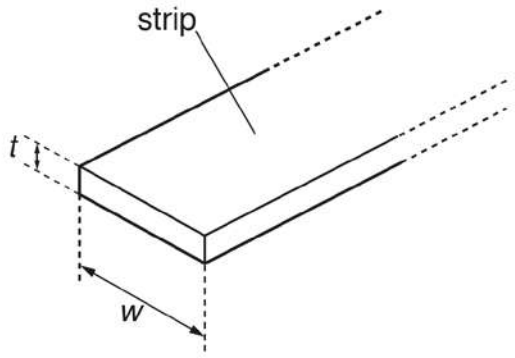


**Fig. 1.6**

$t$ = .....3.00 mm.....

$w$ = .....6.0 cm..... [1]

**(iii)** Calculate the Young modulus $E$ for the material of the strip using

$$E = \frac{FD^3}{4pwt^3}$$

where $F$ = 10.0 N.

$$E = \frac{FD^3}{4pwt^3}$$

$$= \frac{10.0\left(39.9\times10^{-2}\right)^3}{4\left(1.8\times10^{-2}\right)\left(6.0\times10^{-2}\right)\left(3.00\times10^{-3}\right)^3}$$

$$= 5.4\times10^{9}\ \text{N m}^{-2}$$

$E$ = ..... [1]

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**(g)** Repeat **(a)**, **(b)**, **(c)** and **(e)** using **eight** masses.

$D$ = .....31.7 cm.....

$h_1$ = ..... 6.9 cm.....

$h_2$ = ..... 6.4 cm.....

$d$ = ..... 0.5 cm.....

$h_3$ = ..... 6.9 cm.....

$h_4$ = ..... 6.1 cm.....

$p$ = ..... 0.8 cm.....

[2]

**(h)** It is suggested that the relationship between $d$ and $p$ is

$$d = k\,p$$

where $k$ is a constant.

**(i)** Using your data, calculate two values of $k$.

$$k = \frac{d}{p} \qquad k = \frac{d}{p}$$
$$= \frac{1.2}{1.8} \qquad = \frac{0.5}{0.8}$$
$$= 0.67 \qquad = 0.6$$

first value of $k$ = .....0.67.....

second value of $k$ = ..... 0.6.....

[2]

**(ii)** Justify the number of significant figures you have given for your values of $k$.

$k$ is recorded to the least significant figure (s.f.) of the data used for its computation i.e. 2 and 1 s.f. respectively.

[1]

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**(iii)** State whether the results of your experiment support the suggested relationship.

Justify your conclusion by referring to your values in **(d)** and **(f).**

$$\text{percentage difference} = \frac{k_1 - k_2}{k_2} \times 100\%$$
$$= \frac{0.67 - 0.6}{0.6} \times 100\%$$
$$= 12\%$$

Since percentage difference of $k$ is 12% which is lower than the percentage uncertainty of $d$ found in **(d)**, the values of $k$ cannot be considered close and hence my results do not support the suggested relationship.

[2]

[Total: 15]

**2** In this experiment, you will investigate stationary wave patterns.

**(a)** You are provided with a piece of string. The piece of string has a 10 g mass attached to one end.

Using the string, assemble the apparatus as shown in Fig. 2.1.

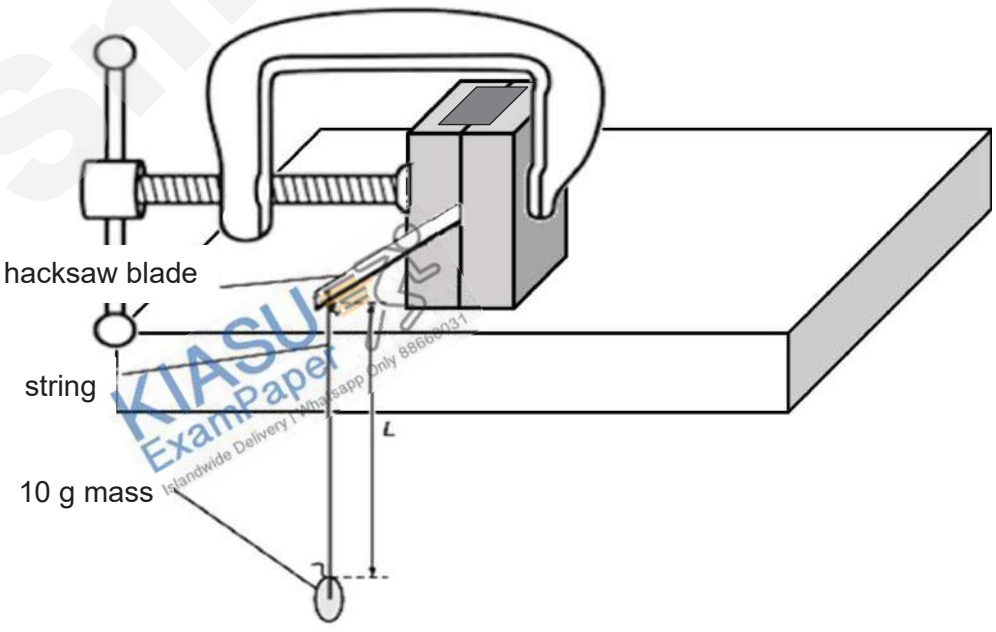


**Fig. 2.1**

The length of string between the hacksaw blade and the 10 g mass is $L$, as shown in

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Fig. 2.1. Measure and record *L*.

*L* = 57.2cm ..... [1]

**(b)** The length of hacksaw blade outside the blocks is *x*, as shown in Fig. 2.2.

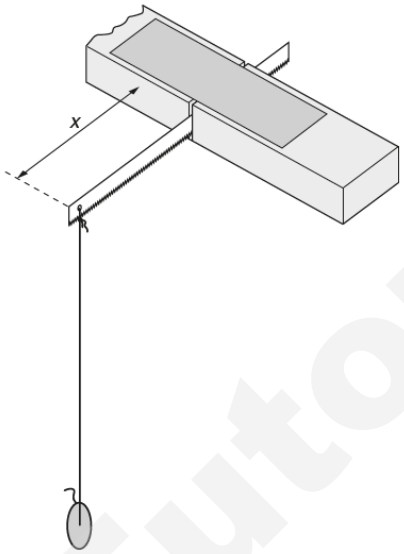


**Fig. 2.2**

When the end of the hacksaw blade is moved a small distance to one side and released, the string vibrates.

For certain values of *x*, the string vibrates in stationary wave patterns. Examples of these λpatterns are shown in Fig. 2.3.

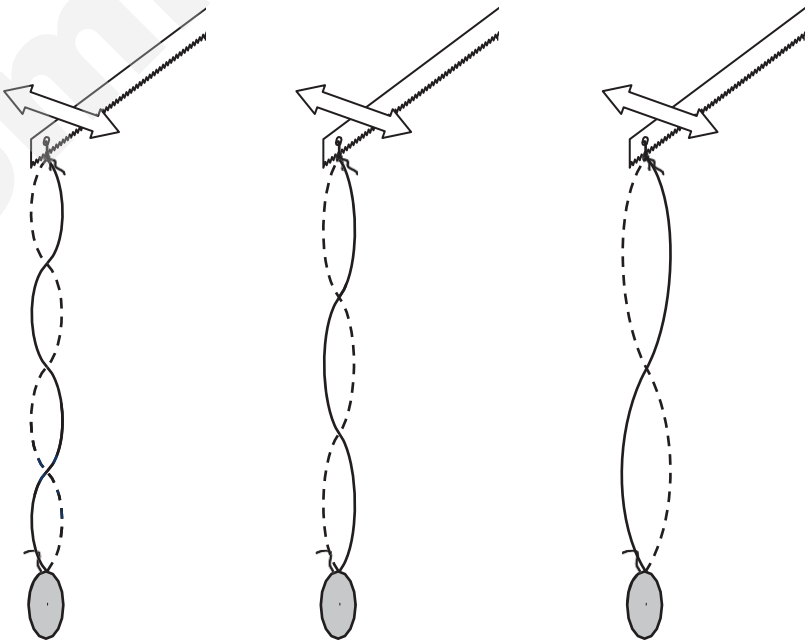


**Fig. 2.3**

**(ii)** Press down on the clamp so that the blocks rest on the tabletop as shown in

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Fig. 2.1. Move the end of the hacksaw blade a small distance to one side and release it.

**(iii)** Change $x$ in small steps. Keep changing $x$, testing for a pattern at each step, **until the pattern B with three loops is clearly produced**.

Measure and record $x$.

$x$ = ..... [2]

**(iii)** Estimate the percentage uncertainty in your value of $x$.

Percentage uncertainty = $\frac{0.3}{13.2} \times 100\% = 2\%$

percentage uncertainty = 2% ..... [1]

**(c)** Calculate the value of $\lambda$ in metres, using

$$\lambda = \frac{2}{n} L$$

where n is the number of loops observed.

$\lambda = \frac{2}{3} L = \frac{2}{3}(0.572) = 0.381$ m

$\lambda$ = 0.381 m ..... m [1]

**(d)** Justify the number of significant figures you have given for your value of $\lambda$.

λ is calculated to 3 significant figures because it was calculated using L which was recorded to 3 significant figures. L was measured using a meter rule, which could be read to 1 mm, giving 3 significant figures to the value of L. [1]

**(e)** You are provided with a card stating the mass per unit length $\mu$ of the string.

**(i)** Record the value of $\mu$ from the card.

$\mu$ = 0.00210 ..... kg $m^{-1}$

**(ii)** Calculate the frequency $f$ of the vibrations, using

$$f = \frac{1}{\lambda}\sqrt{\frac{mg}{\mu}}$$

where $m$ = 0.010 kg and $g$ = 9.81 m $s^{-2}$.

$f = \frac{1}{0.381}\sqrt{\frac{(0.010)(9.81)}{0.00210}} = 17.9$ Hz

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17.9

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*f* = ..... Hz [1]

[Total: 7]

**3** Many electrical components have to function properly in conditions of extreme temperature and moisture content. In this experiment you will maintain a diode at five degrees Celsius and investigate how the current in it varies as the potential difference across it is changed.

**(a)** Set up the circuit shown in Fig. 3.1. The 10 Ω resistor is to prevent current overload in the diode.

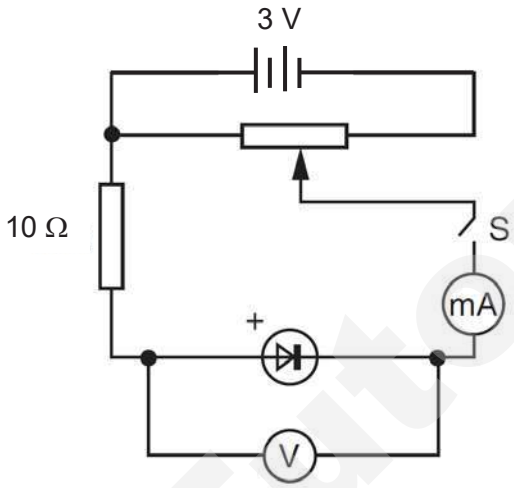


**Fig. 3.1**

**(b)** Close switch S.

Put 50 ml of water into the beaker. Place the diode in the water.

Close switch S. Measure and record the current *I* when the potential difference *V* across the diode is 0.50 V.

*I* = 0.203 V .....

**(c)** Add a quantity of ice to the water in the beaker.

Stir the ice/water mixture gently using the thermometer until the temperature is at, or close to, 5 °C.

**(j)** Record the temperature. You are to maintain the temperature for the rest of the experiment to be within 2 °C of your recorded temperature.

temperature of ice/water mixture = 5.0 °C ..... [1]

**(ii)** Measure and record the current *I* when the potential difference *V* across the diode is 1.0 V.

*I* = 0.399 mA ..... [1]

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**(d)** Vary the resistance of the rheostat and repeat **(c)(ii)** until you have five more sets of readings for *V* and *I*. You should keep the range of *V* between 1.0 V and 2.0 V.

| V/V | I/mA | ln (I/mA) |
|---|---|---|
| 1.00 | 0.399 | -0.919 |
| 1.20 | 0.547 | -0.603 |
| 1.40 | 0.703 | -0.352 |
| 1.60 | 0.827 | -0.190 |
| 1.80 | 0.993 | -0.007 |
| 2.00 | 1.072 | 0.070 |

[6]

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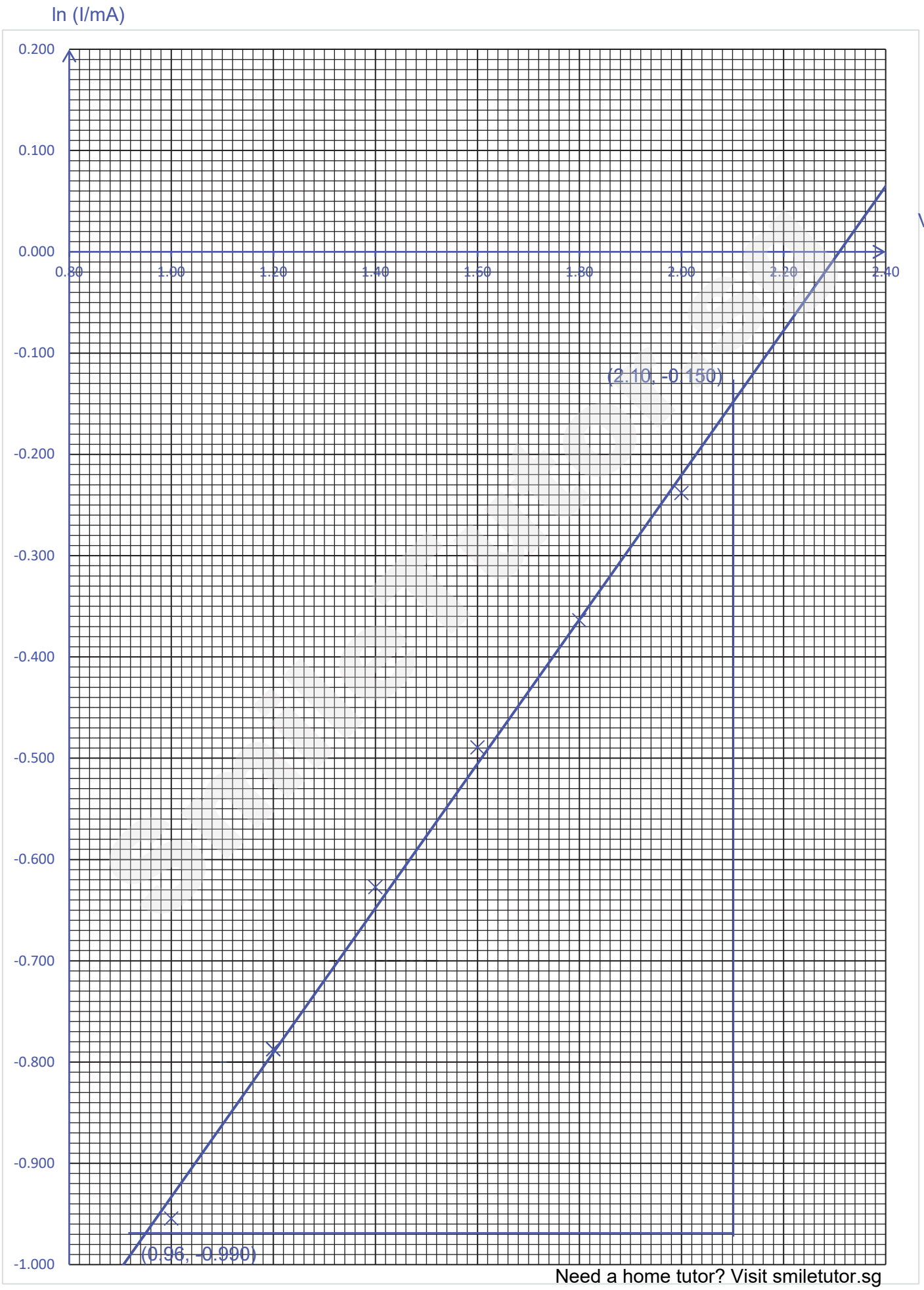


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**(e)** A simplified expression relating the current $I$ in the diode to the potential difference $V$ is

$$I = I_o e^{\frac{aV}{kT}}$$

where $k$ is the Boltzmann constant of $1.38 \times 10^{-23}$ J K$^{-1}$, $a$ is a constant, $T$ is the temperature of diode in kelvin, and $I_o$ is a constant.

Plot a suitable graph to determine the values of $a$ and $I_o$.

Linearising the equation $\ln I = \ln I_o + \frac{a}{kT}V$

A graph of $\ln I$ vs $V$ would give a gradient of $\frac{a}{kT}$ and a $y$-intercept of $\ln I_o$.

gradient= $\frac{-0.150-(-0.990)}{2.10-0.96}$=0.737

y-intercept = -0.150 - gradient (2.10) = -0.150 - (0.737) (2.10) = -1.70

A = k T (gradient) = $(1.38 \times 10^{-23})$ (273.15+5.0) (0.737) = $2.82 \times 10^{-21}$ C

$I_o = e^{\text{y-intercept}}$ = 0.183 mA

$a$ = .....

$I_o$ = .....

[3]

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(f) Using the expression in (e), calculate the current in the diode if it were placed in boiling water with a potential difference of 1.0 V applied across it.

$$I = I_o e^{\frac{eV}{kT}} = (0.183)\, e^{\frac{(2.82\times10^{-21})(1.0)}{(1.38\times10^{-23})(273.15+100.0)}} = 0.317 \text{ mA}$$

$I$ = ..... [1]

(g) (i) Suggest one significant source of error in this experiment.

.....

.....

..... [1]

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

.....

.....

..... [1]

Possible source of errors:

- Temperature of mixture non-uniform

Possible improvements

- Continuous stirring

[3]

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**(h)** A manufacturer wishes to put this diode in their product where the operating temperature is between room temperature and 300 °C.

The simplified expression in **(e)** is only valid for temperatures less than a critical value.

Plan an investigation to determine the critical temperature of the diode.

Your account should include:

- your experimental procedure
- control of variables
- how you would determine the critical temperature.

Experimental procedure:

- Use of oil bath with heater to get temperature range stated ( room to 300°C).
- Use of thermometer to measure the temperature.
- Vary setting in heater/power supply to change the temperature of oil bath, heat source need to be mentioned.
- Temperature of oil bath has to be increasing, not decreasing. It may fail and malfunction beyond the critical temperature.
- Should not be using ice and lower temperature, since requirement is room to 300°C

Control of variables:

- Keeping voltage constant using a rheostat /variable power supply.

Determination of critical temperature:

$$I = I_o e^{\frac{aV}{kT}}$$

- Plot a graph of lnI vs 1/T.
- The critical temperature is determined by looking at the point which the graph start to deviate from the best fit line.
- Not anomalous point.

[Total: 21]

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**4** A student is investigating how the intensity of the reflection of sound from a wall depends on the thickness of foam attached to the wall and the frequency of the sound, as shown in Fig. 4.1.

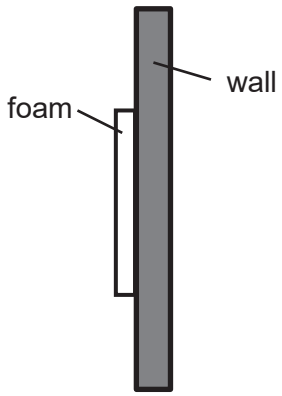


**Fig. 4.1**

It is suggested that the intensity $I$ of the reflected sound is related to the thickness $t$ of the foam and frequency $f$ by the relationship

$$I = At^x f^y$$

where $A$, $x$ and $y$ are constants.

You are provided with a number of pieces of foam of different thickness. You may also use any other equipment usually found in the physics laboratory.

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

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

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

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**Method of data collection [6](M)**

**Methods/instruments to measure D.V.**

- measure I (or amplitude of reflected signal) from CRO/sound meter.

**Methods/instruments to measure I.V.**

- Measure the thickness with a rule/micrometer/vernier calipers.
- Calculate f using f = 1/T and measure T from c.r.o.

**Method to vary the I.V**

- Use of signal generator to vary f and use foams of different thickness.

**Method to create the condition in order to measure the I.V. / D.V. may be required.**

- Labelled diagram of workable experiment including speaker, microphone/sound detector, foam and wall and position of microphone should not in the way of the incident sound on the wall.

**Method of analysis [3]**

- Plot a graph of lg I vs lg t keeping f constant.

  Plot a graph of lg I vs lg f keeping t constant
- x and y = gradient of each graph.
- $A = 10^{\text{y-intercept + ylgf}}$ OR $A = 10^{\text{y-intercept - xlgt}}$

**Additional detail (max 3)**

**A list of specific steps taken to taken to further improve accuracy of results or good experimental practice.**

1) Detailed time-base calculation (eg. T = time base setting x no. of div for 1 complete wave shown on CRO.)
2) Carry out experiment in a quiet room/no other sources of sound
3) Method to keep angles constant/positions of speaker and microphone constant.
4) Make sound large so that the intensity is more measurable.
5) Detailed method to determine amplitude/I from c.r.o, i.e. amplitude (height) × y-gain
6) Control of variable: (i) Keep distance of loudspeaker and microphone from foam constant or (ii) temperature
7) Take preliminary readings in order to check the range of the independent variable that would cause significant change in the dependent variable could be investigated.

**Safety precautions [1]**

- Precaution linked to **loud sounds** (not high frequency), e.g. use ear plugs/muffs/defenders. Allow switch off sound source to prevent damage to ears due to loud noise.

[12]

[Total: 12]

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**NATIONAL JUNIOR COLLEGE**
**SENIOR HIGH 2 Preliminary Examination**
Higher 2

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| SUBJECT CLASS | | REGISTRATION NUMBER | |

# PHYSICS

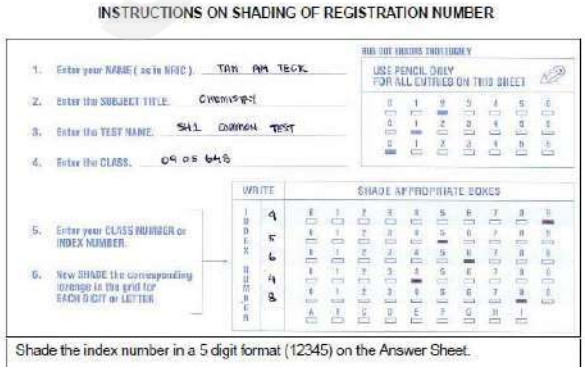
**9749/01**

Paper 1 Multiple Choice

Additional Materials: Multiple Choice Answer Sheet

**19 September 2019**
**1 hour**

**READ THE INSTRUCTION FIRST**
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.
There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.
**Read the instructions 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.




OAS index number is in 5-digit format.

5 digit format: **2nd digit** and the **last four digits** of the Reg Number.

This document consists of **18** printed pages and **2** blank pages**.**

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**[Turn over**

**Data**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -Gm/r$ |
| temperature | $T/\text{K} = T/^\circ\text{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin\omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos\omega t$<br>$= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current / voltage | $x = x_0 \sin\omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** A person is standing still on the ground.

Which value is an estimate of the pressure exerted by the person's feet on the ground?

**A** 120 Pa

**B** 1 200 Pa

**C** 12 000 Pa

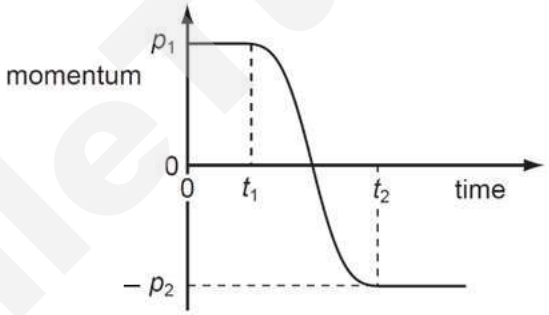
**D** 120 000 Pa

**2** Ball A is projected horizontally at 2.0 m $s^{-1}$ from the top of a vertical cliff while Ball B is released from rest 1.0 s later from the same point. It took Ball B 3.5 s to reach the base of the cliff.

How far from the base of the cliff will Ball A hit the ground?

**A** 7.0 m **B** 9.0 m **C** 53 m **D** 67 m

**3** The graph shows the variation with time of the momentum of a ball as it is kicked in a straight line.




At time $t_1$, the momentum is $p_1$. At time $t_2$, the momentum is $p_2$.

What is the magnitude of the average force acting on the ball between times $t_1$ and $t_2$?

**A** $\frac{p_1 - p_2}{t_2}$

**B** $\frac{p_1 - p_2}{t_2 - t_1}$

**C** $\frac{p_1 + p_2}{t_2}$

**D** $\frac{p_1 + p_2}{t_2 - t_1}$

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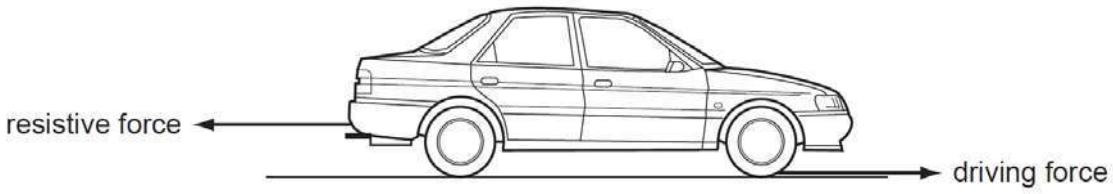
**4** A car of mass 750 kg has a horizontal driving force of 2.0 kN acting on it. It has a forward horizontal acceleration of 2.0 m $s^{-2}$.




What is the resistive force acting horizontally?

**A** 0.5 kN

**B** 1.5 kN

**C** 2.0 kN

**D** 3.5 kN

**5** An object, made from two equal spherical masses joined by a light rod, falls with uniform velocity through air.

The rod remains horizontal.

Which statement about the equilibrium of the system is correct?

**A** It is not in equilibrium because it is in motion.

**B** It is not in equilibrium because there is a resultant force.

**C** It is in equilibrium because there is no resultant torque.

**D** It is in equilibrium because there is no resultant force and no resultant torque.

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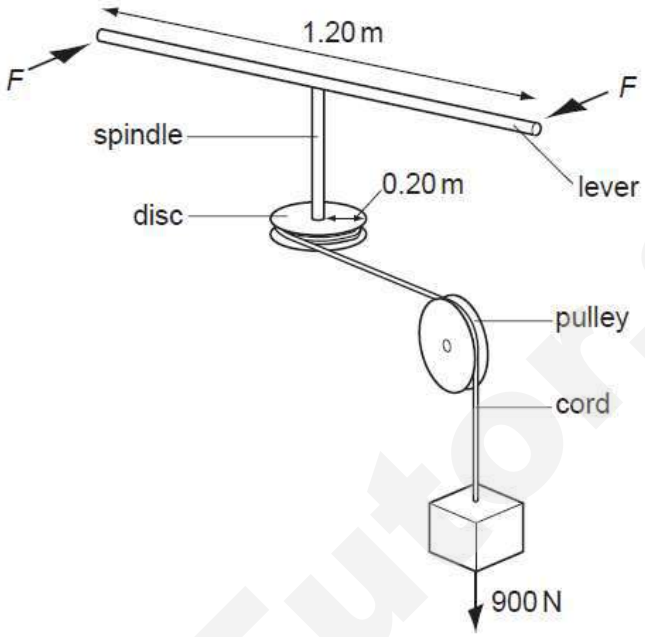
**6** One end of a spindle is attached to the centre of a lever of length 1.20 m and its other end is attached to the centre of a disc of radius 0.20 m as shown in the figure below.

A cord is wrapped around the disc, passes over a pulley and is attached to a 900 N weight at one end.




The mass of the lever, spindle, disc, cord and pulley is assumed to be negligible. Equal and opposite forces of magnitude F is applied to each end of the lever.

Ignoring frictional forces, what is the minimum value of F needed to balance the 900 N weight?

**A** 75 N

**B** 150 N

**C** 300 N

**D** 950 N

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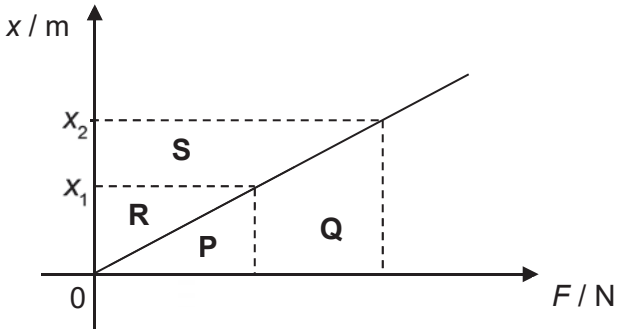
**7** The variation with force *F* of the extension *x* of a spring is shown in the figure below.




The work done in stretching the spring from $x_1$ to $x_2$ is given by the area

**A** P + Q

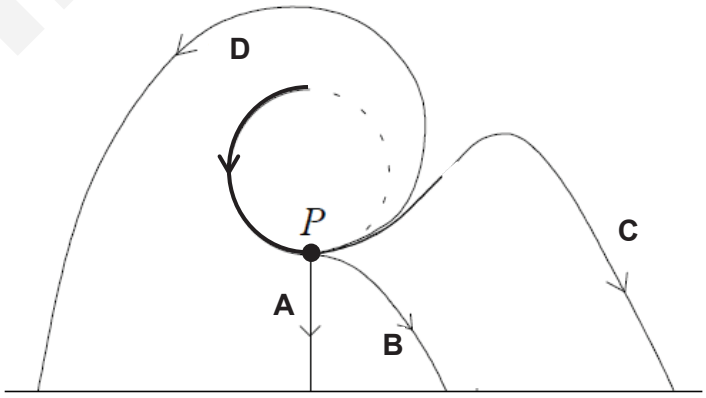
**B** S

**C** R + S

**D** Q

**8** A stone, tied to a piece of string, is whirled in a vertical circle as shown in the figure below. The string suddenly breaks at *P*.

Which of the paths (A to D) represents a possible path for the stone from just before the string breaks until the stone hits the ground?

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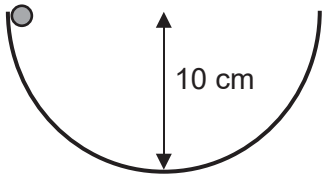
**9** A small object of mass 0.050 kg is released from rest at the rim of a heavy, smooth semi-spherical bowl of radius 10 cm as shown in the figure below.




When the object passes the bottom of the bowl, what is the normal force exerted on it by the bowl?

**A** 0.49 N **B** 0.98 N **C** 1.5 N **D** 2.0 N

**10** Taking the Earth to be a perfect sphere of uniform density rotating about its polar axis, which of the following statements concerning the observed acceleration due to free fall $a$ at the surface of the Earth is true?

**A** The value of $a$ at the equator is larger than that at the poles.

**B** If the rate of rotation of the Earth decreases, the value of $a$ at the equator increases.

**C** If the radius of the Earth increases with its density remaining unchanged, the value of $a$ at the poles decreases.

**D** If the radius of the Earth increases with its density remaining unchanged, the value of $a$ at the equator decreases.

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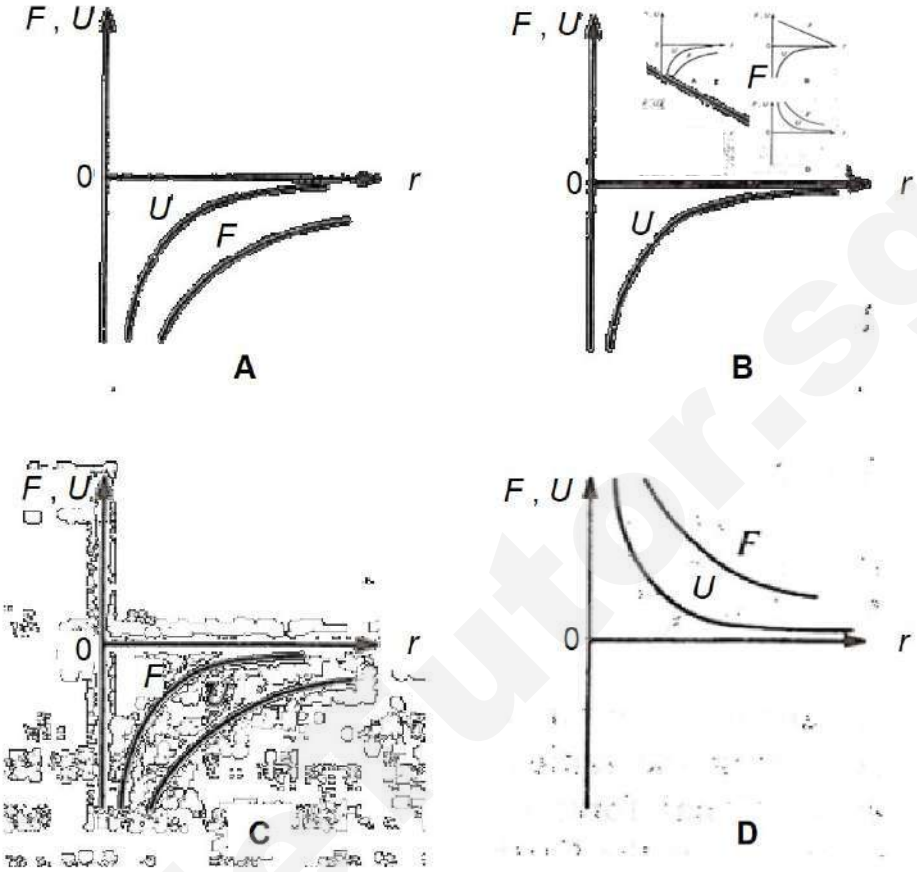
**11** Which one of the following diagrams shows the variation of gravitational force *F* on a point mass and gravitational potential energy *U* of the mass at a distance *r* from another point mass?




**12** 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** 11%

**D** 12%

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**13** The specific latent heat of vaporisation of water at 20 °C is appreciably greater than the value at 100 °C. This is because

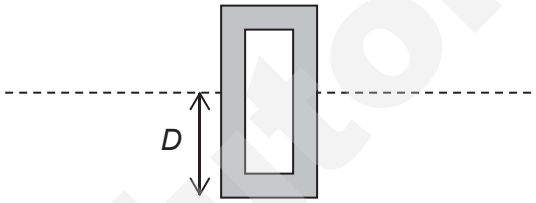
**A** the specific latent heat at 20 °C includes the energy to raise the temperature of one kilogram of water from 20 °C to 100 °C.

**B** more work must be done in expanding the water vapour against atmospheric pressure at 20 °C than at 100 °C.

**C** the molecules in the liquid are more tightly bound to one another at 20 °C than at 100 °C.

**D** vaporisation of water can only take place at 100 °C.

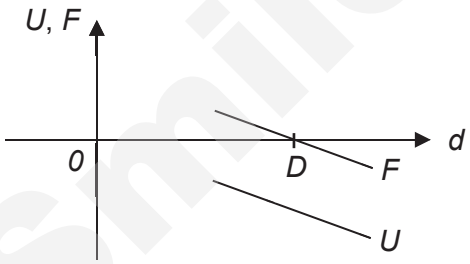
**14** A hollow metal cylinder floats upright in a body of water with the bottom of the cylinder at a depth *D* below the water surface as shown.



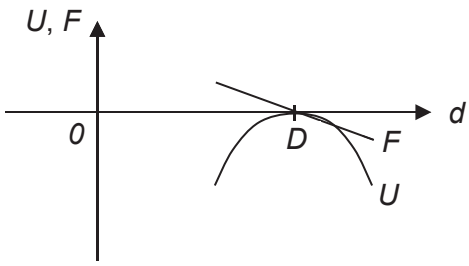

The cylinder is pressed further down into the water and upon release, performs simple harmonic motion.

Which of the following graphs (all drawn to scale) shows how the upthrust *U* and resultant force *F* acting on the cylinder vary with the depth *d* of the bottom of the cylinder below the water surface?

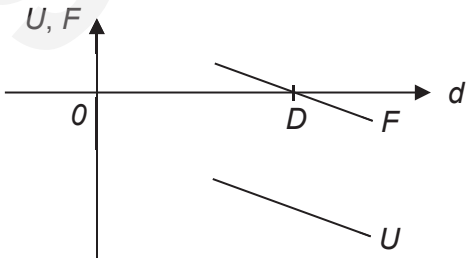
**A**



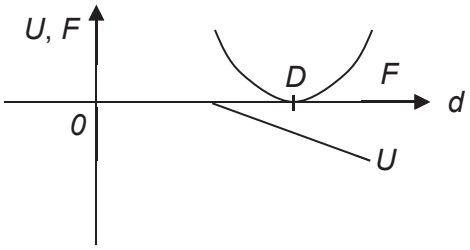

**B**




**C**




**D**

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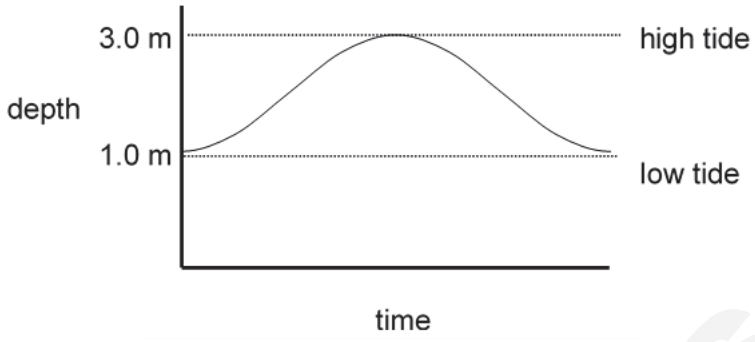
**15** The rise and fall of water in a harbour is simple harmonic. The depth varies between 1.0 m at low tide and 3.0 m at high tide. The time between successive low tides is 12 hours




A boat, which requires a minimum depth of water of 1.5 m, approaches the harbour at low tide. How long will the boat have to wait before entering?

**A** 0.5 hours **B** 1.0 hours **C** 2.0 hours **D** 2.5 hours

**16** When coherent monochromatic light falls on double slits, an interference pattern is observed on a screen some distance from the slits.

The fringe separation can be increased by

**A** decreasing the distance between the screen and the slits.

**B** increasing the distance between the slits.

**C** using monochromatic light of lower frequency.

**D** immersing the whole set up in water.

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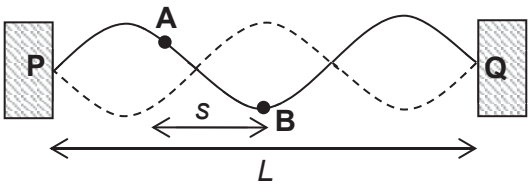
**17** A guitar string of length $L$ is stretched between two fixed points **P** and **Q** and made to vibrate transversely as shown below.




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

Which of the following gives the correct phase difference and relationship between maximum kinetic energies of the points?

| | phase difference | maximum kinetic energy |
|---|---|---|
| **A** | $\frac{3s}{2L} \times 360°$ | $K_A < K_B$ |
| **B** | $\frac{3s}{2L} \times 360°$ | same |
| **C** | 180° | $K_A < K_B$ |
| **D** | 180° | same |

**18** The images of two sources are just resolved.

Which of the following is a correct statement of the Rayleigh criterion for this situation?

**A** The central maximum of the diffraction pattern of one source must coincide with the central maximum of the diffraction pattern of the other source.

**B** Light from the sources must pass through a circular aperture.

**C** Light from the sources must be coherent.

**D** The first minimum of the diffraction pattern of one source must coincide with the central maximum of the diffraction pattern of the other source.

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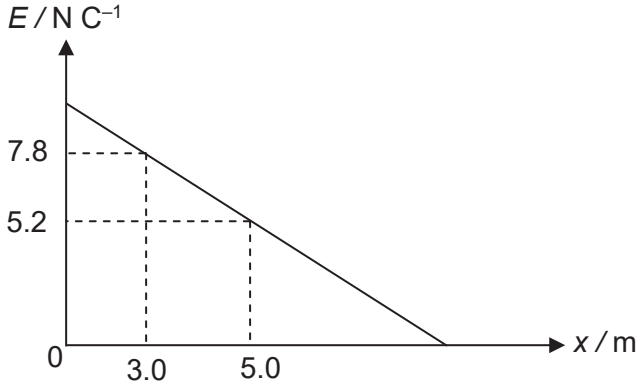
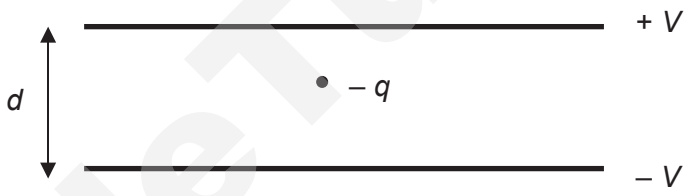
**19** The graph shows how the electric field strength $E$ varies with displacement $x$ from a point A.




What is the change in potential for an electron if it is moved from $x$ = 3.0 m to $x$ = 5.0 m?

**A** 13 V **B** – 13 V **C** 1.3 V **D** – 1.3 V

**20** An oil droplet has a charge $-q$ and is situated between two parallel horizontal metal plates as shown in the diagram.




The separation of the plates is $d$. The droplet is observed to be stationary when the upper plate is at potential $+V$ and the lower at potential $-V$.

For this to occur, the weight of the droplet is equal in magnitude to

**A** $\frac{Vq}{d}$ **B** $\frac{2Vq}{d}$ **C** $\frac{Vd}{q}$ **D** $\frac{2Vd}{q}$

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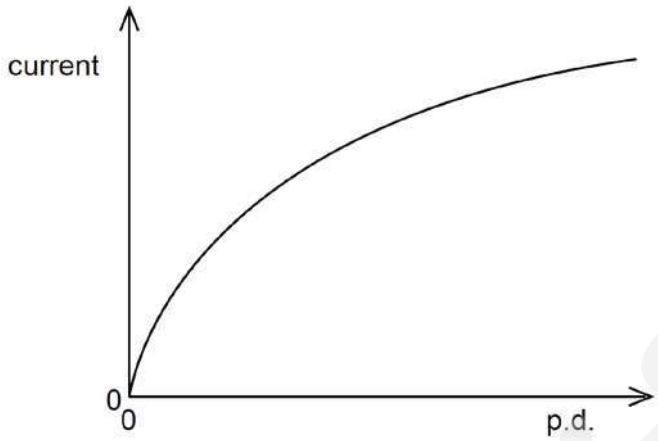
**21** The graph shows how the current through a lamp filament varies with the potential difference (p.d.) across it.




Which statement explains the shape of this graph?

**A** As the filament temperature rises, electrons can pass more easily through the filament.

**B** It takes time for the filament to reach its working temperature.

**C** The power output of the filament is proportional to the square of the current through it.

**D** The resistance of the filament increases with a rise in temperature.

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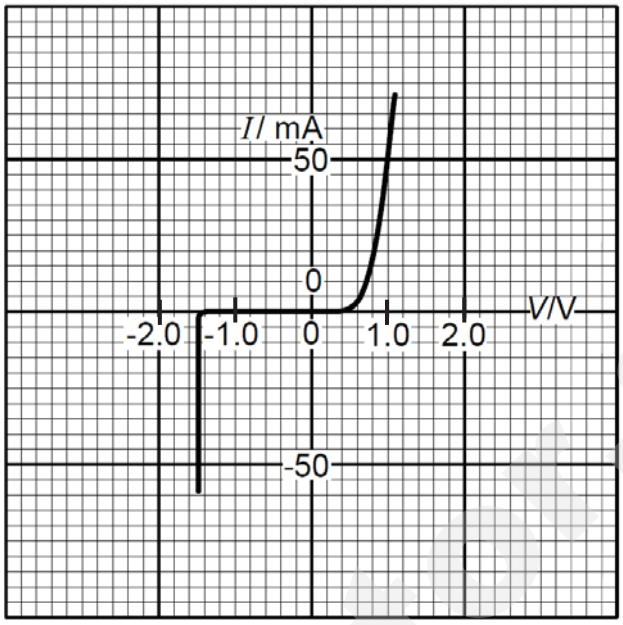
**22** The variation with potential difference $V$ of the current $I$ in a semiconductor diode is shown below.




What is the resistance of the diode for applied potential differences of +1.0 V and –1.0 V?

| | +1.0 V | –1.0 V |
|---|---|---|
| **A** | 20 Ω | infinite |
| **B** | 20 Ω | zero |
| **C** | 0.05 Ω | infinite |
| **D** | 0.05 Ω | zero |

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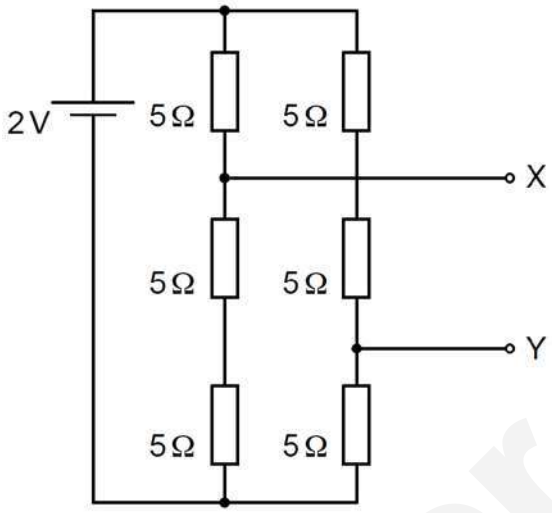
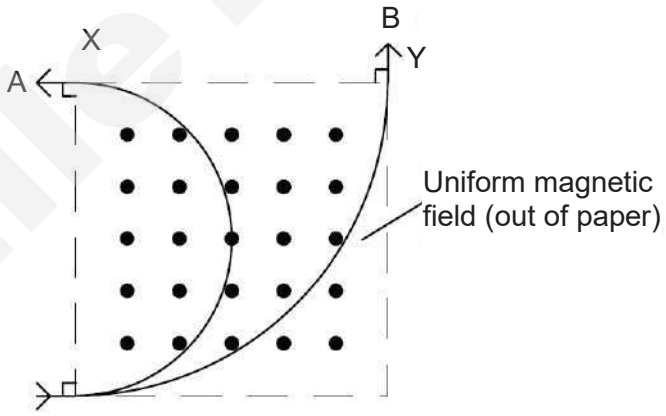
**23** Six resistors, each of resistance 5 Ω, are connected to a 2 V cell of negligible internal resistance.




What is the potential difference between terminals X and Y?

**A** 0.67 V **B** 0.89 V **C** 1.3 V **D** 2.0 V

**24** Particles *A* and *B*, both moving at the same speed, enter a square region of uniform magnetic field as shown in the figure below. Particle *A* leaves at □ while particle *B* leaves at □.




If the ratio of charge to mass of particle *A* is *k*, what is that of particle *B*?

**A** $\frac{k}{2}$ **B** $\frac{k}{4}$ **C** $2k$ **D** $4k$

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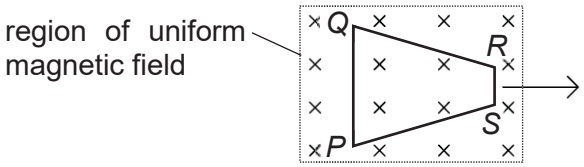
**25** A trapezoidal coil *PQRS* is moving with constant velocity in a direction perpendicular to a uniform magnetic field as shown in the figure below.




At the instant shown, which of the following statements is correct?

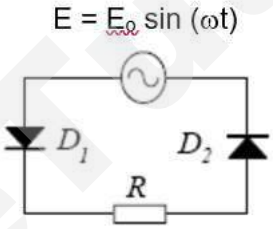
**A** An induced current it flowing in the coil in the clockwise direction.

**B** An induced current is flowing in the coil in the anticlockwise direction.

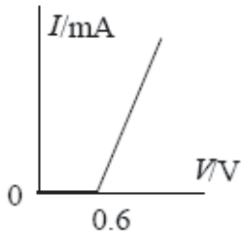
**C** There is no induced current flowing in the coil.

**D** An electromagnetic force acts on the side *PQ* in a direction opposing its motion.

**26** The circuit below shows the rectification of a sinusoidal a.c. supply using two identical diodes $D_1$ and $D_2$.




Each of the diodes has the *I*-*V* characteristics as shown.




For a current to flow through *R*, the value of $E_0$ must be at least

**A** 0.3 V

**B** $0.3\sqrt{2}$ V

**C** $0.6\sqrt{2}$ V

**D** $1.2\sqrt{2}$ V

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**27** Which piece of evidence about the photoelectric effect cannot be explained using a wave model?

**A** Increasing the intensity of the illumination increases the rate at which electrons are ejected.

**B** Shining ultraviolet radiation onto a zinc surface ejects electrons.

**C** Increasing the frequency of the radiation increases the kinetic energy of the ejected electrons.

**D** There is a minimum frequency of radiation below which no electrons are ejected from the metal surface despite increasing the intensity of radiation.

**28** What is the de Broglie wavelength of an electron having a kinetic energy of 54 eV?

**A** $3.7 \times 10^{-27}$ m **B** $6.7 \times 10^{-20}$ m **C** $1.7 \times 10^{-10}$ m **D** $2.3 \times 10^{-8}$ m

**29** The table shows the ionizing effect of different types of radiation.

| | **X** | **Y** | **Z** |
|---|---|---|---|
| ionising effect | strong | weak | very weak |

What are the radiations **X**, **Y** and **Z**?

| | **X** | **Y** | **Z** |
|---|---|---|---|
| **A** | Gamma | Beta | Alpha |
| **B** | Beta | Alpha | Gamma |
| **C** | Alpha | Beta | Gamma |
| **D** | Gamma | Alpha | Beta |

**30** Which statement concerning $\alpha$-particles is correct?

**A** An $\alpha$-particle has charge +4e.

**B** An $\alpha$-particle is a helium atom.

**C** An $\alpha$-particle has mass $4u$.

**D** When $\alpha$-particles travel through a sheet of gold foil, they make the gold radioactive.

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**NATIONAL JUNIOR COLLEGE**

**SENIOR HIGH 2 Preliminary Examination**

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

**PHYSICS** **9749/02**

Paper 2 Structured Questions

**29 August 2019**
**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THE INSTRUCTION FIRST**

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a 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.

Answers **all** questions.

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

**This document consists of 24 printed pages.**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -Gm/r$ |
| temperature | $T/\text{K} = T/^\circ\text{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin\omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos\omega t$<br>$= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current / voltage | $x = x_0 \sin\omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |



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**1 (a)** The speed $v$ of sound in a gas is given by the expression

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

where $P$ is the pressure of the gas of density $\rho$ and $\gamma$ is a constant.

**(i)** State the S.I. base units of pressure.

base units: …….. [1]

**(ii)** Show that $\gamma$ has no unit.

[2]

**(b)** A student conducted an experiment to determine the speed of sound $v$ in air which he found to be 328.85 m $s^{-1}$.

**(i)** He used a pressure gauge with a precision of 5 kPa to measure the pressure $P$ of air which he found to be 105 kPa.

Calculate the fractional error of $P$.

fractional error = ……. [1]



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**(ii)** The density $\rho$ of air is measured to be $(1.2 \pm 0.1)$ kg m$^{-3}$.

**1.** Calculate the absolute uncertainty in $v$.

absolute uncertainty in $v$ = ..... m s$^{-1}$ [2]

**2.** State the value of $v$ and its absolute uncertainty to the appropriate number of significant figures.

$v$ = ..... $\pm$ ..... m s$^{-1}$ [1]

**(c)** The student repeated the experiment in **(b)** and obtained several values for the speed of sound $v$

330 m s$^{-1}$, 326 m s$^{-1}$, 334 m s$^{-1}$, 328 m s$^{-1}$, 332 m s$^{-1}$

The theoretical value of $v$ is 340 m s$^{-1}$.

Explain whether there was a systematic error in the experiment.

.....

..... [1]

[Total: 8]



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**2** A long bar magnet is suspended from the free end of a helical spring. One pole of the magnet lies within a coil of wire, as shown in Fig. 2.1.

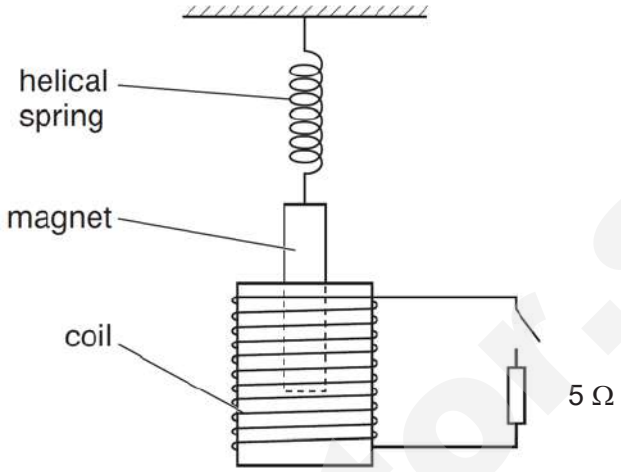


**Fig. 2.1**

The coil is connected in series with a switch and a 5 Ω resistor. The switch is open.

The magnet is displaced vertically and then released.

As the magnet passes through its rest position, a timer is started. The variation with time *t* of the vertical displacement *y* of the magnet from its rest position is shown in Fig. 2.2.

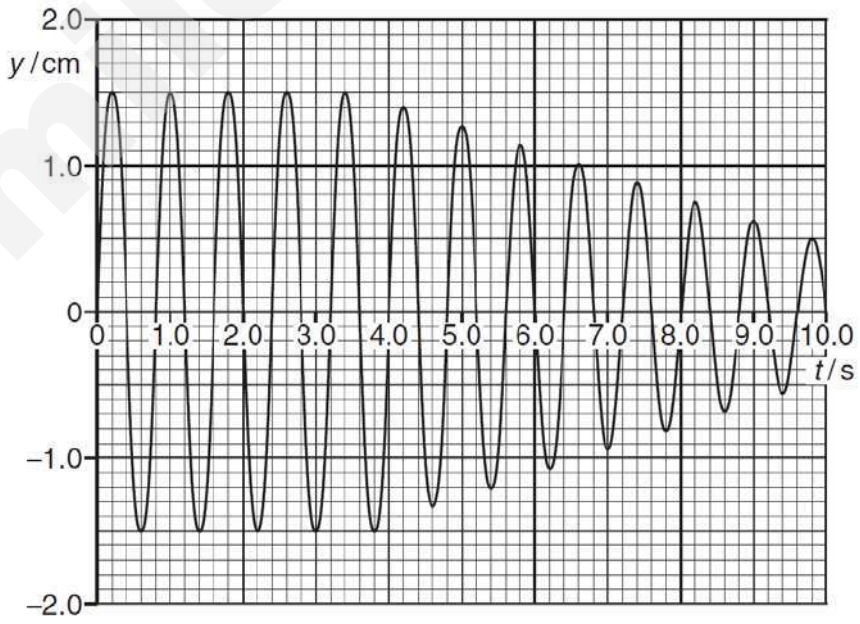


**Fig. 2.2**

At time *t* = 4.0 s, the switch is closed.



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**(a)** Explain why, after time $t$ = 4.0 s, the amplitude of oscillation of the magnet decreases.

……..

……..

……..

……..

……..

……..

…… [4]

**(b)** The spring is removed and an oscillator is attached to the magnet so that the magnet undergo a periodic motion in the coil.

The switch is closed. The potential difference $V$ measured across the resistor is given by

$$V = 27.0 \cos (15.7\, t)$$

$V$ is in millivolts and the time $t$ is in seconds.

**(i)** Determine the mean power dissipated from the 5 Ω resistor.

mean power = ..... W [3]



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**(ii)** Sketch the variation with time $t$ of the power $P$ dissipated from the resistance in Fig. 2.3. (Include appropriate values in your graph.)

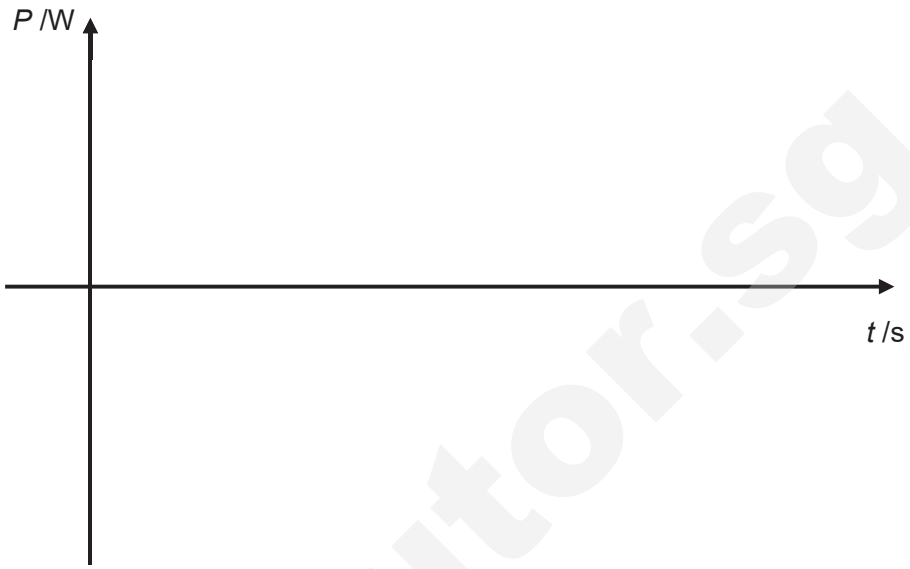


**Fig 2.3**

[3]

[Total: 10]

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**Question 3 begins over the page.**

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**3 (a)** State what is meant by *coherent sources*.

……

…… [1]

**(b)** Two coherent microwave emitters $S_1$ and $S_2$ are in phase with one another. They emit waves of equal frequency, equal intensity and with the same direction of polarisation. A microwave detector is placed at point P, as shown in Fig. 3.1.

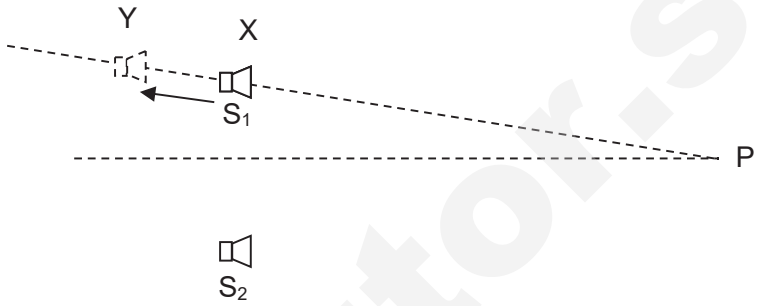


**Fig. 3.1**

The initial distances of $S_1$ and $S_2$ from P are equal. The intensity of the individual microwaves from $S_1$ and $S_2$ at P is $I$.

**(i)** $S_1$ is moved slowly away from P along the line PXY as shown.

Explain why the intensity of the microwave detected at P fluctuates.

……

……

……

……

…… [3]

**(ii)** $S_1$ is moved from point X to Y and the intensity of the microwave at P changes from a maximum to a minimum. The distance XY is 8.2 cm.

Calculate the frequency of the microwaves emitted by the sources.

frequency = …… Hz [2]



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**(iii)** $S_1$ remains at point Y.

A polariser is placed between $S_1$ and P. The direction of polarisation of the microwave from $S_1$ is changed by 40°. The power of $S_1$ is adjusted such that the intensity of the microwave from $S_1$ at P remains as $I$.

Explain, without numerical calculation, the intensity of the microwave at P.

……

……

……

…… [2]

**(c)** Fig. 3.2 shows the variation with time of the displacement of the microwave from $S_2$ at P.

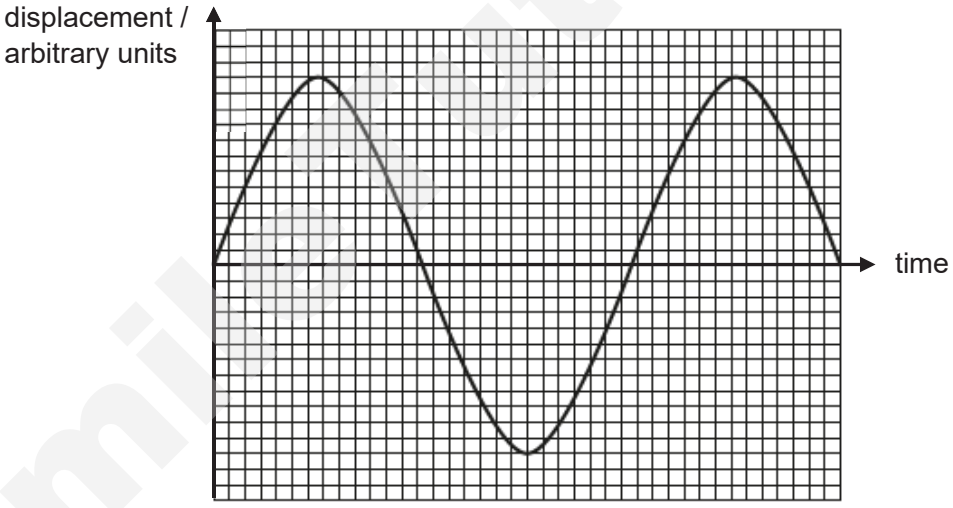


**Fig. 3.2**

**(i)** The polariser in **(b)(iii)** is removed and the intensity of the microwave from $S_1$ at P is reduced to $\frac{1}{2}I$.

Show that the amplitude of the microwave from $S_1$ at P is approximately 8.5 units.

[2]

**(ii)** Sketch the variation with time of the displacement of the microwave from $S_1$ at P in Fig 3.2. [2]

[Total: 12]

**[ Turn over**

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**4 (a) (i)** State the *first law of thermodynamics*.

……

……[1]

**(ii)** Suggest why there is a considerable difference in magnitude between the specific latent heat of fusion and vaporisation.

……

……

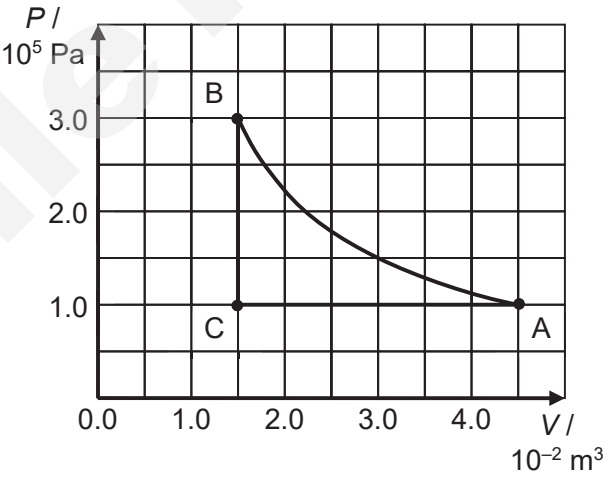
……

……

……

……[3]

**(b)** The diagram below shows the *P*–*V* graph of a fixed mass of ideal gas undergoing changes between the three states A, B and C.




**(i)** Show that the change A → B is an isothermal (constant temperature) process.

[2]



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**(ii)** Describe qualitatively, with reference to molecular movement, how the changes A $\rightarrow$ B and C $\rightarrow$ B differ in the manner the pressure of the gas is increased.

……

……

……

……[2]

**(iii)** Estimate the heat removed from the gas in the change A $\rightarrow$ B.

heat removed = …… J [2]

[Total: 10]

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**5** In a proposed fusion reactor, one possible reaction is

$$^{4}_{2}\mathrm{He} + ^{9}_{4}\mathrm{Be} \rightarrow ^{12}_{6}\mathrm{C} + ^{1}_{0}\mathrm{n}$$

The binding energy per nucleon are given as follows

| | binding energy per nucleon / MeV |
|---|---|
| $^{4}_{2}\mathrm{He}$ | 7.075175 |
| $^{9}_{4}\mathrm{Be}$ | 6.462767 |
| $^{12}_{6}\mathrm{C}$ | 7.675310 |

**(a) (i)** Explain what is meant by *binding energy*.

……

……

……..[1]

**(ii)** Calculate the energy released during this process.

energy released = ..... MeV [3]



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**(b)** Uranium (U) has at least fourteen isotopes. Uranium-238 ($^{238}_{92}U$) is an isotope and the mean radius of its nucleus is $8.9 \times 10^{-15}$ m.

**(i)** Explain what is meant by an *isotope*.

……

……

……..[1]

**(ii)** For a uranium-238 nucleus, show that

**1.** its mass is $3.95 \times 10^{-25}$ kg,

mass = ..... kg [1]

**2.** its mean density is $1.3 \times 10^{17}$ kg $m^{-3}$.

density = ..... kg $m^{-3}$ [2]

**(iii)** The density of a lump of uranium is $1.9 \times 10^{4}$ kg $m^{-3}$.

Using your answer to **(b)(ii)(2)**, suggest what can be inferred about the structure of the atom.

……

……

……

……..[2]

[Total: 10]



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**6** A photodiode is a circuit component used to convert a light signal into an electrical one. Fig. 6.1 shows an enlarged cross-section through a photodiode to illustrate how it is constructed.

Light incident on the thin transparent conducting surface layer of the diode passes through it to be absorbed in the insulating layer. The energy of each photon is sufficient to release one electron in the insulating layer. The potential difference *V*, applied across the insulating layer, causes these electrons to move to one of the conducting layers.

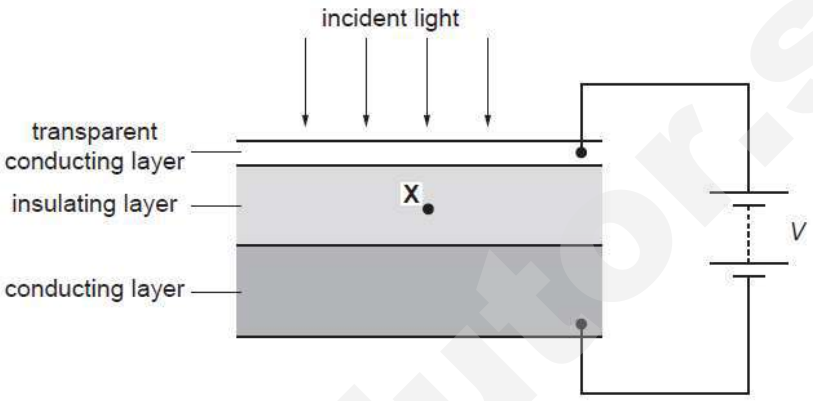


**Fig. 6.1**

In one particular application, red light of wavelength $6.33 \times 10^{-7}$ m, from a helium-neon laser, is incident on the photodiode. The power of the laser beam is 1.0 mW.

**(a)** Explain what is meant by a *photon.*

……..

…….[1]

**(b)** Calculate the energy of one photon emitted by the helium-neon laser.

energy = ……J [2]

**(c)** Show that about $3 \times 10^{15}$ photons are emitted by the helium-neon laser each second.

[1]

**[ Turn over**

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**(d)** The energy level diagram of the neon atom is shown in Fig. 6.2.

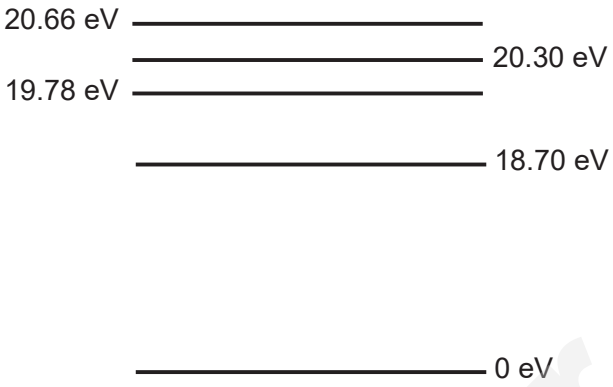


**Fig 6.2**

On Fig 6.2, draw an arrow to indicate the transition that gave rise to the photon of wavelength $6.33 \times 10^{-7}$ **m** emitted by the helium-neon laser. [1]

**(e)** **(i)** On Fig. 6.1, draw an arrow to show the direction of motion of an electron released at point **X** in the centre of the insulating layer. [1]

**(ii)** Experiments show that only 20% of the red light photons incident on the photodiode release electrons in the insulating layer.

Calculate the current through the photodiode.

current =…… A [3]

**(iii)** Suggest one reason why the efficiency of the photodiode is less than 100%.

…….

…….

…….

…….[1]

[Total: 10]

**[ Turn over**

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**7** Read the passage below and answer the questions that follow.

**Law of Gravitation and Celestial Mechanics**

For thousands of years, Man has studied the night sky and some ancient buildings provide evidence of careful and patient astronomical observations by people of many different cultures. As instrumentation has improved, so has the precision with which astronomical observations could be made. Between 1576 and 1597, Danish astronomer Tycho Brahe wanted to determine how the heavens were constructed and pursued a project to determine the positions of both stars and planets.

German astronomer Johannes Kepler was Brahe's assistant for a short while before Brahe's death, whereupon he acquired his mentor's astronomical data and spent 16 years trying to deduce a mathematical model for the motion of the planets.

Kepler deduced three laws:

1. All planets move in elliptical orbits with the Sun at one focus.
2. The radius vector drawn from the Sun to a planet sweeps out equal areas in equal time intervals.
3. The square of the circular orbital period of any planet is proportional to the cube of the radius of the circle.

As a result of Kepler's work, Newton formulated the law of gravitation.

**(a) (i)** *Newton's law of gravitation* partially states that the force between two masses is inversely proportional to the square of their distance apart.
Using concepts on an object moving in *circular motion*, explain how this statement can be deduced from Kepler's third law.

……

……

…… [2]



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**(ii)** Using Newton's laws, show that, for a circular orbit of an object about a planet,

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where $T$ is the orbital period of the body,
$M$ is the mass of the planet, and
$r$ is the distance between the centre of mass of the body and the planet.

[3]

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**(b)** The planet Jupiter has several moons. Data for some of these moons are shown in Table 7.1.

**Table 7.1**

| moon | period $T$ / days | mean distance from centre of Jupiter $r$ / $10^9$m | $\log_{10}$ ($T$ / days) | $\log_{10}$ ($r$ / m) |
|---|---|---|---|---|
| Sinope | 758 | 23.7 | 2.88 | 10.37 |
| Leda | 239 | 11.1 | | |
| Callisto | 16.7 | 1.88 | | |
| Io | 1.77 | 0.422 | | |
| Metis | 0.295 | 0.128 | -0.53 | 8.11 |

**(i)** Complete Table 7.1 for the moons – Leda, Callisto and Io. [2]

**(ii)** On the axes of Fig. 7.1, plot a graph of $\log_{10}$ ($T$/days) against $\log_{10}$ ($r$/m). [3]

**(iii)** Determine the gradient of the graph in Fig. 7.1.

gradient = ……[2]

**(iv)** Hence, discuss whether the data in Table 7.1 support the relation given in **(a)(ii)**.

……

……

……

……

…… [2]



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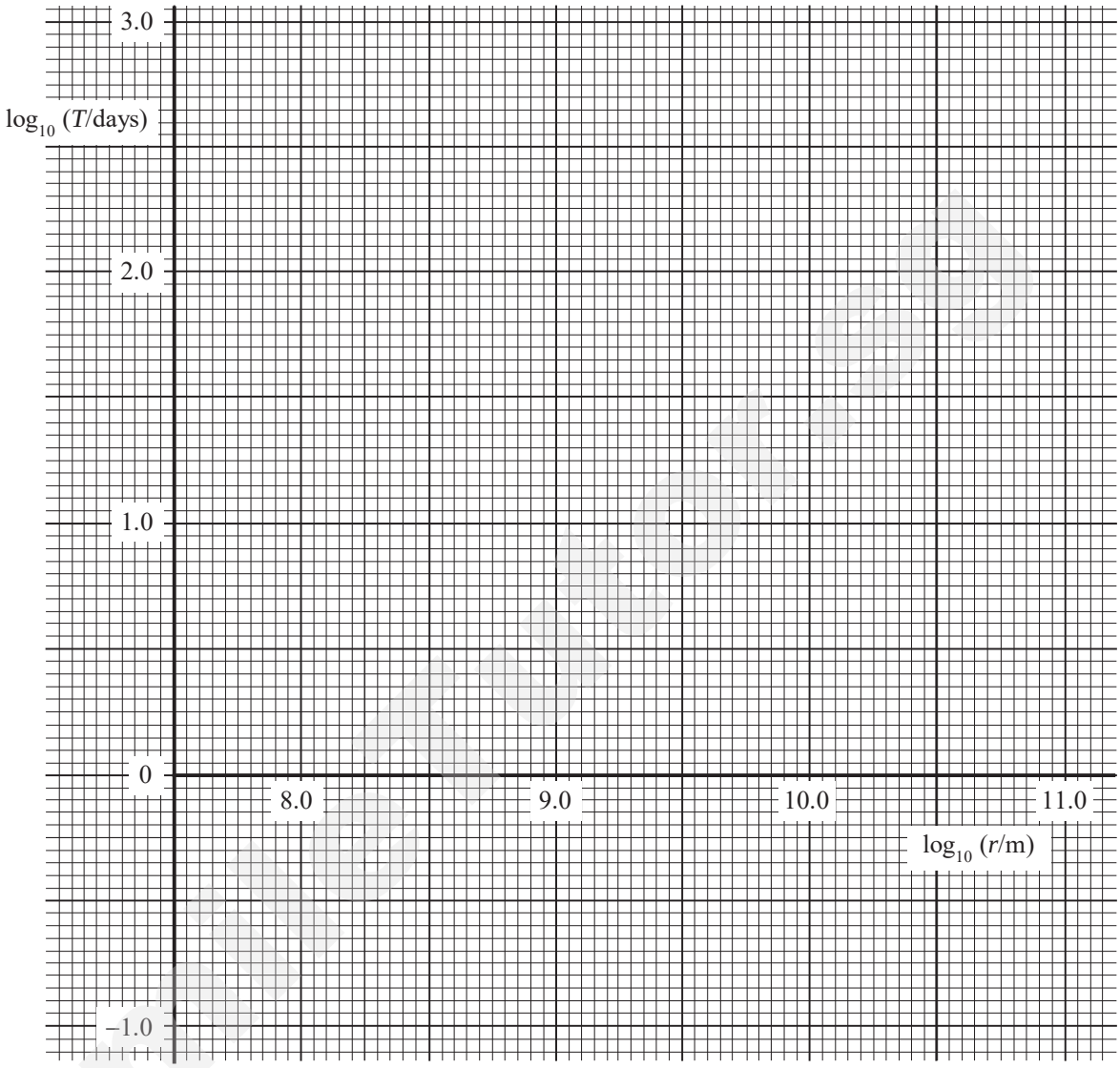


**Fig. 7.1**

**(c)** Observation shows that the moon Ganymede orbits Jupiter with a period of 7.16 days.

Use Fig. 7.1 to estimate the orbital radius of Ganymede.

orbital radius = …… m [2]



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**(d)** It is reported in the media that the moon Thebe is discovered to orbit Jupiter once every 16.2 hours at a height of $2.22 \times 10^5$ km above the surface of Jupiter.

Comment on the accuracy of this media report.

……...

……...

……...

……..... [2]

**(e)** Suggest whether Fig. 7.1 could be used to check data on the orbital radii and periods of the moons of another planet (e.g. Saturn).

……...

……...

……...

……..... [2]

[Total: 20]

**End of Paper**

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**NATIONAL JUNIOR COLLEGE**

**SENIOR HIGH 2 PRELIMINARY EXAMINATIONS**

Higher 2

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# PHYSICS

**9749/03**

Paper 3 Longer Structured Questions **(Section A)**

**3 September 2019**
**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

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

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

**Section A**
Answers **all** questions.

**Section B**
Answer **one** question only.

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

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

| For Examiner's Use | |
|---|---|
| 1 | / 12 |
| 2 | / 6 |
| 3 | / 7 |
| 4 | / 9 |
| 5 | / 12 |
| 6 | / 7 |
| 7 | / 7 |
| 8 | / 20 |
| 9 | / 20 |
| Total (60m) | |

**This document consists of 25 printed pages.**

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**Data**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -Gm/r$ |
| temperature | $T/\text{K} = T/^\circ\text{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin\omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos\omega t$<br>$= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current / voltage | $x = x_0 \sin\omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**Section A (60 marks)**

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

**1** A ball is thrown horizontally from the top of a building, as shown in Fig. 1.1.

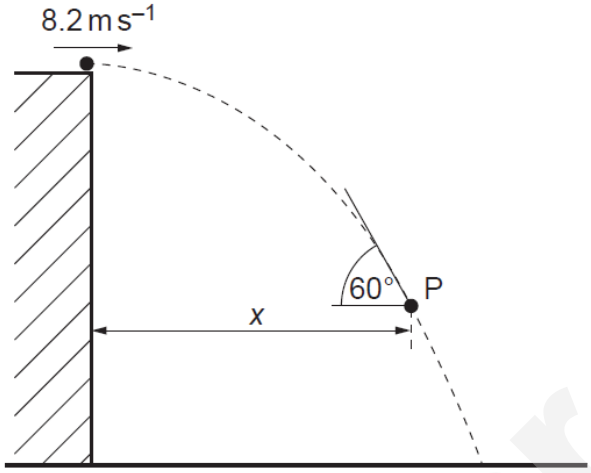


**Fig. 1.1**

The ball is thrown with a horizontal speed of 8.2 m $s^{-1}$. The side of the building is vertical. At point P on the path of the ball, the ball is at a distance *x* from the building and is moving at an angle of 60° to the horizontal. Air resistance is negligible.

**(a)** For the ball at point P,

**(i)** show that the vertical component of its velocity is 14.2 m $s^{-1}$,

[2]

**(ii)** determine the vertical distance through which the ball has fallen,

vertical distance = ..... m [2]

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**(iii)** determine the horizontal distance *x*.

distance *x* = ..... m [2]

**(b)** The path of the ball in **(a)**, with an initial horizontal speed of 8.2 m $s^{-1}$, is shown again **in** Fig. 1.2.

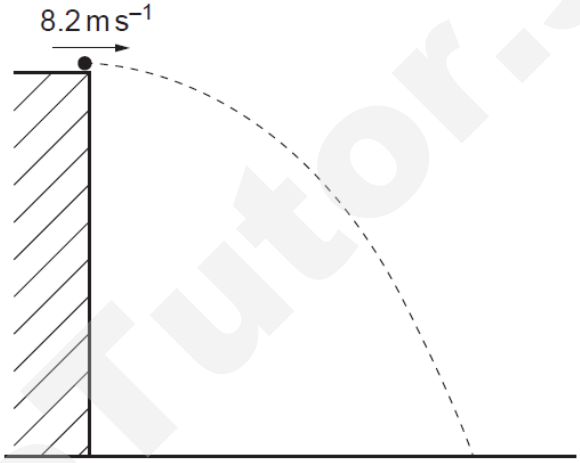


**Fig. 1.2**

On Fig. 1.2, sketch the new path of the ball for the ball having an initial horizontal speed

**(i)** greater than 8.2 m $s^{-1}$ and with negligible air resistance. Label this path G. [2]

**(ii)** equal to 8.2 m $s^{-1}$ but with air resistance. Label this path A. [2]

**(c)** State and explain in which case, **b(i) or b(ii)**, the ball will reach the bottom of the building first.

.....

.....

.....

..... [2]

[Total: 12]

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**2** A ball B of mass 1.2 kg travelling at constant velocity collides head-on with a stationary ball S of mass 3.6 kg, as shown in Fig. 2.1.

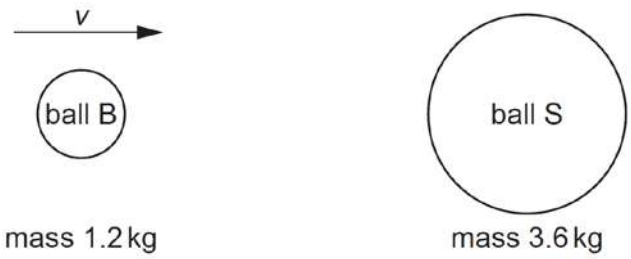


**Fig. 2.1**

Frictional forces are negligible.

The variation with time $t$ of the velocity $v$ of ball B before, during and after colliding with ball S is shown in Fig. 2.2.

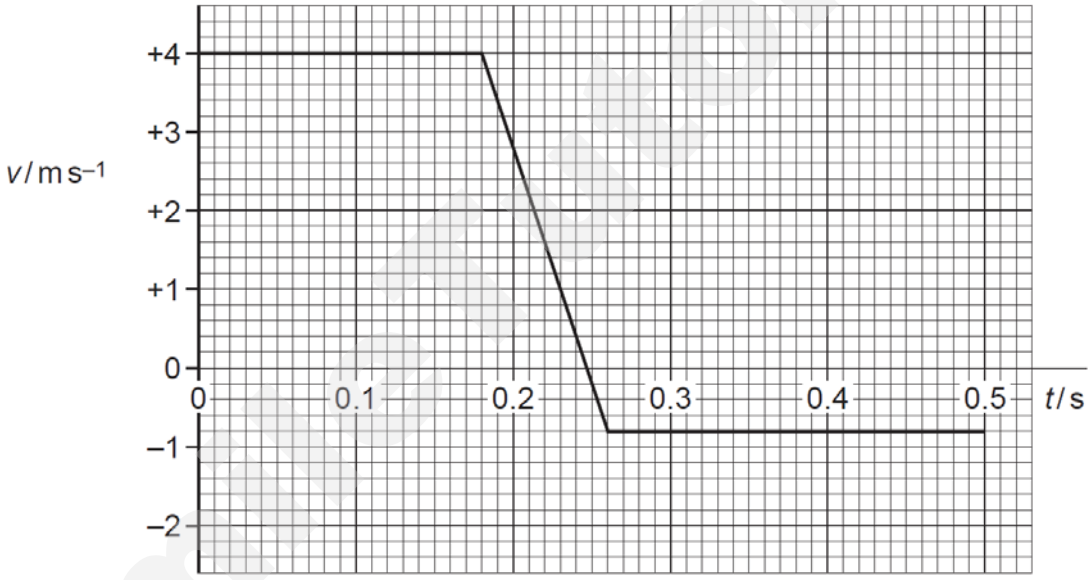


**Fig. 2.2**

Using Fig. 2.2, for ball B during the collision with ball S,

**(a)** **(i)** show that the change in momentum of ball B is 5.76 N s,

[1]

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**(ii)** calculate the speed of ball S after the collision,

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

**(b)** Using your answer in **(a)(ii)** and information from Fig. 2.2, deduce whether the collision is elastic or inelastic. Support your answer with working.

……..

……..

…… [3]

[Total: 6]

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**3** A train ride for kids in an amusement park can vary between two power setting – *High* or *Low*. The power at *High* setting is double that of *Low*.

The total mass of the train and the passengers is 4000 kg. The frictional force acting on the train is constant at 700 N.

**(a)** When the train is travelling at 8.0 m $s^{-1}$ and the power provided by the train is set to *High*, the train accelerates at 0.30 m $s^{-2}$.

Show that the power provided by the train is 15200 W.

[2]

**(b)** When the power provided by the train is set to *Low*,

**(i)** determine its maximum speed,

maximum speed = ..... m $s^{-1}$ [2]

**(ii)** determine the maximum speed when it is climbing up a slope that rises 1 m for every 25 m of road travelled.

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

[Total: 7]

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**Question 4 begins over the page**

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**4** An amusement park ride spins customers so fast that they are 'held' to the sides of a vertical wall as shown in Fig. 3.1.

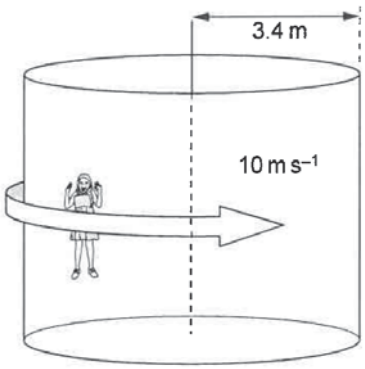


**Fig. 3.1**

A girl of mass 60 kg is spun around at a constant speed of 10 m $s^{-1}$ in a circular path of radius 3.4 m.

**(a)** Explain why the girl is accelerating even though her speed is constant.

.....

.....

.....

..... [2]

**(b)** **(i)** Calculate the centripetal force on the girl.

centripetal force = ..... N [2]

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**(ii)** The wall of the ride exerts a frictional force $f$ on the girl given by

$$f = \mu N$$

where $N$ is the normal contact force exerted by the wall on the girl and $\mu$ is a constant that depends on the roughness of the wall.

Determine the value of $\mu$. Explain your working.

$\mu$ = ..... [3]

**(c)** In another similar ride, the wall of the ride is tilted at an angle $\theta$ to the vertical, as shown in Fig 3.2.

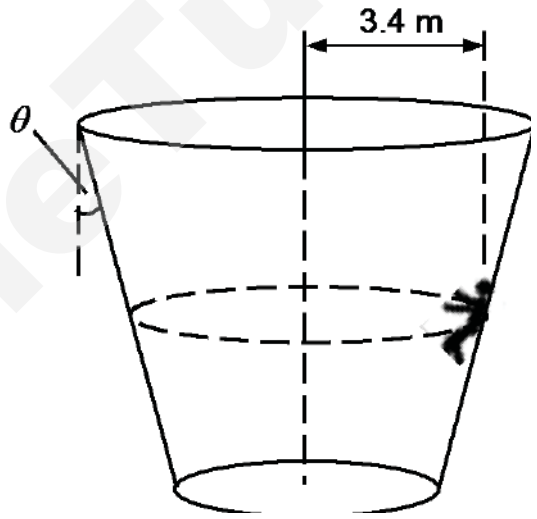


**Fig. 3.2**

The same girl is being spun around at the same constant speed of 10 m $s^{-1}$ in a circular path of radius 3.4 m. The girl's feet is not touching the floor of the ride.

Explain whether the girl can remain at constant height while the ride is spinning, if the wall is frictionless.

……

……

……

…… [2]

[Total: 9]

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**5** Two vertical springs, each having spring constant $k$, support a mass. The lower spring is attached to an oscillator as shown in Fig. 5.1.

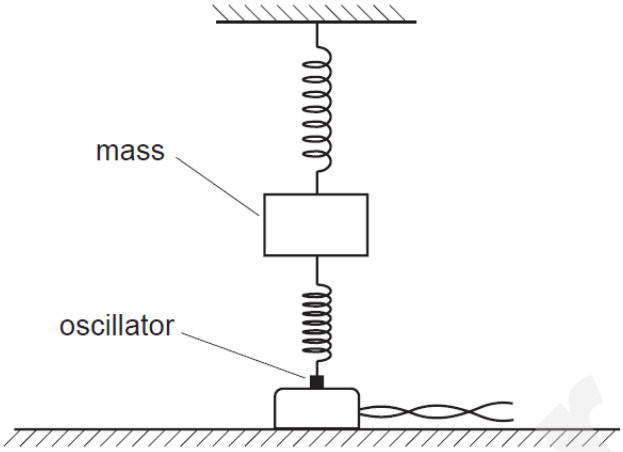


**Fig. 5.1**

The oscillator is switched off. The mass is displaced vertically and then released so that it vibrates. During these vibrations, the springs remain extended. The vertical acceleration $a$ of the mass $m$ is given by the expression

$$a = \frac{-2kx}{m}$$

where $x$ is the vertical displacement of the mass from its equilibrium position.

**(a)** **(i)** Define *Simple Harmonic Motion*

……

……

…… [2]

**(ii)** Show that, for a mass of 240 g and springs with spring constant 3.0 N cm$^{-1}$, the frequency of vibration of the mass is approximately 8.0 Hz.

[4]

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**(b)** The oscillator is switched on and the frequency $f$ of the vibrations is gradually increased. The amplitude of vibration of the oscillator is constant. Fig. 5.2 shows the variation with $f$ of the amplitude $A$ of vibration of the mass.

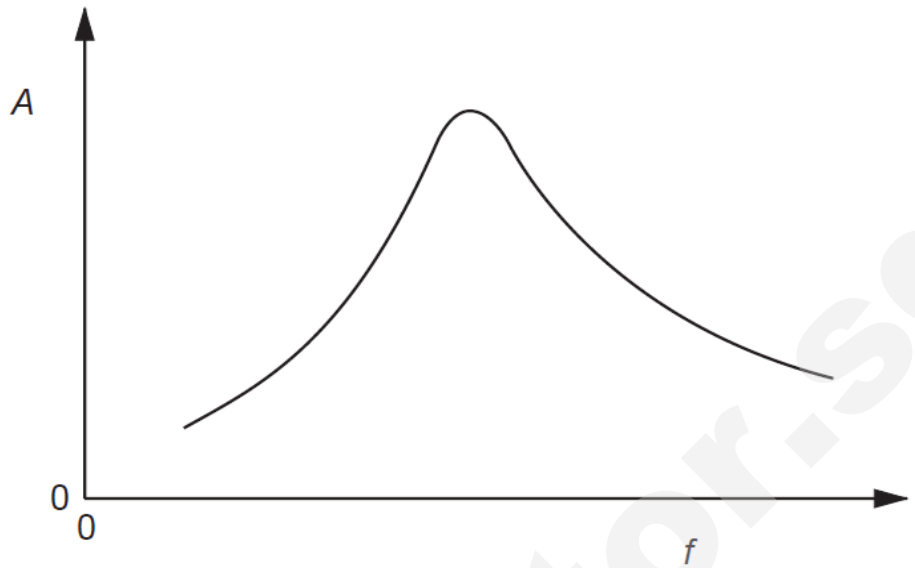


**Fig.5.2**

**(i)** State

**1.** the name of the phenomenon illustrated in Fig. 5.2,

..... [1]

**2.** the frequency $f_0$ at which maximum amplitude occurs.

frequency = ..... Hz [1]

**(ii)** Explain, in terms of energy, the reason why the maximum amplitude occurs at the frequency stated in **(i) 2**.

……

…… [1]

**(iii)** Suggest and explain how the apparatus in Fig. 5.1 could be modified to make the peak on Fig. 5.2 flatter, without significantly changing the frequency $f_0$ at which the peak occurs.

……

……

……

……

…… [3]

[Total: 12]

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**6 (a)** Positive ions are travelling through a vacuum in a narrow beam. The ions enter a region of uniform magnetic field and are deflected in a semi-circular arc, as shown in Fig. 6.1.

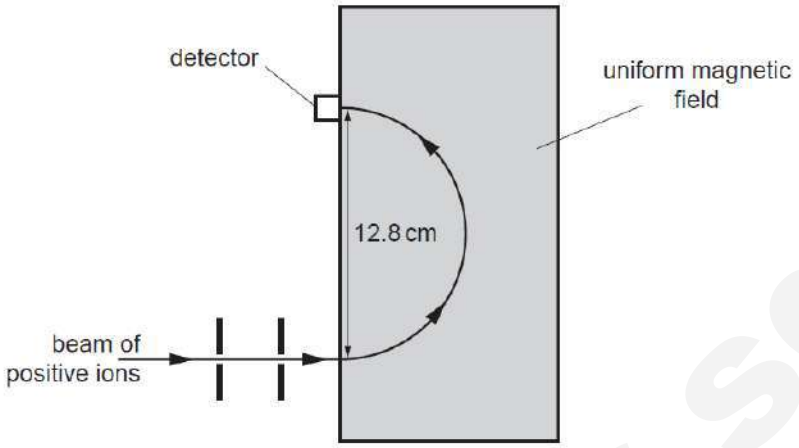


**Fig. 6.1**

The ions, travelling at a constant speed $1.40 \times 10^5$ m s$^{-1}$, are detected at a detector when the diameter of the arc in the magnetic field is 12.8 cm.

**(a)** With reference to Fig. 6.1, state the direction of the magnetic field.

..... [1]

**(b)** The ions have mass 20*u* and charge $+1.60 \times 10^{-19}$ C (where *u* is the unified atomic mass unit.)

Show that the magnetic flux density is 0.454 T. Explain your working.

[3]

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**(c)** Ions of mass 22*u* with the same charge and speed as those in **(b)** are also present in the beam.

**(i)** On Fig. 6.1, sketch the path of these ions in the magnetic field of magnetic flux density 0.454 T. [1]

**(ii)** In order to detect these ions at the fixed detector, the magnetic flux density is changed. Calculate this new magnetic flux density.

magnetic flux density = ..... T [2]

[Total: 7]

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**7** A cubical container, shown in Fig. 7.1, is filled with an ideal gas.

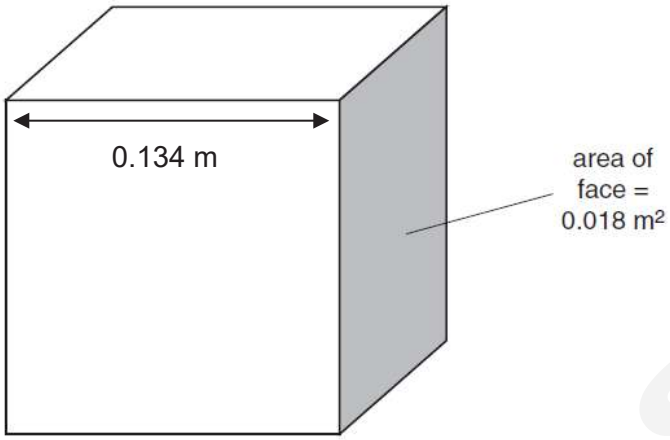


**Fig. 7.1**

When an ideal gas atom makes an elastic collision perpendicular to a face of the container, it experiences a change of momentum of $1.85 \times 10^{-23}$ N s.

**(a)** In one second there are the equivalent of $1.49 \times 10^{24}$ collisions perpendicular to each face of the container.

Calculate the force exerted by the gas on one face of the container.

force = ..... T [2]

**(b)** Calculate the pressure exerted by the gas.

pressure = ..... Pa [1]

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**(c)** The temperature of the ideal gas in the container is 27 °C.

Determine the number of ideal gas molecules present in the container.

number of molecules = ..... [2]

**(d)** The mass of one ideal gas molecule is $6.86 \times 10^{-27}$ kg.

Calculate the root-mean-square (r.m.s.) speed of the gas molecules.

r.m.s. speed = ..... m $s^{-1}$ [2]

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## Section B

Answer **one** question from this Section in the spaces provided.

**8** An engineer designs a resistor made from a thin layer of graphite mounted on an insulating base. Fig. 8.1 shows the arrangement.

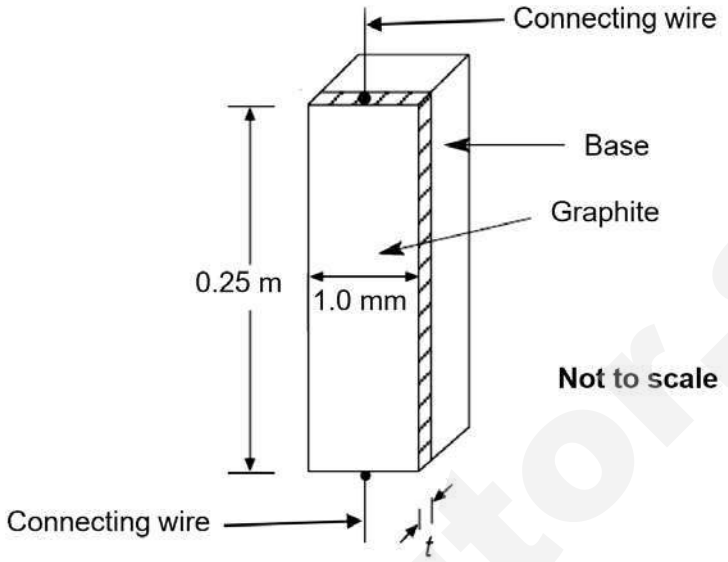


**Fig. 8.1**

**(a)** The graphite layer has a length of 0.25 m, a width of 1.0 mm, and a resistance of 1.2 kΩ. The resistivity of graphite is $15.0 \times 10^{-5}$ Ω m. The number density of electrons in graphite is $2.2 \times 10^{28}$ $m^{-3}$.

**(i)** Calculate the thickness $t$ of the graphite layer.

$t$ = ..... m [2]

**(ii)** A potential difference of 9.0 V is applied to the connecting wires.
Determine the drift velocity of the electrons in the graphite.

drift velocity = ..... $m\ s^{-1}$ [3]

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**(b)** The engineer has also some connecting wires and a cell. The cell has negligible internal resistance. He wants to connect a circuit to provide a potential difference which is dependent on illumination.

**(i)** State another electrical component that he needs to complete the circuit.

…….. [1]

**(ii)** With the electrical component in **(b)(i)** and the newly designed resistor, draw a circuit diagram to show how this circuit should be connected.

Your diagram should show clearly the cell and the potential difference output.

[2]

**(iii)** Explain how your circuit in **(b)(ii)** provides a varying potential difference which is dependent on illumination.

……

……

……

……

……

……[3]

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**(c)** Two of these newly designed resistors are connected in a circuit with 2 cells and an ammeter. The electromotive force e.m.f. of the cells are 5.0 V and 12.0 V as shown in Fig 8.2. The cells have negligible internal resistance, and the ammeter is considered ideal.

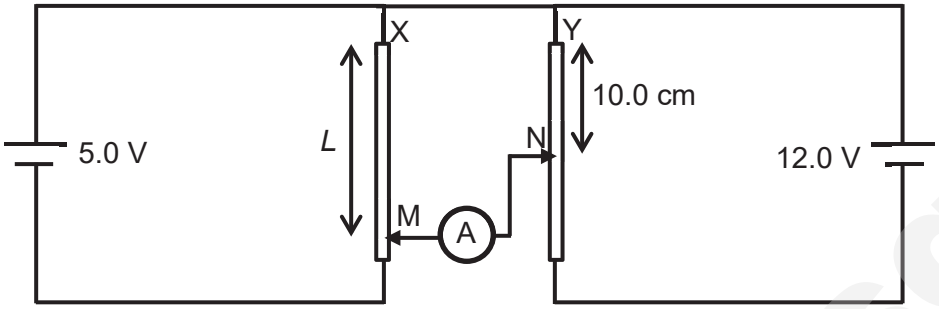


**Fig. 8.2**

The reading of the ammeter is zero.

**(i)** Distinguish between electromotive force and potential difference.

……

……

……[2]

**(ii)** Explain how the potential difference across XM is compared to YN such that the ammeter reading is zero.

……

……

……[2]

**(iii)** Determine the length *L*.

*L* = ..... m [2]

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**(iv)** Explain how length *L* should be changed such that the ammeter continues to reads zero current, if the 12.0 V cell has internal resistance, but not the 5.0 V cell.

……

……

……

……

……[3]

[Total: 20]

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**9 (a)** State the *principle of moments*.

……..

……..

…… [2]

**(b)** Fig. 9.1. shows mass A and a negatively charged sphere X balanced on a rod of negligible mass. The rod is free to rotate about the pivot P which is at the center of the rod.

Another negatively charged sphere Y is placed near sphere X.

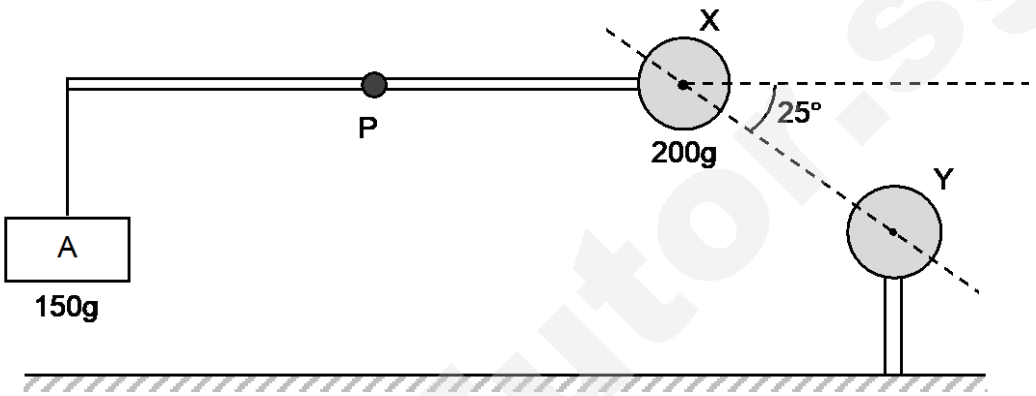


**Fig. 9.1**

Mass A is 150 g and the mass of sphere X is 200g.

**(i)** Explain why sphere Y must be negatively charged for the rod to be horizontal, as shown in Fig. 9.1.

……

……

……

…… [2]

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**(ii)** The dotted line XY shows the axis joining the centers of charge of sphere X and sphere Y. The axis XY is 25° below the horizontal. Spheres X and Y are assumed to be point charges.

Calculate the electric force on sphere X

force = ..... N [3]

**(iii)** Sketch the contact force on the rod by pivot P on Fig. 9.1. Label this force N. [1]

**(c)** Sphere X is now mounted on a rigid rod as shown in Fig. 9.2. The negative charge on sphere X is greater than the negative charge on Y

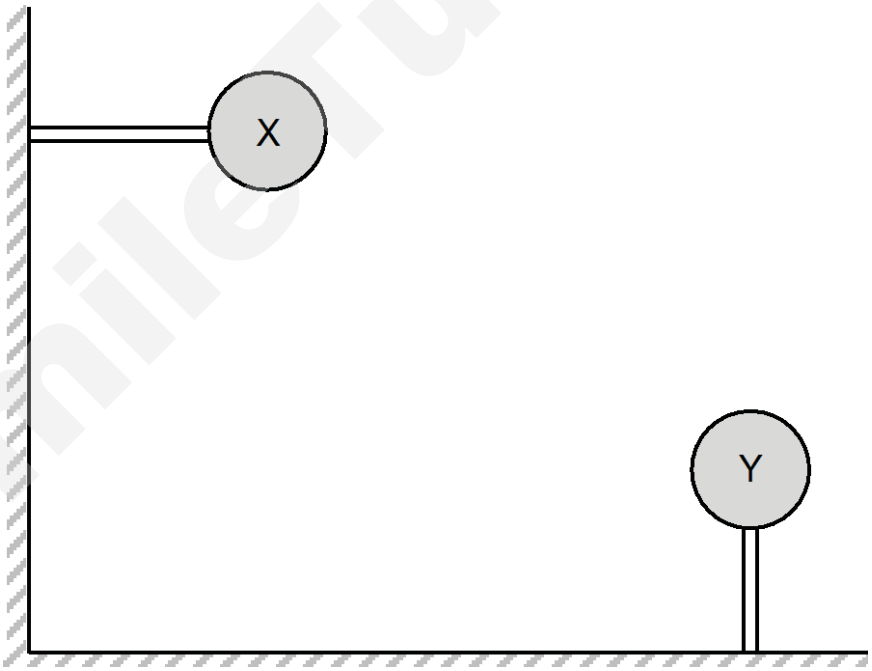


**Fig. 9.2**

Sketch the electric field between spheres X and Y on Fig. 9.2. [2]

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**(d)** The distance *d* from the centre of charge of sphere X to a point along the line joining the centres of the two spheres is shown in Fig. 9.3.

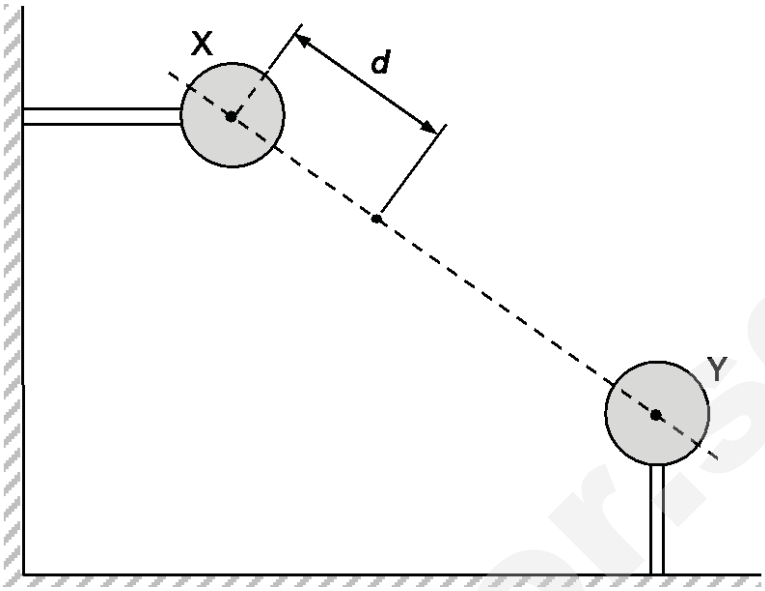


**Fig. 9.3**

Fig. 9.4 shows the variation with the distance *d* of the electric potential due to sphere X and the electric potential due to sphere Y.

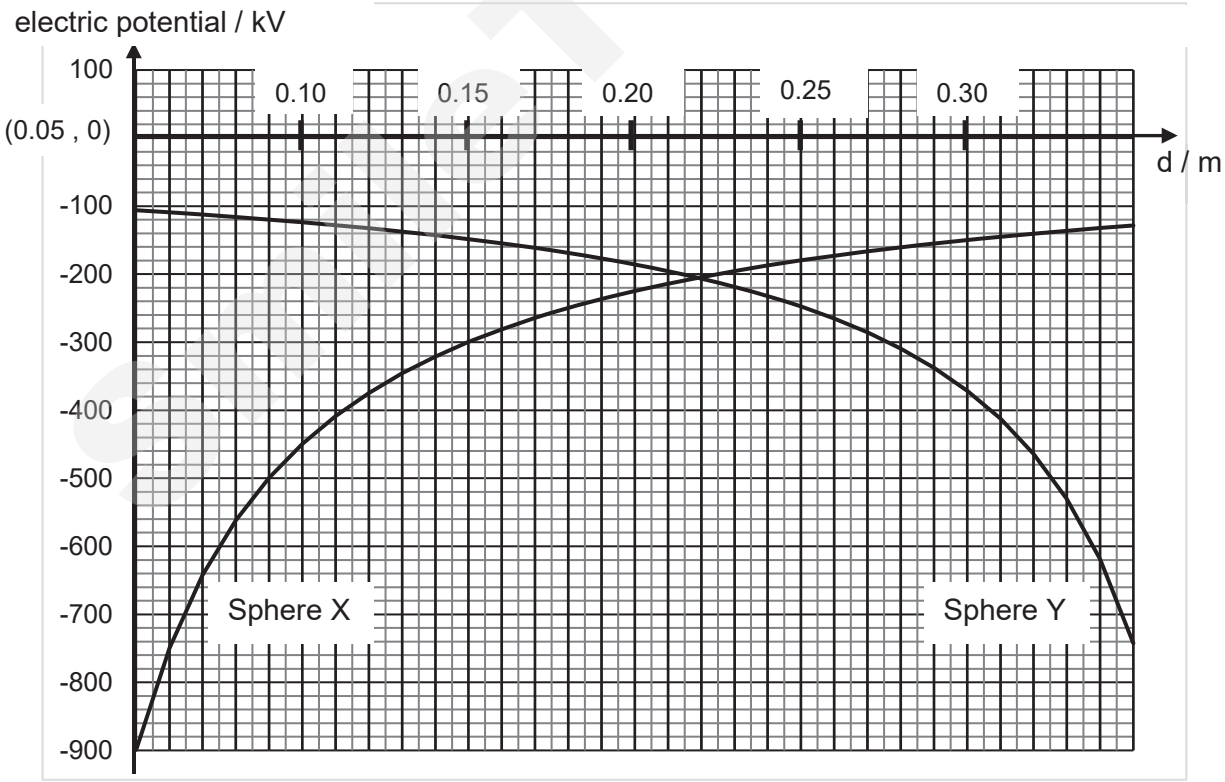


**Fig. 9.4**

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**(i)** An electron moves along the line joining the centres of both spheres.

Describe how the electric potential energy of the electron changes as it moves from $d$ = 0.05 m to $d$ = 0.35 m.

……...

……...

……...

……...

…… [3]

**(ii)** Determine the potential energy of an electron at $d$ = 0.30 m.

potential energy = ..... J [3]

**(iii)** At a particular distance between the charged spheres, the net electric force on the electron is zero. Explain the relative magnitude and direction of the potential gradient of sphere X to the potential gradient of sphere Y at this point.

……...

……...

……...

……...

……...

……...

…… [4]

[Total: 20]

**END OF PAPER**

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| | | |
|---|---|---|
| **1** | A man is standing still on the ground.<br><br>What is an appropriate value for the pressure his feet exerts on the ground? | |
| | **A** | 120 Pa |
| | **B** | 1 200 Pa |
| | **C** | 12 000 Pa |
| | **D** | 120 000 Pa |

| | |
|---|---|
| | Ans: C – Assume area of feet is 10 cm by 25 cm. Area is 0.050 $m^2$. Take weight of man to be 65 kg. |

| | | |
|---|---|---|
| **2** | Ball A is projected horizontally at 2.0 m $s^{-1}$ from the top of a vertical cliff while Ball B is released from rest 1 s later from the same point. It took Ball B 3.5 s to reach the base of the cliff. How far from the base of the cliff will Ball A hit the ground? | |
| | **A** | 7.0 m |
| | **B** | 9.0 m |
| | **C** | 53 m |
| | **D** | 67 m |

| | |
|---|---|
| | Ans: A<br><br>Both A and B will take the same amount of time and thus 3.5 s. Hence, horizontal distance = 3.5 x 2 = 7.0 m |

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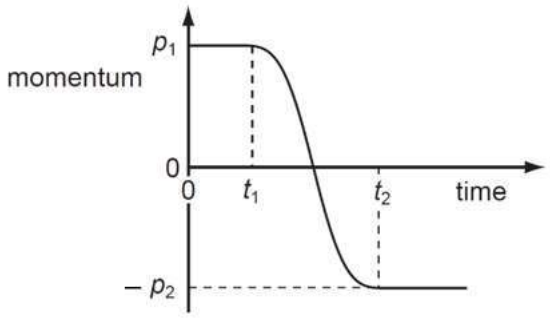
**3** The graph shows the variation with time of the momentum of a ball as it is kicked in a straight line.

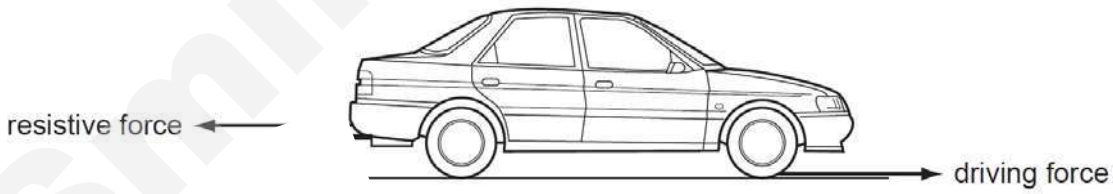



Initially, the momentum is $p_1$ at time $t_1$. At time $t_2$ the momentum is $p_2$.
What is the magnitude of the average force acting on the ball between times $t_1$ and $t_2$?

| | | |
|---|---|---|
| | **A** | $\frac{p_1 - p_2}{t_2}$ |
| | **B** | $\frac{p_1 - p_2}{t_2 - t_1}$ |
| | **C** | $\frac{p_1 + p_2}{t_2}$ |
| | **D** | $\frac{p_1 + p_2}{t_2 - t_1}$ |

Ans: D – <F> = □p/□t = $p_f - p_i$ / $(t_2 - t_1)$ = $-p_2 - p_1$ / $(t_2 - t_1)$ = – $(p_2 + p_1)$ / $(t_2 - t_1)$

**4** A car of mass 750 kg has a horizontal driving force of 2.0 kN acting on it. It has a forward horizontal acceleration of 2.0 m $s^{-2}$.




What is the resistive force acting horizontally?

| | | |
|---|---|---|
| | **A** | 0.5 kN |
| | **B** | 1.5 kN |
| | **C** | 2.0 kN |
| | **D** | 3.5 kN |

Ans: A – F = ma
2000 – f = 750 (2)
F = 500 N

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| | | |
|---|---|---|
| **5** | An object, made from two equal spherical masses joined by a light rod, falls with uniform speed through air.<br><br>The rod remains horizontal.<br><br>Which statement about the equilibrium of the system is correct? | |
| | **A** | It is not in equilibrium because it is falling steadily. |
| | **B** | It is not in equilibrium because it is in motion. |
| | **C** | It is not in equilibrium because there is a resultant torque. |
| | **D** | It is in equilibrium because there is no resultant force and no resultant torque. |

| | |
|---|---|
| | Ans: D |

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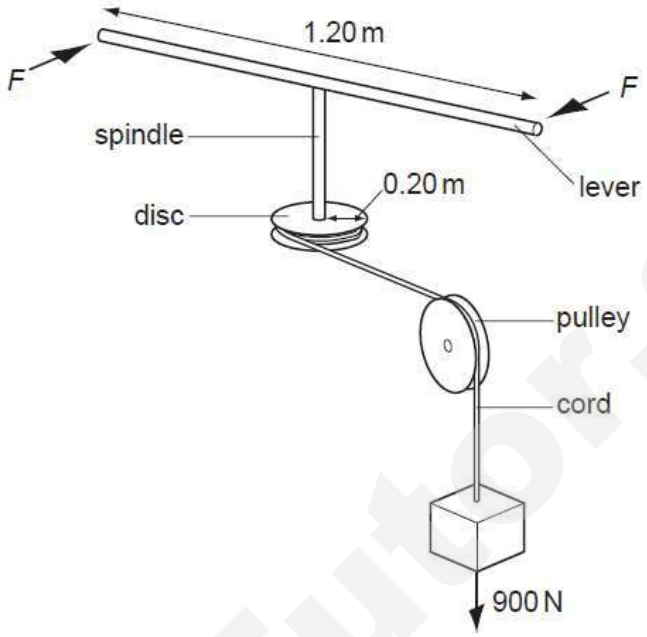
**6** One end of a spindle is attached to the centre of a lever of length 1.20 m and its other end is attached to the centre of a disc of radius 0.20 m as shown in the figure below.

A cord is wrapped around the disc, passes over a pulley and is attached to a 900 N weight at one end.




The mass of the lever, spindle, disc, cord and pulley is assumed to be negligible. Equal and opposite forces of magnitude F is applied to each end of the lever.

Ignoring frictional forces, what is the minimum value of F needed to balance the 900 N weight?

| | | |
|---|---|---|
| | **A** | 75 N |
| | **B** | 150 N |
| | **C** | 300 N |
| | **D** | 950 N |

Ans: B

Tension in the cord = 900 N
Torque on disc = 900 x 0.20 = 180 Nm
Torque due to F = F x 1.20 = 180
F = 180/1.2 = 150 N

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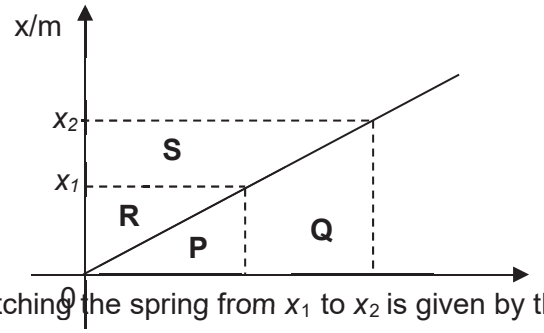
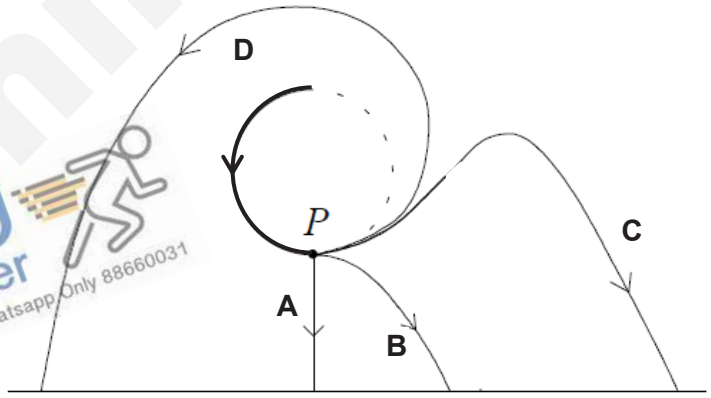
| | |
|---|---|
| **7** | The variation with force of the extension of a spring is shown in the figure below.<br>  <br><br>The work done in stretching the spring from $x_1$ to $x_2$ is given by the area |

| | | |
|---|---|---|
| | **A** | P + Q |
| | **B** | S |
| | **C** | R + S |
| | **D** | Q |

| | |
|---|---|
| | Ans: B<br><br>Area under F-x graph and thus answer is S |

| | |
|---|---|
| **8** | A stone, tied to a piece of string, is whirled in a vertical circle as shown in the figure below. The string suddenly breaks at *P*.<br>  <br><br>Which of the paths (A to D) represents a possible path for the stone from just before the string breaks until the stone hits the ground? |

| | |
|---|---|
| | Ans: B |

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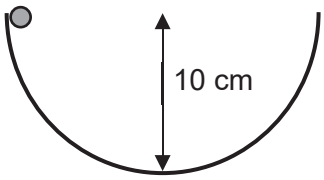
| | | |
|---|---|---|
| **9** | A small object of mass 0.050 kg is released from rest at the rim of a heavy, smooth semi-spherical bowl of radius 10 cm as shown in the figure below.<br>  <br><br>When the object passes the bottom of the bowl, what is the normal force exerted on it by the bowl? | |
| | **A** | 0.49 N |
| | **B** | 0.98 N |
| | **C** | 1.5 N |
| | **D** | 2.0 N |

| | |
|---|---|
| | Ans: C<br>From energy conservation:<br>$\frac{1}{2}mv^2 = mgh$<br>$v^2 = 2gh = 2gr$<br>At the bottom:<br>$N - mg = \frac{mv^2}{r}$<br>$N = mg + \frac{mv^2}{r} = mg + 2mg$<br>= 3mg |
| **10** | Taking the Earth to be a perfect sphere of uniform density rotating about its polar axis, which of the following statements concerning the observed acceleration due to free fall, *a*, at the surface of the Earth is true? |
| **A** | The value of *a* at the equator is larger than that at the poles. |
| **B** | If the rate of rotation of the Earth slows down, *a* at the equator increases. |
| **C** | If the radius of the Earth increases with its density remaining unchanged, *a* at the poles decreases. |
| **D** | If the radius of the Earth increases with its density remaining unchanged, *a* at the equator decreases. |

| | |
|---|---|
| | Ans: B<br>$a = g - r\omega^2$ |

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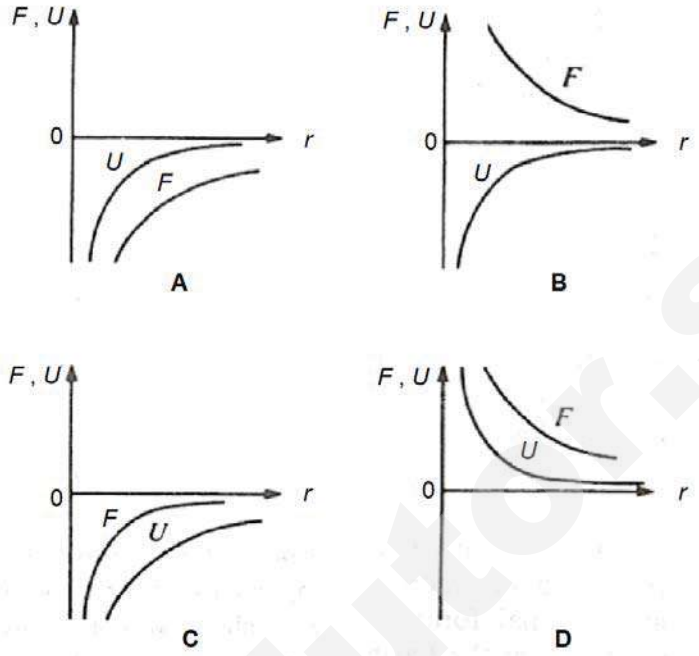
| | |
|---|---|
| **11** | Which one of the following diagrams shows the variation of gravitational force *F* on a point mass and gravitational potential energy *U* of the mass at a distance *r* from another point mass? |




| | |
|---|---|
| | Ans: C<br><br>F = -dU/dr and since r is usually large, F is numerically smaller. |

| | | |
|---|---|---|
| **12** | The temperature of a 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 % |

| | |
|---|---|
| | Ans: A<br><br>$v_{rms} \propto \sqrt{T}$<br><br>% change = ( $\sqrt{305.1}$ - $\sqrt{313.5}$)/ $\sqrt{305.1}$ = 1.4% |

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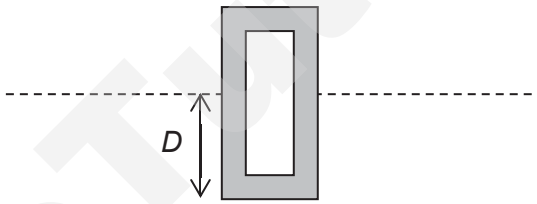
| 13 | The specific latent heat of vaporisation of water at 20 °C is appreciably greater than the value at 100 °C. This is because | |
|---|---|---|
| | **A** | the specific latent heat at 20 °C includes the energy necessary to raise the temperature of one kilogram of water from 20 °C to 100 °C. |
| | **B** | more work must be done in expanding the water vapour against atmospheric pressure at 20 °C than at 100 °C. |
| | **C** | the molecules in the liquid are more tightly bound to one another at 20 °C than at 100 °C. |
| | **D** | vaporisation of water can only take place at 100 °C. |

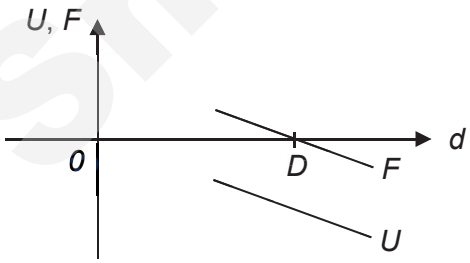
| | Ans: C |
|---|---|

**14** A hollow metal cylinder floats upright in a body of water with the bottom of the cylinder at a depth of *D* below the water surface as shown in the figure below.

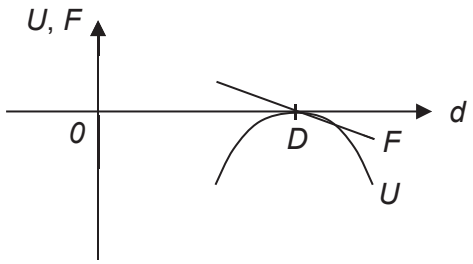



The cylinder is pressed further down into the water and upon release, performs simple harmonic motion. Which of the following graphs (all drawn to scale) shows how the upthrust *U* and net force *F* acting on the cylinder vary with *d*, the depth the bottom of the cylinder below the water surface?

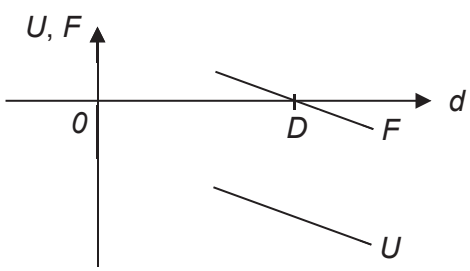
**A**



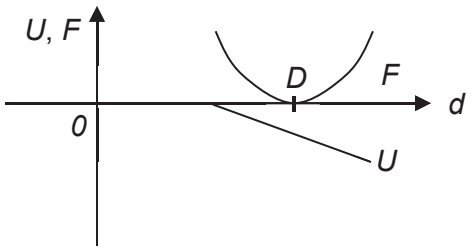

**B**




**C**




**D**




| | Ans: A<br>Both must be linear and U = 0 when d = 0 |
|---|---|

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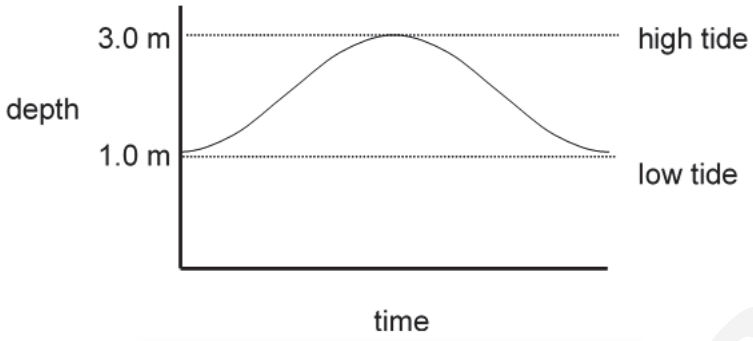
| | | |
|---|---|---|
| **15** | The rise and fall of water in a harbour is simple harmonic. The depth varies between 1.0 m at low tide and 3.0 m at high tide. The time between successive low tides is 12 hours.<br>  <br><br>A boat, which requires a minimum depth of water of 1.5 m, approaches the harbour at low tide. How long will the boat have to wait before entering? | |
| | **A** | 0.5 hours |
| | **B** | 1.0 hours |
| | **C** | 2.0 hours |
| | **D** | 2.5 hours |

| | |
|---|---|
| | Ans: C<br><br>-0.5 = cos (2π/12)t and thus t = 2.0 hrs |

| | | |
|---|---|---|
| **16** | When coherent monochromatic light falls on double slits, an interference pattern is observed on a screen some distance from the slits. The fringe separation can be increased by | |
| | **A** | Decreasing the distance between the screen and the slits. |
| | **B** | Increasing the distance between the slits. |
| | **C** | Using monochromatic light of lower frequency. |
| | **D** | Immersing the whole set up in water. |

| | |
|---|---|
| | Ans: C, $x = \frac{\lambda D}{a}$, hence decreasing D, increasing a causes x to be lower. Lower frequency means higher λ resulting in higher x. Immersing set up in water causes speed of light to decrease which in turn causes wavelength to decrease (frequency stays the same) resulting in lower x. |

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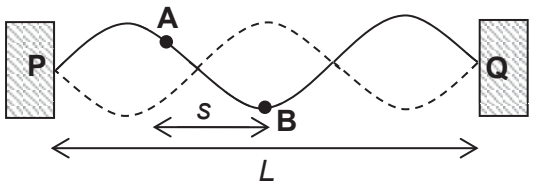
**17** A guitar string of length $L$ is stretched between two fixed points **P** and **Q** and made to vibrate transversely as shown below.




Two points **A** and **B** on the string are separated by a distance $s$. The maximum kinetic energies of points **A** and **B** are $K_A$ and $K_B$ respectively. Which of the following gives the correct phase difference and relationship between maximum kinetic energies of the points?

| | Phase difference | Maximum kinetic energy |
|---|---|---|
| **A** | $\frac{3s}{2L} \times 360°$ | $K_A < K_B$ |
| **B** | $\frac{3s}{2L} \times 360°$ | same |
| **C** | $180°$ | $K_A < K_B$ |
| **D** | $180°$ | same |

Ans: C

The adjacent segments of a stationary wave on a string are in antiphase. Point B has a larger amplitude of vibration than point A. Thus the maximum kinetic energy that point B can have during the vibration is greater than A.

**18** The images of two sources are just resolved. Which of the following is a correct statement of the Rayleigh criterion for this situation?

| | |
|---|---|
| **A** | The central maximum of the diffraction pattern of one source must coincide with the central maximum of the diffraction pattern of the other source. |
| **B** | Light from the sources must pass through a circular aperture. |
| **C** | Light from the sources must be coherent. |
| **D** | The first minimum of the diffraction pattern of one source must coincide with the central maximum of the diffraction pattern of the other source. |

Ans: D

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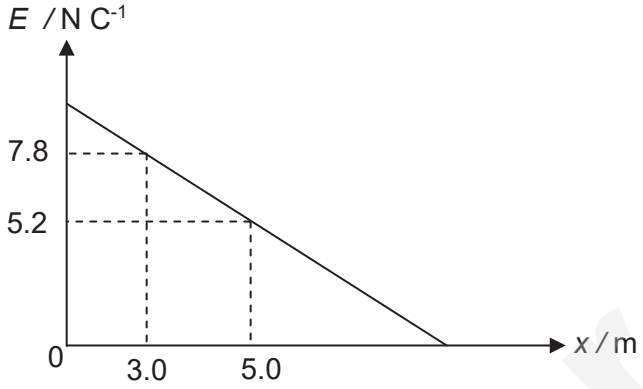
**19** The graph below shows how the electric field strength *E* varies with displacement *x* from a point A. What is the change in potential for an electron if it is moved from a point 3.0 m away from A to another point 5.0 m away from A?




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **A** | 13 V | **B** | – 13 V | **C** | 1.3 V | **D** | – 1.3 V |

Ans: B

Electric Field Strength, $E = -\frac{dV}{dr}$

$\Delta V = -\int E\, dr$ Hence *magnitude* of the change in potential is the area under this graph. Because E is positive here, the change in potential must be negative (a decrease)

$$dv = \frac{1}{2}(7.8 + 5.2)(5.0 - 3.0) = 13\,\text{V}\ \text{(a decrease in the positive x direction)}$$

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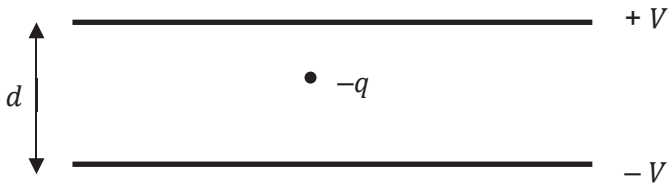
**20** An oil droplet has a charge $-q$ and is situated between two parallel horizontal metal plates as shown in the diagram.




The separation of the plates is $d$. The droplet is observed to be stationary when the upper plate is at potential $+V$ and the lower at potential $-V$.

For this to occur, the weight of the droplet is equal in magnitude to

| | | |
|---|---|---|
| | **A** | $\frac{Vq}{d}$ |
| | **B** | $\frac{2Vq}{d}$ |
| | **C** | $\frac{Vd}{q}$ |
| | **D** | $\frac{2Vd}{q}$ |

Ans:B

$$E = \frac{\Delta V}{d} = \frac{2V}{d}$$

Weight = electric force = $qE = \frac{2Vq}{d}$

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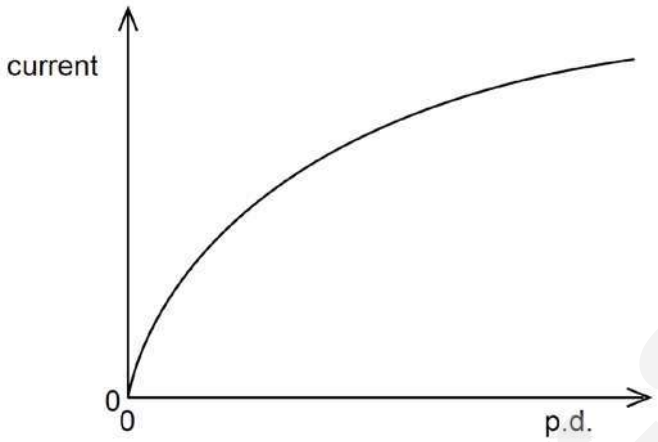
| | | |
|---|---|---|
| **21** | The graph shows how the current through a lamp filament varies with the potential difference (p.d.) across it.<br>  <br><br>Which statement explains the shape of this graph? | |
| | **A** | As the filament temperature rises, electrons can pass more easily through the filament. |
| | **B** | It takes time for the filament to reach its working temperature. |
| | **C** | The power output of the filament is proportional to the square of the current through it. |
| | **D** | The resistance of the filament increases with a rise in temperature. |

| | |
|---|---|
| | Ans: D – resistance is the ratio of p.d. over current, and it can be seen from this graph that it is increasing as the p.d., thus temperature, increases. |

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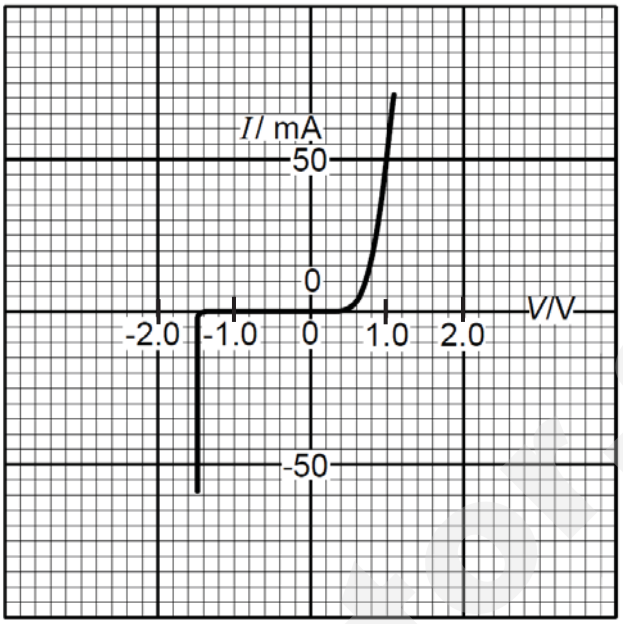
**22** The variation with potential difference $V$ of the current $I$ in a semiconductor diode is shown below.




What is the resistance of the diode for applied potential differences of +1.0 V and –1.0 V?

| | +1.0 V | –1.0 V |
|---|---|---|
| **A** | 20 Ω | infinite |
| **B** | 20 Ω | zero |
| **C** | 0.05 Ω | infinite |
| **D** | 0.05 Ω | zero |

Ans: A – at -1.0 V, the resistance must be very large so that the current is zero. At +1.0 V, $R = V/I = 1/(50 \times 10^{-3}) = 20\ \Omega$

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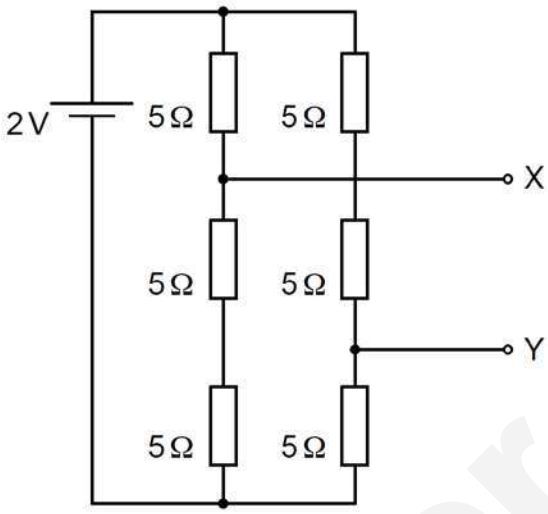
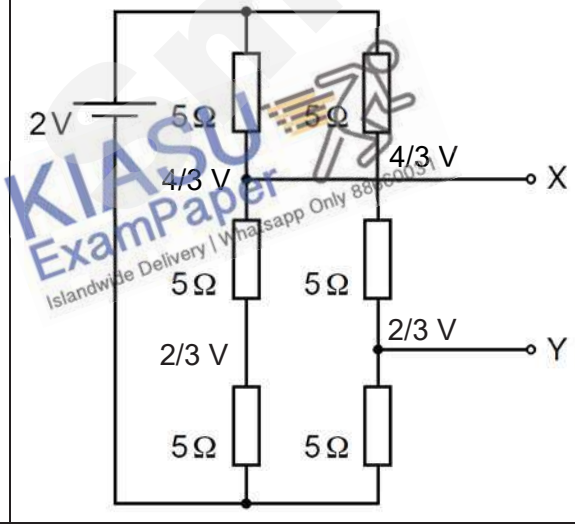
**23** Six resistors, each of resistance 5 Ω, are connected to a 2 V cell of negligible internal resistance.




What is the potential difference between terminals X and Y?

| | | |
|---|---|---|
| | **A** | $\frac{2}{3}$ V |
| | **B** | $\frac{8}{9}$ V |
| | **C** | $\frac{4}{3}$ V |
| | **D** | 2 V |

Ans: A




$\Delta$ = 4/3 – 2/3 = 2/3 V

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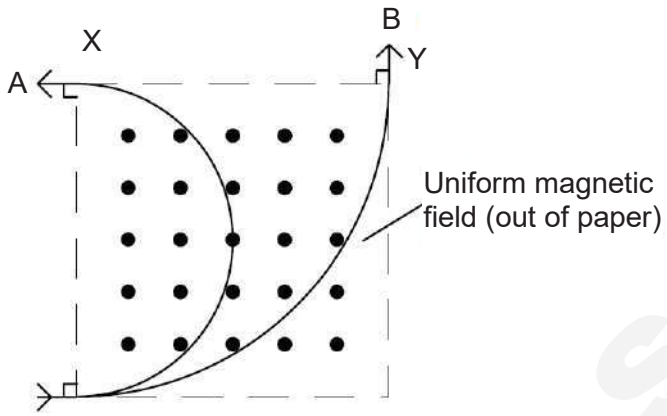
**24** Particles *A* and *B* moving at the same speed enter a square region of uniform magnetic field as shown in the figure below. Particle *A* leaves at □ while particle *B* leaves at □.




If the ratio of charge to mass of particle *A* is $k$, what is that of particle *B*?

| | | |
|---|---|---|
| | **A** | $\frac{k}{2}$ |
| | **B** | $\frac{k}{4}$ |
| | **C** | $2k$ |
| | **D** | $4k$ |

Ans: A

For A:

$Bqv = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{Bq} = \frac{v}{Bk}$

For B:

Radius = 2r $\Rightarrow k' = \frac{1}{2}k$

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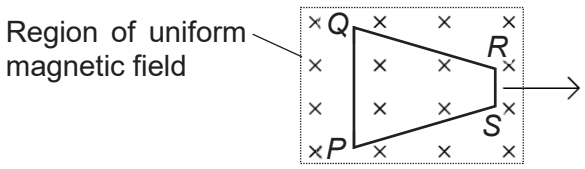
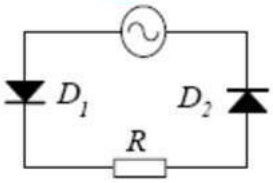
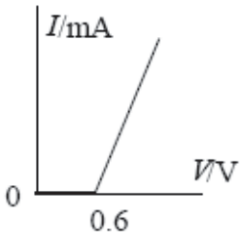
| | | |
|---|---|---|
| **25** | A trapezoidal coil *PQRS* is driven with constant velocity in a direction perpendicular to a uniform magnetic field as shown in the figure below.<br>  <br><br>At the instant shown, which of the following statements is correct? | |
| | **A** | An induced current it flowing in the coil in the clockwise direction. |
| | **B** | An induced current is flowing in the coil in the anticlockwise direction. |
| | **C** | There is no induced current flowing in the coil. |
| | **D** | An electromagnetic force acts on the side *PQ* in a direction opposing its motion. |

| | |
|---|---|
| | Ans: C |

| | | |
|---|---|---|
| **26** | The circuit below shows the rectification of a sinusoidal a.c. supply using two identical diodes $D_1$ and $D_2$.<br>$E = E_0 \sin(\omega t)$<br>  <br><br>Each of the diodes has the *I-V* characteristics as shown.<br>  <br><br>For a current to flow through *R*, the value of $E_0$ must be at least | |
| | **A** | 0.3 V |
| | **B** | $0.3\sqrt{2}$ V |
| | **C** | $0.6\sqrt{2}$ V |
| | **D** | $1.2\sqrt{2}$ V |

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| | |
|---|---|
| | Ans: D<br><br>For A, B and C, the value of E can never be 1.2 V. So cannot be the answer. |

| | | |
|---|---|---|
| **27** | Which piece of evidence about the photoelectric effect cannot be explained using a wave model? | |
| | **A** | Increasing the intensity of the illumination increases the rate at which electrons are ejected. |
| | **B** | Shining ultraviolet radiation onto a zinc surface ejects electrons. |
| | **C** | Increasing the frequency of the radiation increases the kinetic energy of the ejected electrons. |
| | **D** | There is a minimum frequency of radiation below which no electrons are ejected from the metal surface despite increasing the intensity of radiation. |

| | |
|---|---|
| | Ans: D |

| | | |
|---|---|---|
| **28** | What is the de Broglie wavelength of an electron having a kinetic energy of 54 eV? | |
| | **A** | $3.7 \times 10^{-27}$ m |
| | **B** | $6.7 \times 10^{-20}$ m |
| | **C** | $1.7 \times 10^{-10}$ m |
| | **D** | $2.3 \times 10^{-8}$ m |

| | |
|---|---|
| | Ans: C<br><br>$k.e. = \frac{p^2}{2m} = 54 \times 1.6 \times 10^{-19} \Rightarrow p = 3.97 \times 10^{-24}$<br>$\lambda = \frac{h}{p} = 1.67 \times 10^{-10}$ |

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**29** The table shows the ionizing effect of different types of radiation.

| | X | Y | Z |
|---|---|---|---|
| Ionising Effect | Strong | Weak | Very weak |

What are the radiations **X**, **Y** and **Z**?

| | | X | Y | Z |
|---|---|---|---|---|
| | **A** | Gamma | Beta | Alpha |
| | **B** | Beta | Alpha | Gamma |
| | **C** | Alpha | Beta | Gamma |
| | **D** | Gamma | Alpha | Beta |

Ans: C

**30** Which statement concerning α-particles is correct?

| | | |
|---|---|---|
| | **A** | An α-particle has charge +4e. |
| | **B** | An α-particle is a helium atom. |
| | **C** | An α-particle has mass 4u. |
| | **D** | When α-particles travel through a sheet of gold foil, they make the gold radioactive. |

Ans: C – An alpha particle is a helium nucleus with a charge of 2e and mass 4u.

ꕥ END OF PAPER ꕥ

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**NJC 2019 Prelim Paper 2**

| | | | | |
|---|---|---|---|---|
| **1** | **(a)** | **(i)** | $\frac{kgms^{-2}}{m^2} = kgm^{-1}s^{-2}$ | |
| | | **(ii)** | Units of $v = ms^{-1}$<br>Units of $\rho = kgm^{-3}$<br><br>Units of $\gamma = \frac{(ms^{-1})^2 kgm^{-3}}{kgm^{-1}s^{-2}}$<br>= no units | |
| | **(b)** | **(i)** | Fractional error of P $= \frac{5}{105} = 0.048$ (2s.f) | |
| | | **(ii)** | 1. $\frac{\Delta v}{v} = \frac{1}{2}\frac{\Delta P}{P} + \frac{1}{2}\frac{\Delta \rho}{\rho} = \frac{1}{2} \times 0.048 + \frac{1}{2} \times \frac{0.1}{1.2} = 0.066$<br>$\Delta v = 0.66 \times 328.85 = 21.7 \approx 20\ ms^{-1}$<br><br>2. $v = (330 \pm 20) ms^{-1}$ | |
| | **(c)** | | Yes as all the obtained values are all lower than the theoretical value. | |

| | | | | |
|---|---|---|---|---|
| **2** | **(a)** | | Oscillating magnet causes a rate of change of magnetic flux linkage in the coil, by Faraday's Law, an EMF is induced.<br><br>Since circuit is closed, by Lenz's Law, an induced current flows such that it produce a magnetic field to oppose the change in magnetic flux that causes it.<br><br><u>AND:</u><br><br>This magnetic field thus opposes the motion of the oscillating magnet.<br>Since the motion is opposed, the amplitude is reduced.<br><u>Alternatively:</u><br>The induced current flows through the resistor causing a heating effect.<br>This dissipate thermal energy which originated from the energy stored in the spring.<br>Thus the motion of the magnet reduces in amplitude. | |
| | | | | |
| | **(b)** | **(i)** | $V_{rms} = V_0 / \sqrt{2} = 27.0 / \sqrt{2} = 19.092$ mV<br>Therefore, <P> = $19.092^2 / 5$<br>= 73 μW | |
| | | **(ii)** | T = $2\pi / \omega = 2(3.14)/15.7 = 0.4$ s<br>Labelled cosine square graph<br>$P_o = V_0^2/R = (27 \times 10^{-3})^2 / 5 = 146$ μW OR 2<P> = 146 μW | |

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| | | | | |
|---|---|---|---|---|
| **3** | **(a)** | | Coherence means that the phase difference between two waves remain constant and do not vary with time. | |
| | **(b)** | | | |
| | | **(i)** | The microwaves waves from the two sources undergo interference. The path/phase difference at P is changing as $S_1$ moves.<br><br>When the waves are in phase at P such that the path difference between the sources is an integer number of wavelengths (or equivalent statement about phase difference); constructive interference occurs at P resulting in maximum intensity.<br><br>When the waves are anti-phase at P when the path difference is an integer number of wavelengths plus half a wavelength (or equivalent statement about phase difference), destructive interference occurs at P resulting in minimum/zero intensity. | |
| | | **(ii)** | path difference = XY = $\frac{\lambda}{2}$<br>$\lambda$ = 0.164 m<br><br>$v = f\lambda$<br>$f = \frac{3.0\times10^8}{0.164} = 1.8 \times 10^9\ Hz$ | |
| | | **(iii)** | As the microwaves from S1 and S2 are no longer have the same axis of polarization, destructive interference does not take place (or the waves do not cancel out).<br><br>Hence, the intensity of the microwave at P is now between the minimum and the maximum. | |
| | **(c)** | | | |
| | | **(i)** | Original amplitude of $S_1$ = 12 units<br><br>As intensity is proportional to the square of the amplitude<br>New amplitude of $S_1$ = $\sqrt{\frac{I/2}{I}} \times 12$<br>= 8.5 units. | |
| | | **(ii)** | Wave in antiphase with original but with only 8.5 units | |

| | | | | |
|---|---|---|---|---|
| **4** | **(a)** | **(i)** | The increase in internal energy of a system is equal to the sum of heat (or thermal energy) supplied to the system (or heating) and the work done on the system. | |
| | | **(ii)** | Increase in volume (or intermolecular separation) is more significant in vaporisation compared to melting<br>Hence, the increase in internal energy and work done by the substance in expanding against atmospheric pressure is greater in vaporisation compared to melting resulting in a larger specific latent heat of vaporisation compared to specific latent heat of fusion for the same substance. | |
| | **(b)** | **(i)** | At point A: $p_A V_A = 1.0 \times 10^5 \times 4.5 \times 10^{-2} = 4500$<br>At point B: $p_B V_B = 3.0 \times 10^5 \times 1.5 \times 10^{-2} = 4500$<br><br>Since (from the equation of state of an ideal gas) $pV$ is directly proportional to the thermodynamic temperature of the gas, it follows that $p_A V_A = p_B V_B$ means the temperature at A and B are the same and hence A→B is an isothermal process | |

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| | | | | |
|---|---|---|---|---|
| | | **(ii)** | pressure $= \frac{Force}{Area}$ and Force $= \Delta v \frac{Nm}{t} = (m\Delta v)\left(\frac{N}{t}\right) = (\Delta p)\left(\frac{N}{t}\right)$<br><br>From A→B, the temperature is constant, increase in pressure is due to the increase in the rate of collision between the gas molecules and the walls of the container due to the decrease in the volume of the gas.<br>From C→B, the volume of the gas is constant while temperature of the gas is increased resulting in the increase in mean square speed of the gas molecules. This increases the rate of collision as well as the change in momentum of each molecule as it collides with the wall. | |
| | | **(iii)** | Area under the graph $\approx \frac{1}{2}(1 + 2.25) \times 10^5 \times (4.5 - 1.5) \times 10^{-2} = 4900$ J<br>Since $q + w = 0$ $q = -w = -4900$ J<br>Heat removed = 4900 J (accept 4000 to 5500 J) | |

| | | | | |
|---|---|---|---|---|
| **5** | **(a)** | **(i)** | Amount of work needed to take all its constituent nucleons apart so that they are separated an infinite distance from one another. | |
| | | **(ii)** | Total binding energy of He-4 = 7.075175 × 4 = 28.30070 MeV<br>Total binding energy of Be-9 = 6.462767 × 9 = 58.16490 MeV<br>Total binding energy of C-12 = 7.675310 × 12 = 92.10372 MeV<br>(2m, any one wrong will be awarded 1 m only for the question)<br><br>Energy released = 92.10372 – (28.30070 + 58.16490) = 5.638120 MeV | |
| | **(b)** | **(i)** | Nuclei/Atoms with same proton number/atomic number, but contain different numbers of neutrons/different atomic mass. | |
| | | **(ii)** | **1.**<br>mass = 238 × 1.66 × $10^{-27}$<br>= 3.95 × $10^{-25}$ kg<br><br>**2.**<br>Volume = 4/3 π × $(8.9 \times 10^{-15})^3 = 2.95 \times 10^{-42}$<br><br>density = $(3.95 \times 10^{-25})/(2.95 \times 10^{-42})$<br>= 1.3 × $10^{17}$ kg $m^{-3}$ | |
| | | **(iii)** | The nucleus contains most of mass of atom.<br>*either* The nuclear's diameter/volume is very much less than that of atom<br>*or* The atom is mostly (empty) space. | |

| | | | | |
|---|---|---|---|---|
| **6** | **(a)** | | A photon is a quantum (packet) of electromagnetic radiation / wave / field. | |
| | **(b)** | | $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{6.33\times10^{-7}}$ = 3.14 x $10^{-19}$ J | |
| | **(c)** | | $P = \frac{Nhf}{t}$ $\frac{N}{t} = \frac{P}{hf} = \frac{1\times10^{-3}}{3.14\times10^{-19}} = 3.2 \times 10^{15}$ | |

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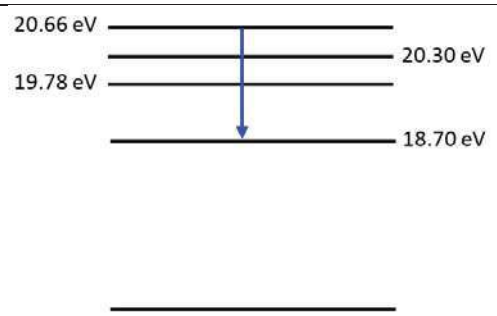
| | | | | |
|---|---|---|---|---|
| | **(d)** | |  <br>Fig 6.2 | |
| | **(e)** | **(i)** | UP | |
| | | **(ii)** | Number of photoelectrons emitted per unit time $= \frac{20}{100} \times 3 \times 10^{15}$<br>$= 6 \times 10^{14}$<br><br>Current, $I = \frac{Ne}{t} = 6 \times 10^{14} \times 1.6 \times 10^{-1}$<br><br>$= 9.6 \times 10^{-5}$ A | |
| | | **(ii)** | Most of the incident photons are reflected by the photodiode. | |

| | | | | |
|---|---|---|---|---|
| **7** | **(a)** | **(i)** | $T^2 \alpha r^3$<br>$(2\pi r/v)^2 \alpha r^3$<br>$r^2 / v^2 \alpha r^3$<br>$a \alpha 1/r^2$ and thus we can conclude F is inversely proportional to $r^2$ since F = ma | |
| | | **(ii)** | Gravitational force provides the centripetal force for circular motion to take place.<br>By Newton's 2nd Law,<br>F = ma<br>$GMm/r^2 = mr\omega^2$<br>$GM/r^3 = (2\pi/T)^2$<br>$T^2 = 4\pi^2 r^3/ GM$ | |
| | **(b)** | **(i)** | <table><tr><th>lg (T/days)</th><th>lg (r/m)</th></tr><tr><td>2.38</td><td>10.05</td></tr><tr><td>1.22</td><td>9.27</td></tr><tr><td>0.25</td><td>8.63</td></tr></table> | |

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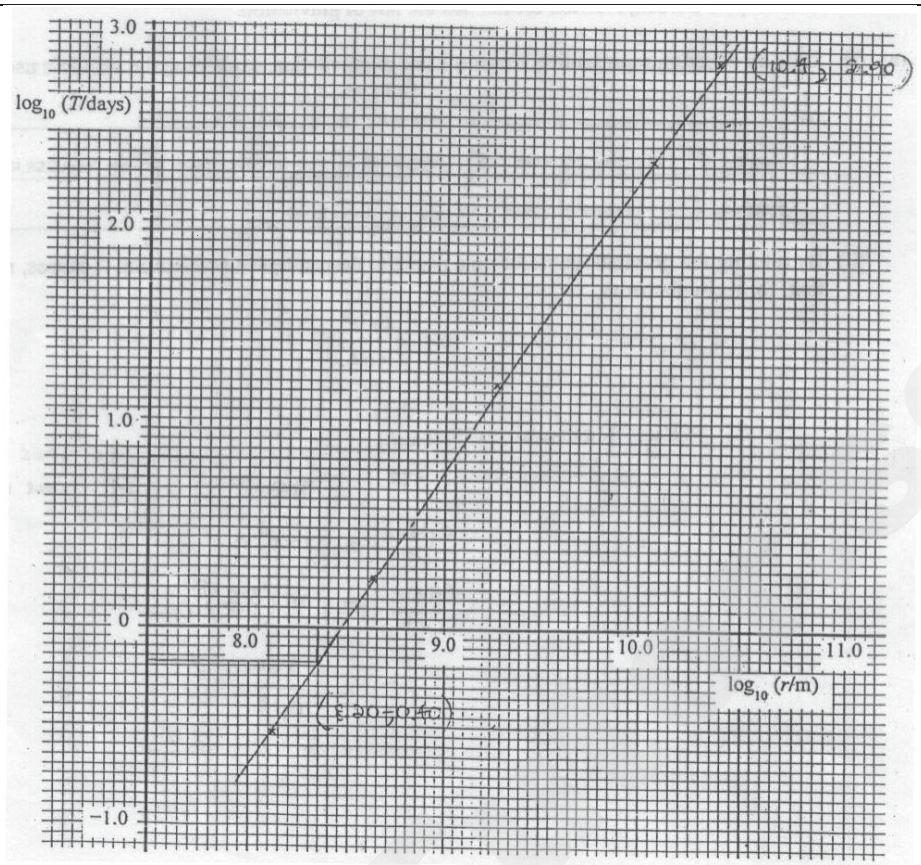
| | | | | |
|---|---|---|---|---|
| | | **(ii)** |  | |
| | | **(iii)** | Gradient = 2.90 – (-0.40) / (10.40 – 8.20) = 1.50 | |
| | | **(iv)** | $T^2 = 4\pi^2 r^3 / GM$<br>$T^2 = kr^3$, where $k = 4\pi^2 / GM$ (constant because all the moons are orbiting around Jupiter)<br>lg T = (3/2) lg r + lg k<br><br>If lg T is plotted against lg r, the gradient should be 1.5 and this corresponds with the graphically obtained value. Hence, the data support the relation. | |
| | **(c)** | | $T_G$ = 7.16, lg $T_G$ = 0.85<br>From graph, lg ($r_G$) = 9.05, $r_G = 1.12 \times 10^9$ m | |
| | **(d)** | | $T_T$ = 16.2 / 24 days, lg $T_T$ = -0.17<br>From graph, lg ($r_G$) = 8.35, $r_G = 2.24 \times 10^8$ m<br><br>$r_G$ calculated is the distance of the Thebe to the centre of Jupiter. We can only decide on the accuracy of the statement if the radius of Jupiter is known. | |
| | **(e)** | | No, because the k value mentioned in (c)(ii) will be different. Orbital radii and periods of moons depend on the mass of the planet where the moons are orbiting. | |
| | | | | |

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**NJC 2019 Prelim Paper 3**

| | | | | |
|---|---|---|---|---|
| **1** | **(a)** | **(i)** | horizontal speed constant at 8.2 m $s^{-1}$<br>vertical component of speed = 8.2 tan 60°<br>= 14.2 m $s^{-1}$ | |
| | | **(ii)** | 14.22 = 2 × 9.8 × h<br>vertical distance = 10.3 m | |
| | | **(iii)** | time of descent = 14.2 / 9.8 = 1.45 s<br>x = 1.45 × 8.2<br>= 11.9 m | |
| | **(b)** | **(i)** | smooth path curved and above given path<br>hits ground at more acute angle | |
| | | **(ii)** | smooth path curved and below given path<br>hits ground at steeper angle | |
| | **(c)** | | b(ii) will take a longer time as its KE at any point is lower and thus average velocity is lower.<br>Since, vertical distance is same, the time take is lower. | |
| | | | | |

| | | | | |
|---|---|---|---|---|
| **2** | **(a)** | **(i)** | $\Delta p = \Delta(mv) = m\,\Delta v = m\,(v_f - v_i)$<br>$= 1.2\,(-0.8 - 4)$<br>$= -5.76$ kg m $s^{-1}$ | |
| | | **(ii)** | Ball S must have a change of momentum of 5.76 kg m $s^{-1}$ as well, thus<br>$5.76 = m\,(v_f - v_i)$<br>$= 3.6\,(v_f - 0)$<br>$v_f = 1.6$ m $s^{-1}$ | |
| | **(b)** | | Relative speed of approach = $u_1 - u_2 = 4 - 0 = 4$ m $s^{-1}$<br>relative speed of separation = $v_2 - v_1 = 1.6 - (-0.8) = 2.4$ m $s^{-1}$<br>Since they are different, this is an inelastic collision.<br>(accept ans using KE conservation. $KE_i$ = 9.60 J, $KE_f$ = 4.99 J) | |

| | | | | |
|---|---|---|---|---|
| **3** | **(a)** | | Resultant Force, $F_R = ma = 4000\,(0.30) = 1200$ N<br>Applied force, $F = F_R + f = 1200 + 700 = 1900$ N<br>Therefore power = 1900 (8.0) = 15200 W | |
| | | | | |
| | **(b)** | **(i)** | Applied force, P = Fv<br>7600 = 700 v F = f, since max speed, a = 0<br>V = 10.9 m $s^{-1}$ | |
| | | **(ii)** | sin□□ = 1/25<br>Total opposing force $f_T = f + mg \sin\theta = 700 + 39240\,(0.04) = 2270$ N<br>P = Fv<br>v = 7600 / 2270 = 3.35 m $s^{-1}$ | |

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| | | | | |
|---|---|---|---|---|
| **4** | **(a)** | | Direction of girl's velocity is changing<br><br>Acceleration is the rate of change of velocity | |
| | | | | |
| | **(b)** | **(i)** | $F = \frac{mv^2}{r} = \frac{(60)(10^2)}{3.4}$<br><br>= 1760 N | |
| | | **(ii)** | N = centripetal force = 1760 N<br><br>$f = mg = (60)(9.81)$<br><br>$\mu = 0.33$ | |
| | **(c)** | | Vertical component of the normal force is directed upwards<br><br>it can balance the weight of the girl hence no need for friction | |

| | | | | |
|---|---|---|---|---|
| **5** | **(a)** | **(i)** | Simple harmonic motion is defined as the motion of a particle about a fixed point such that its acceleration **a** is proportional to its displacement **x** from a fixed point, and is directed towards the fixed point. | |
| | | **(ii)** | use of $a = -\omega^2 x$ clear<br><br>either $\omega = \sqrt{(2k/m)}$ or $\omega^2 = (2k/m)$<br>$\omega = 2\pi f$<br><br>f = $(1/2\pi)\sqrt{(2 \times 300)/0.240)}$<br>= 7.96 ≈ 8 Hz | |
| | **(b)** | **(i)** | **1**. resonance<br><br>**2**. 8 Hz | |
| | | **(ii)** | There is maximum energy transfer from the driver to the oscillating mass during resonance. | |
| | | **(iii)** | (increase amount of) damping<br>without altering (k or) m …(some indirect reference is acceptable)<br>sensible suggestion. | |

| | | | | |
|---|---|---|---|---|
| **6** | **(a)** | | Into the page / into the (plane of) paper.<br>(Do not accept into the plane unless candidate specify which plane they are referring to) | |
| | **(b)** | | Magnetic force (acting on ions) provides the centripetal force (or centripetal acceleraton)<br><br>$Bqv = \frac{mv^2}{r}$ or $Bq(v\sin\theta) = \frac{m(v\sin\theta)^2}{r}$<br><br>$B = \frac{(20\times1.66\times10^{-27})(1.40\times10^5)}{(1.60\times10^{-19})(\frac{0.128}{2})}$<br><br>= 0.4539 ≈ 0.454 T (shown) | |
| | **(c)** | **(i)** | Proper semi-circle with **slightly larger** diameter | |

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| | | | | |
|---|---|---|---|---|
| | | | | |
| | | (ii) | From $Bqv = \frac{mv^2}{r}$ $\quad B \propto m$<br>$\frac{B}{0.454} = \frac{22}{20}$<br>$B = 0.499$ T<br>Or $\quad B = \frac{(22\times1.66\times10^{-27})(1.40\times10^{5})}{(1.60\times10^{-19})\left(\frac{0.128}{2}\right)}$ $\quad B = 0.499$ T | |

| | | | | |
|---|---|---|---|---|
| **7** | **(a)** | | $F = (\Delta v)\frac{Nm}{t} = (m\Delta v)\frac{N}{t} = 1.85 \times 10^{-23} \times 1.49 \times 10^{24}$<br>$= 27.6$ N | |
| | | | | |
| | **(b)** | | $p = \frac{F}{A} = \frac{27.6}{0.018} = 1530$ Pa $\quad$ (accept $p = \frac{27.6}{(0.134)^2}$) | |
| | **(c)** | | From $pV = NkT$ $\quad N = \frac{pV}{kT}$<br>$N = \frac{(1530)(0.018\times0.134)}{(1.38\times10^{-23})(273+27)}$<br>$= 8.9 \times 10^{20}$ | |
| | **(d)** | | From $\frac{1}{2}mc_{rms}^2 = \frac{3}{2}kT$ $\quad c_{rms} = \sqrt{\frac{3kT}{m}}$<br>$c_{rms} = \sqrt{\frac{3(1.38\times10^{-23})(273+27)}{6.86\times10^{-27}}}$<br>$= 1350$ ms$^{-1}$<br>Accept $\Delta p = 2mc_{rms}$ although this is not the preferred method unless student mentioned that based on the assumptions of kinetic theory of gases, the collision between the gas molecules and the container is perfectly elastic. | |

| | | | | |
|---|---|---|---|---|
| **8** | **(a)** | **(i)** | R = ρl / A<br>1200 = 15.0 × $10^{-5}$ (0.25) / (1 × $10^{-3}$ × t)<br>t = 3.13 × $10^{-5}$ m | |
| | | **(ii)** | V = IR<br>9 = I(1200)<br>I = 7.5 x $10^{-3}$ A<br>I = nAve<br>V = I/(nAe) = 7.5 × $10^{-3}$ / (2.2 × $10^{28}$ × 1 × $10^{-3}$ × 3.13 × $10^{-5}$ × 1.6 x $10^{-19}$)<br>= 6.81 x $10^{-5}$ m s$^{-1}$ | |
| | **(b)** | **(i)** | Light Dependent Resistor<br>("LDR" not accepted) | |

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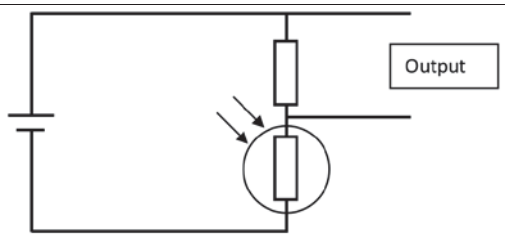
| | | | | |
|---|---|---|---|---|
| | | **(ii)** |  | |
| | | **(iii)** | The resistor and the light-dependent resistor are connected in series with the cell so that the cell's e.m.f. is shared between them. Thus, when the potential difference of one of the component increases, the other should decrease using the potential divider principle. The light dependent resistor characteristic is such that when the ambience light is bright, the resistance is low, thus the potential difference across it will be low and the potential difference across the resistor will be high, and vice versa. | |
| | **(c)** | **(i)** | E.m.f. of a source is defined as the amount of energy converted from other forms of energy to electrical energy when the source drives a unit charge round a complete circuit. Whereas for potential difference, it is energy converted from electrical to other forms of energy. | |
| | | **(ii)** | Since there is not current in the ammeter, the potential difference across XM and YN must be the same, and the potential at X must be the same as Y. | |
| | | **(iii)** | $V_{10}$ = 12 × 10/25= 4.8 V<br>Thus $V_L$ = 4.8 = 5 × L/25<br>L = 24 cm | |
| | | **(iv)** | If the 12 V cell has internal resistance, the EMF of the cell will have to drop some p.d. across the internal resistance. Thus the p.d. across $V_{10}$ will decrease.<br>For the ammeter to continue to have a null deflection, length L will need to be decreased.<br>OR<br>For the ammeter to continue to have a null deflection, thus the length between YP must increase | |

| | | | | |
|---|---|---|---|---|
| **9** | **(a)** | | The principle of moments states that for a body to be in (rotational) equilibrium, the sum of clockwise moments about any point must be equal to the sum of anti-clockwise moments about the same point. (Accept net/total moment about a fixed point is zero) | |
| | | | | |
| | **(b)** | **(i)** | As sphere X is heavier than mass A, the clockwise moment due to the weight of sphere X about P is greater than the anticlockwise due to the weight of mass A about P.<br>By the principle of moments, for mass A and sphere X to be balanced, the electric force on sphere X must provide an anti-clockwise moment.<br>Sphere Y must be negatively charged to provide such an electric force on sphere X. | |
| | | **(ii)** | Let the electric force be F and $l$ the length of the rod.<br><br>By the principle of moments,<br>Clockwise moments about P = anti-clockwise moments about P<br>$0.200 \times 9.81 \times \frac{l}{2} = 0.150 \times 9.81 \times \frac{l}{2} + Fsin25° \times \frac{l}{2}$<br>$Fsin25° = 0.4905\ N$<br>$F = 1.16N$ | |
| | | **(iii)** | Pointing upwards and to the right | |

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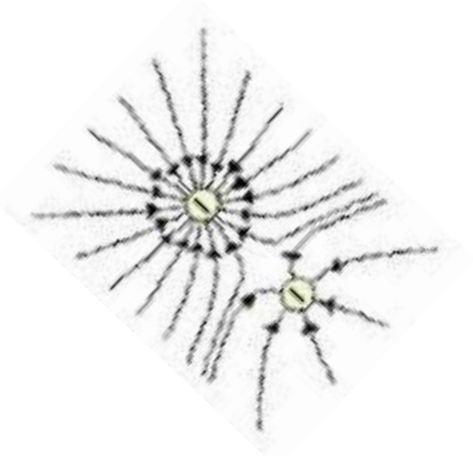
| | | | | |
|---|---|---|---|---|
| | **(c)** | |  | |
| | **(d)** | **(i)** | The potential energy of the decreases as it is moved from d = 0.05 m<br>and reaches a minimum potential energy in between d = 0.05 m to d = 0.35 m.<br>It then increases as it is moved towards d = 0.35 m. | |
| | | **(ii)** | Potential due to X = - 150kV<br>Potential due to Y = - 370 kV<br><br>Total potential = - 150 – 370 = - 520 kV<br><br>Potential energy = qV = $-520000 \times (-1.6 \times 10^{-19}) = 8.32 \times 10^{-14} J$ | |
| | | **(iii)** | Negative potential gradient is the electric field strength<br>Since net force is zero, the net electric field strength is zero.<br>Hence, the magnitude of the potential gradient of X is equal to that of Y at this point<br>The direction of the potential gradient of X is opposite to that of Y at this point. | |

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H

# NATIONAL JUNIOR COLLEGE

## SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

**PHYSICS**
Paper 4 Practical

**9749/04**

**22 August 2019**
**2 hours 30 minutes**

Candidate answers on the Question Paper.
Additional Materials: As listed on Instructions.

**READ THESE INSTRUCTIONS FIRST**
Write your subject class, registration number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answers **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| 1 | / 16 |
| 2 | / 6 |
| 3 | / 21 |
| 4 | / 12 |
| Total (55m) | |



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**1** In this experiment you will investigate the behaviour of a sphere rolling across a sloping board.

**(a)** Place the thread over the top of the board and clip it in place with the spring clip.

Set up the apparatus as shown in Fig. 1.1, with the board at an angle of approximately 45° to the bench. The length of the thread between the spring clip and the sphere should be approximately 20 cm.

**Do not remove the clamp from your bench.**

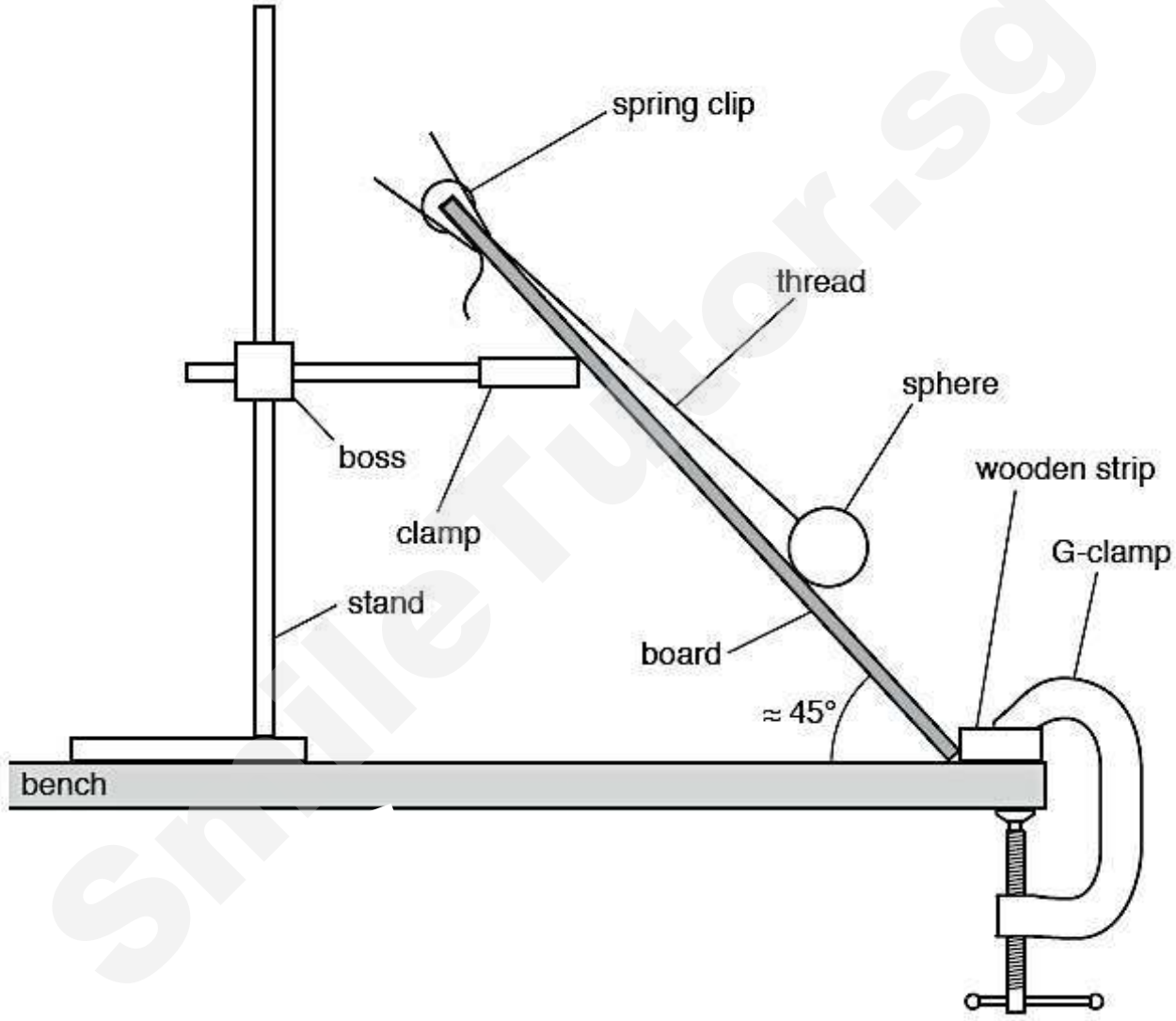


**Fig. 1.1** (not to scale)

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**(b)** **(i)** Measure and record the angle $\theta$ between the board and the bench, as shown in Fig. 1.2.

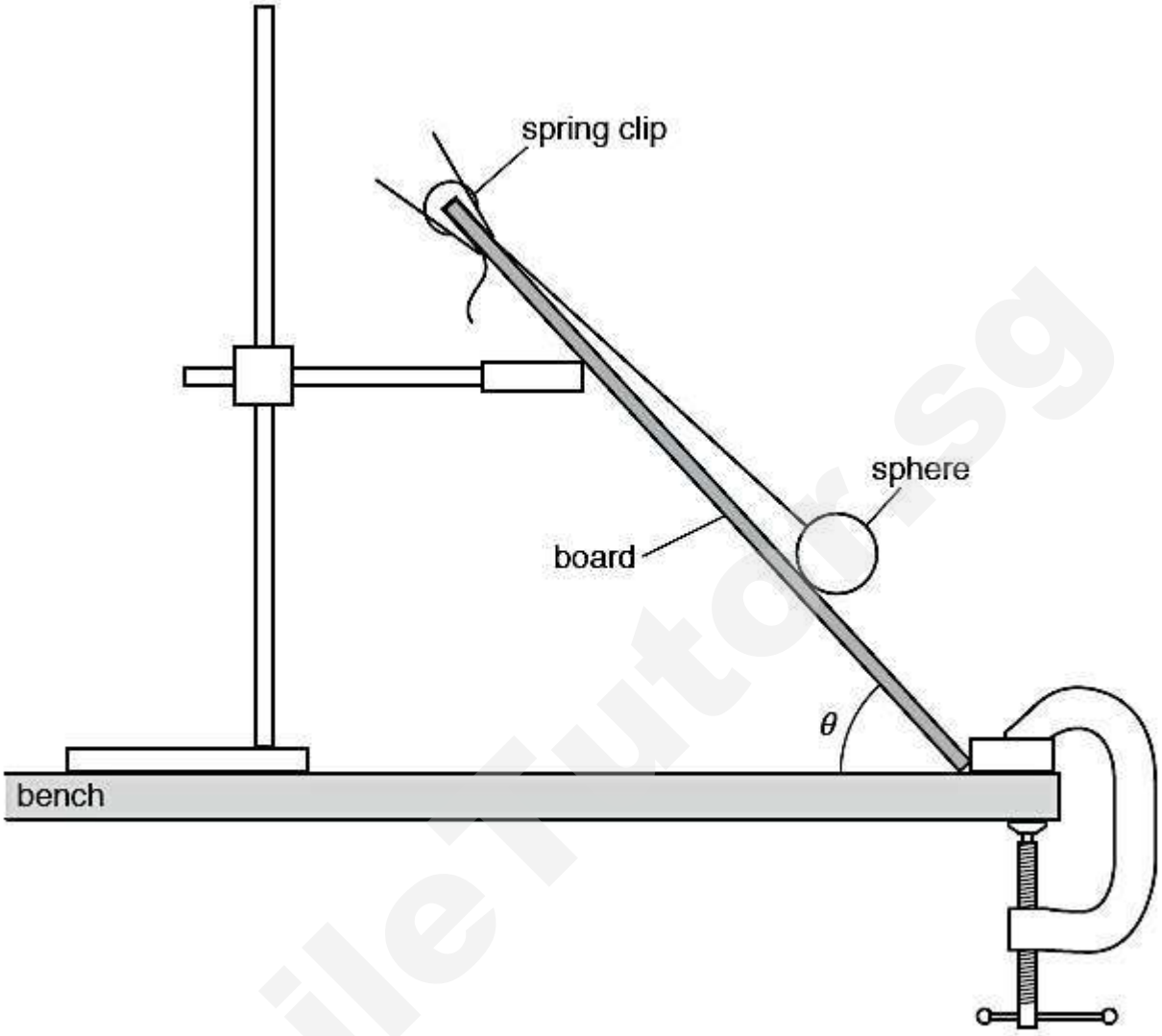


**Fig. 1.2** (not to scale)

| |
|---|
| 45° Value of $\theta$ from 40° to 50°, to nearest degree, with unit |

$\theta$ = ..... [1]

**(ii)** Push the sphere to one side. Release the sphere so that it oscillates from side to side.

**(iii)** Take measurements to find the period *T* of the oscillations.

Record *T*.

| |
|---|
| For 5 oscillations, $t_1 = 6.14\ s$, $t_2 = 6.32\ s$ |
| $T = \frac{6.14+6.32}{2\times5} = 1.25\ s$ |
| Value of T from 1.0 to 2.0 s, with unit |
| Evidence of repeat readings |

*T* = ..... [2]

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**(c)** Change $\theta$ by moving the boss and clamp and repeat **(b)** to take further values of $\theta$ and *T*.

Do **not** change the length of the thread between the sphere and the spring clip.

| $\theta/°$ | n (no. of osc) | $t_1/s$ | $t_2/s$ | $T/s$ | $T^{-3}/s^{-3}$ |
|---|---|---|---|---|---|
| 60 | 5 | 5.55 | 5.60 | 1.12 | 0.721 |
| 55 | 5 | 5.66 | 5.72 | 1.14 | 0.679 |
| 50 | 5 | 5.98 | 5.98 | 1.20 | 0.585 |
| 45 | 5 | 6.14 | 6.32 | 1.25 | 0.517 |
| 40 | 5 | 6.67 | 6.75 | 1.34 | 0.414 |
| 35 | 5 | 6.92 | 6.93 | 1.39 | 0.376 |

6 readings

$\theta$ values must include $35°$ or less and $55°$ or more

Column headings with correct presentation and units (column for T not required)

d.p.: $t_1$ and $t_2$ to nearest 0.01 s

s.f.: correct s.f. for $T^{-3}$, depending on s.f. of $t_1$ and $t_2$ ( same no. or one greater than)

Calculation : $T^{-3}$ calculated correctly

[7]

**(d)** $\theta$ and *T* are related by the expression

$$\theta = \frac{a}{T^3} + b$$

where *a* and *b* are constants.

Plot a suitable graph to determine the values of *a* and *b*.

Plot $\theta$ against $\frac{1}{T^3}$ where a is the gradient and b the y-intercept

Using points (0.70, 57) and (0.40, 38)

Gradient = $\frac{58.5-36.5}{0.70-0.40} = 73.3$ [1] (gradient triangle must be more than half the drawn line, coordinates of points read to half a small square)

a = $73.3°s^3$ correct calculation and units

y-intercept = $58.5 - 0.70 \times 73.3 = 7.2$ (points used must be read to nearest half a small square)

b = 7.2° correct calculation and units

*a* = .....

*b* = ..... [6]

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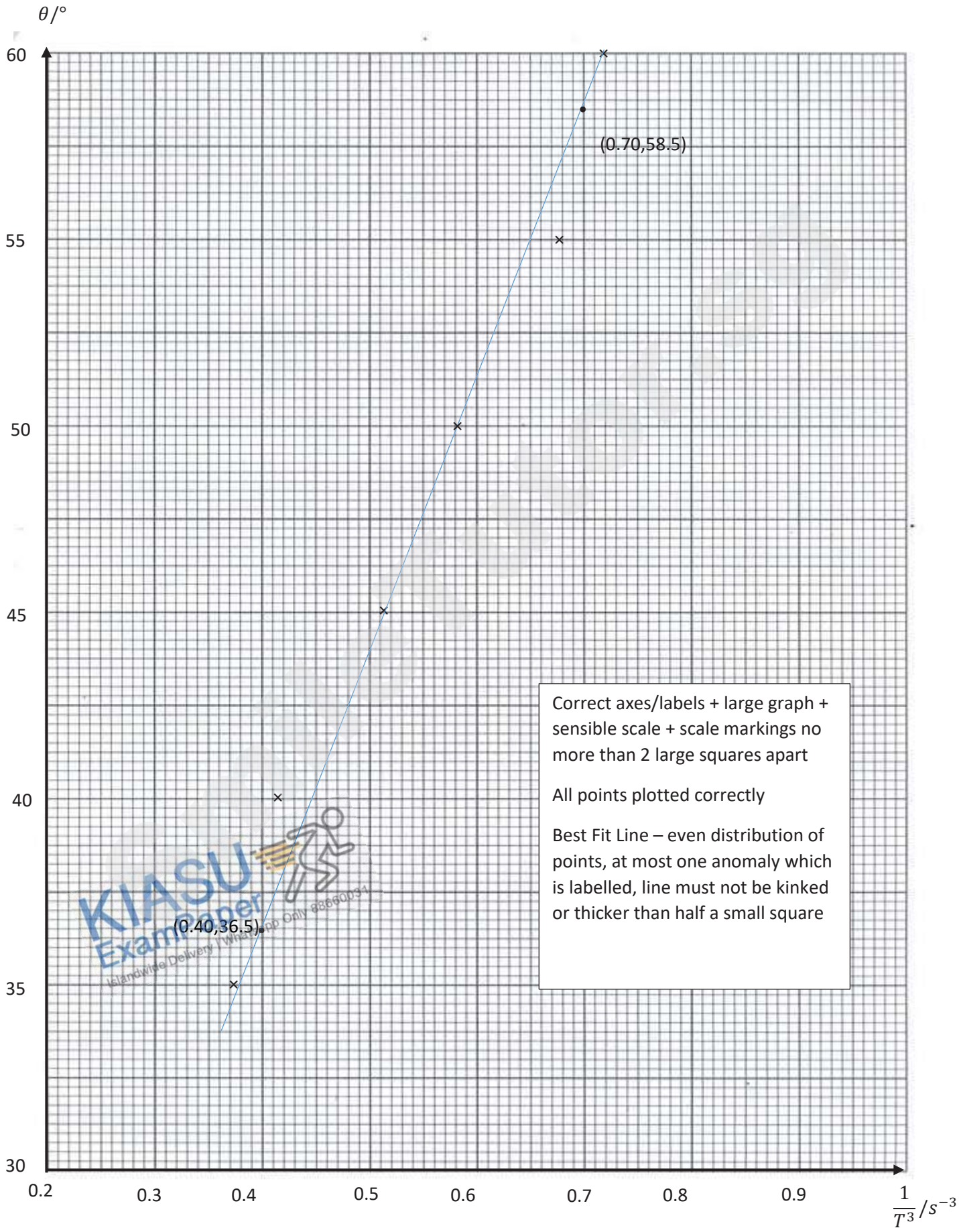


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[Total: 16]

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**2** In this experiment you will investigate an electrical circuit.

**(a)** **(i)** You have been provided with a resistor A of unknown resistance, an electrical component B and a switch.

Connect the circuit as shown in Fig. 2.1.

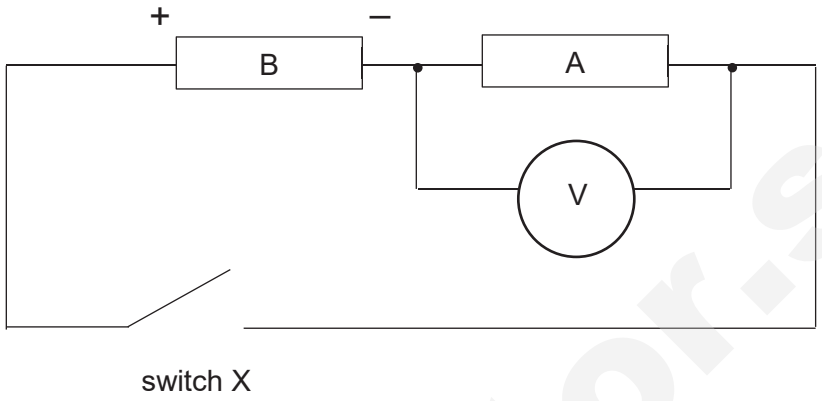


**Fig. 2.1**

The positive and negative terminals of component B are indicated on component B and **must** be connected as shown in the Fig. 2.1.

**(ii)** Switch the voltmeter to the 20 V range and close switch X.

**(iii)** Open switch X when the reading on the voltmeter is 0.01 V or less.

**(iv)** If the readings for this question needs to be re-taken, you should repeat the procedure starting from **(a)(i)** before taking the readings again.

**(b)** **(i)** Connect the battery cell to the circuit as shown in Fig. 2.2.

⚡Switch Y and Switch X must **not** be closed together as this will lead to a short circuit and a large current. ⚡

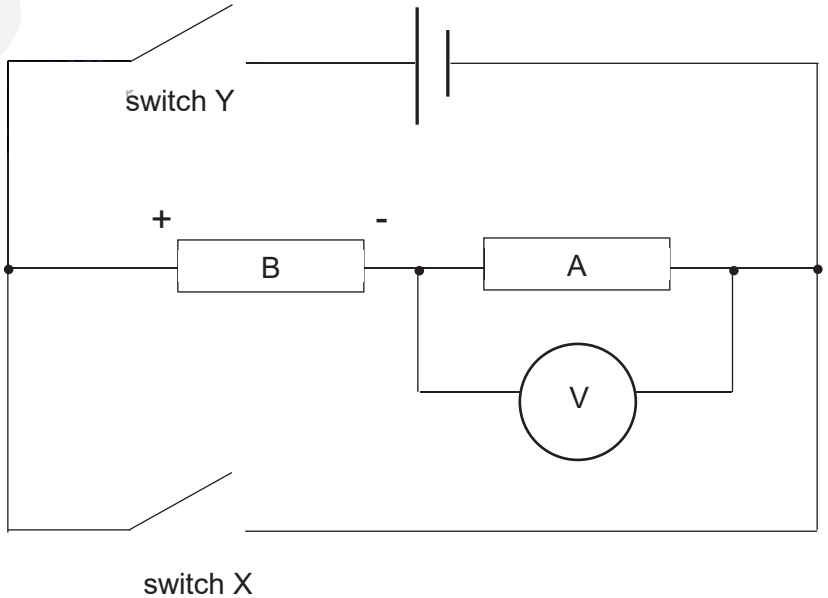


**Fig. 2.2**

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**(ii)** Close switch Y and start the stopwatch. Switch X must be **open**.

**(iii)** Record the numerical value of the potential difference $V_0$ across resistor A when the stopwatch is first started. This should be the highest value observed on the voltmeter when carrying out the steps **(b)(i)** to **(b)(iv)**.

1.44 V

$V_0$ = .....

**(iv)** Record the numerical value of the potential difference $V$ across resistor A when the time on the stopwatch reaches 10 s.

Note that the value of the potential difference should be decreasing continuously for the 10 s.

0.22 V (2 d.p. and correct unit)

$V$ = ..... [1]

**(v)** Allow switch Y to be closed for 1 minute.

**(vi)** Open switch Y.

**(c)** **(i)** Close switch X and start the stopwatch. Switch Y must be **open**.

**(ii)** Record the numerical value of the potential difference $V_0$ across resistor A when the stopwatch is first started. This should be the highest value observed on the voltmeter when carrying out the steps **(c)(i)** to **(c)(iii)**.

1.44 V

$V_0$ = .....

**(iii)** Record the numerical value of the potential difference $V$ across resistor A when the time on the stopwatch reaches 10 s.

0.24 V (2 d.p. and correct unit)

$V$ = ..... [1]

**(d)** Theory suggests that

$$V = V_0 e^{-\frac{10000}{R}}$$

where $R$ is the resistance of resistor A and $V_0$ the e.m.f. of the battery cell.

**(i)** Calculate the average value of $R$.

$ln\frac{V}{V_0} = -\frac{10000}{R}$

$R = \frac{-10000}{\ln(V/V_0)}$

1st value of R $= \frac{-10000}{\ln(0.22/1.44)} = 5300\Omega$

2nd value of R $= \frac{-10000}{\ln(0.24/1.44)} = 5600\Omega$

(correct calculation of both values of R)

Average R = $\frac{5300+5600}{2} = 5500\Omega$ (correct calculation of average, 2 to 3 s.f.)

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..... [2]

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**(ii)** If you were to repeat this experiment with other battery cells of different e.m.f., describe the graph that you would plot to determine *R*.

$V = V_0 e^{-\frac{10000}{R}}$

$lnV = lnV_0 - \frac{10000}{R}$ (show linearization)

Plot ln V against ln $V_0$ [2]

[Total: 6]

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**Question 3 begins on the next page**

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**3** In this experiment, you will investigate the appearance of a line viewed through a beaker of water.

**(a)** You have been provided with an empty beaker.

The thickness of the beaker is *t*.

Measure and record *t*.

$t_1 = 0.192cm, t_2 = 0.217cm$

$t = 0.205cm$ (repeated values, t to nearest 0.001 cm, 0.1 to 0.3 cm)

*t* = ..... [1]

**(b)** **(i)** The outer diameter of the beaker is *d* as shown in Fig. 3.1.




**Fig. 3.1**

Measure and record *d*.

$d = 6.99\ cm$ (d to nearest 0.01 cm, correct unit)

*d* = ..... [1]

**(ii)** Calculate the inner diameter *D* of the beaker where

$$D = d - 2t$$

$D = 6.99 - 2 \times 0.205 = 6.58cm$

*D* = .....

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**(c)** **(i)** Add water to the beaker until it is approximately three-quarters full.

**(ii)** The height *h* of water in the beaker is shown in Fig. 3.2.

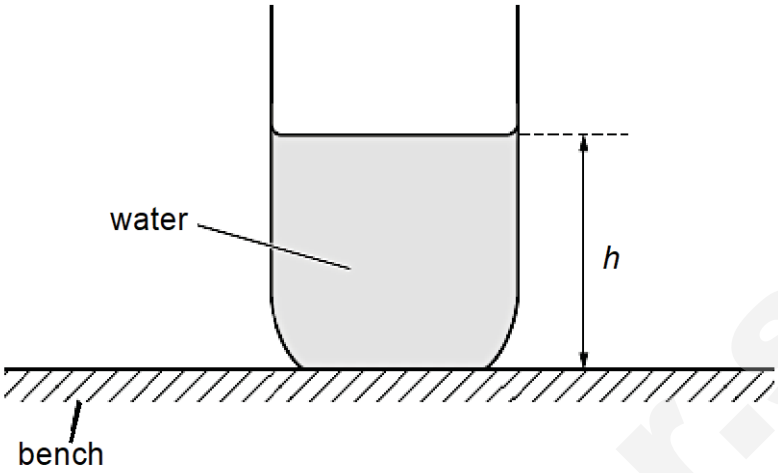


**Fig. 3.2**

Measure and record *h*.

h = 6.5 cm (h to nearest 0.1 cm, correct unit)

*h* = ..... [1]

**(iii)** Calculate the approximate volume *V* of water in the beaker using

$$V = \frac{\pi D^2 h}{4}$$

$V = \frac{\pi 6.58^2 \times 6.5}{4} = 220 cm^3$

Correct calculation with correct unit

*V* = ..... [1]

**(iv)** Justify the number of significant figures that you have given for your value of *V*.

V is calculated using d, t and h.

s.f of h is the smallest which is 2 s.f. Hence V is 2 s.f.

[1]

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**(d)** Draw a straight line of approximate length 25 cm in the centre of the A4 sheet of paper.

**(e)** **(i)** Place the beaker centrally on the line as shown in Fig. 3.3.

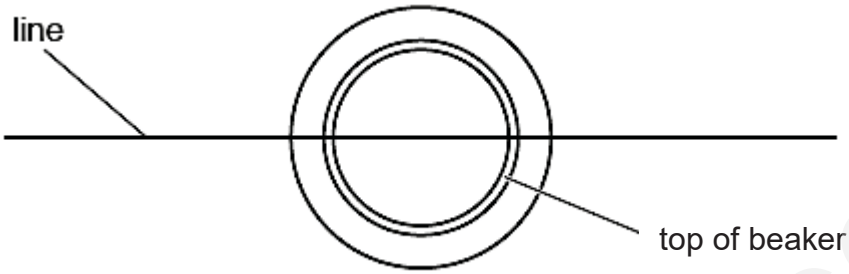


**Fig. 3.3**

Look down on the beaker from directly above. The line should appear to pass through the centre of the beaker as an unbroken straight line.

**(ii)** Move your head backwards and forwards.

When viewed through the water, the line (shown dotted) appears to move, as shown in Fig. 3.4.

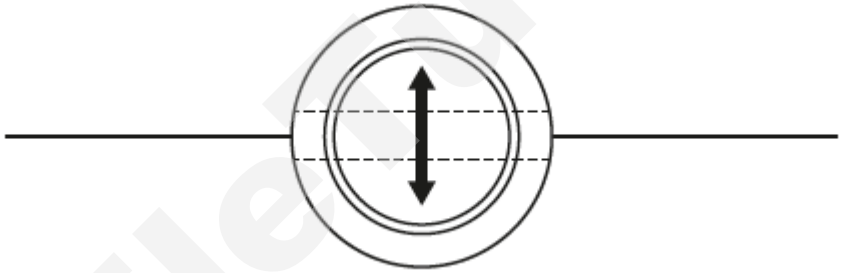

**Fig. 3.4**

**(iii)** Place the nails on the line either side of the beaker, as shown in Fig. 3.5.

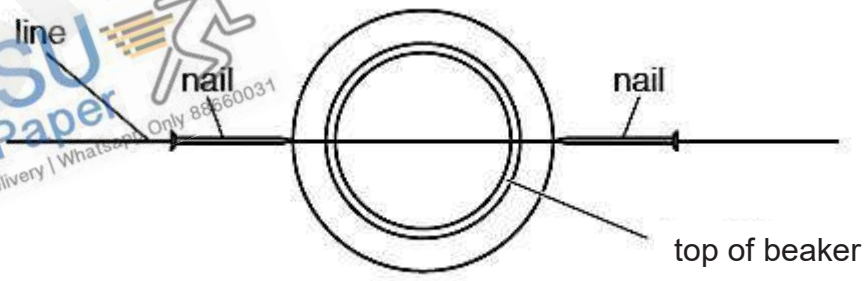


**Fig. 3.5**

**(iv)** For a particular height of the nails, the nails and the line viewed through the water appear to move together when you move your head backwards and forwards.

Raise the nails to this height.

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**(v)** The distance between the surface of the water and the nails is *y* as shown in Fig. 3.6.

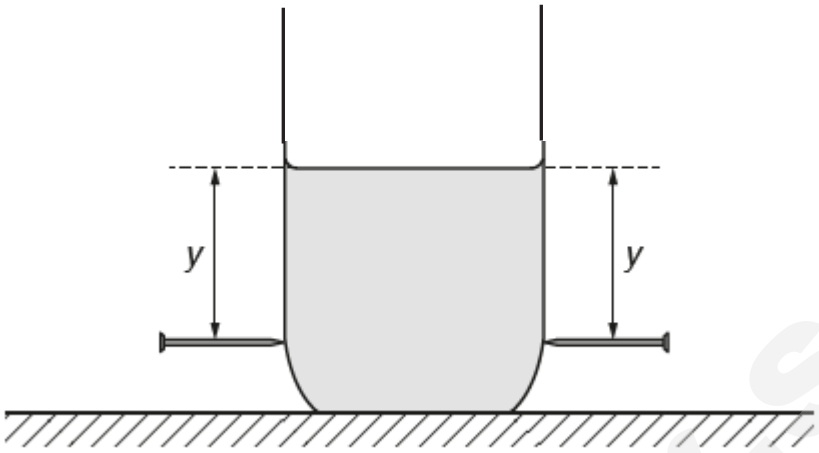


**Fig. 3.6**

Measure and record *y*.

$y_1 = 4.7\ cm, y_2 = 4.6\ cm$

y = 4.7 cm (repeated data, nearest 0.1 cm, correct unit)

*y* = ..... [1]

**(f)** Estimate the percentage uncertainty in your value of *y*.

$\Delta y = 0.5\ cm$ ( accept from 0.2 to 0.8 cm)

Percentage uncertainty = $\frac{0.5}{4.7} \times 100\% = 11\%$ (2 s.f.)

percentage uncertainty = ..... [1]

**(g)** Pour water out of the beaker until it is approximately half full.

Repeat **(c)(ii)**, **(c)(iii)** and **(e)**.

$h = 4.7\ cm$ (lower value)

$V = 160\ cm^3$ (correct calculation)

*h* = .....

$y_1 = 3.5cm$

$y_2 = 3.2\ cm$

$y = 3.4\ cm$ (lower value)

*V* = .....

*y* = ..... [3]

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**(h)** It is suggested that the relationship between $y$ and $V$ is

$$y = kV$$

where $k$ is a constant.

**(i)** Using your data, calculate two values of $k$.

$k_1 = \frac{y}{V} = \frac{4.7}{220} = 0.021 cm^{-2}$

$k_2 = \frac{y}{V} = \frac{3.4}{160} = 0.021 cm^{-2}$

Two values of k calculated correctly (units not required)

first value of $k$ = .....

second value of $k$ = ..... [1]

**(ii)** State whether your results support the suggested relationship.

Justify your conclusion by referring to your value in **(f)**.

Percentage difference $= \frac{0.021-0.021}{(0.021+0.021)/2} \times 100\% = 0\%$

As the percentage difference is smaller than the percentage error in (f), the relationship is supported.

(Calculation of percentage difference, test against criterion in (f), concluding statement)

.....

.....

.....

..... [1]

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**(i)** **(i)** Suggest **two** significant sources of errors in this experiment.

1. Too few readings/only 2 readings <u>not enough to draw a valid conclusion</u>

2. Difficult to measure t with reason (curved surface, thickness not the same)

3. Difficult to judge correct position of nails (nails are too thick)

4. Difficult to measure y with reason e.g. holding the nail and rule both in position

[2]

**(ii)** Suggest **two** improvements that could be made to this experiment to address the sources of errors identified in **(i)(i)**. You may suggest the use of other apparatus or a different procedure.

1. Take more readings (for different volumes) <u>and</u> plot a graph/ take more values of k and compare

2. Use travelling microscope to measure t, take more values of t

3. Use optical pins/thinner nails

4. Have scale on side of jar/ place nails on lab jacks/use marker pen instead of nails/ clamp rule/use a marker to mark position of nail

[2]

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**(j)** The apparent position of the line beneath the beaker depends on the properties of the fluid in the beaker.

It is suggested that, if the water is replaced with a sugar solution, the distance *y* is inversely proportional to the density $\rho$ of the sugar solution.

Explain how you would investigate this relationship using the same apparatus. You may use additional equipment that can be found in a school laboratory.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show that *y* is inversely proportional to $\rho$.

1. Use an electronic balance to measure the mass of the beaker M.
2. Stir some sugar into water and use a measuring cylinder to measure the volume V of the sugar solution. (original method of estimating V is acceptable.)
3. Pour the sugar solution into the beaker until it is about three quarters full and measure the mass of the plastic container and sugar solution using an electronic balance to determine the mass m of the sugar solution.
4. The density of the sugar solution is given by $\rho = \frac{m}{V}$
5. Place the beaker with the sugar solution centrally over the drawn line and repeat the same procedure using the nails to determine the distance y.
6. Pour more sugar into the sugar solution and repeat steps 3 to 5 for 10 more sets of readings.
7. A ruler should be used to check that the height of the sugar solution and its volume stays constant.
8. Tabulate m, V, $\rho$, y and $\frac{1}{y}$
9. Plot $\frac{1}{y}$ against $\rho$
10. If a straight line graph passing close to the origin is obtained, y is inversely proportional to $\rho$.

[5]

[Total:21]

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**4** A fairground ride carries passengers in chairs which are attached by metal rods to a rotating central pole, as shown in Fig. 4.1. When the pole rotates with angular velocity $\omega$, the rods make an angle $\theta$ to the vertical.

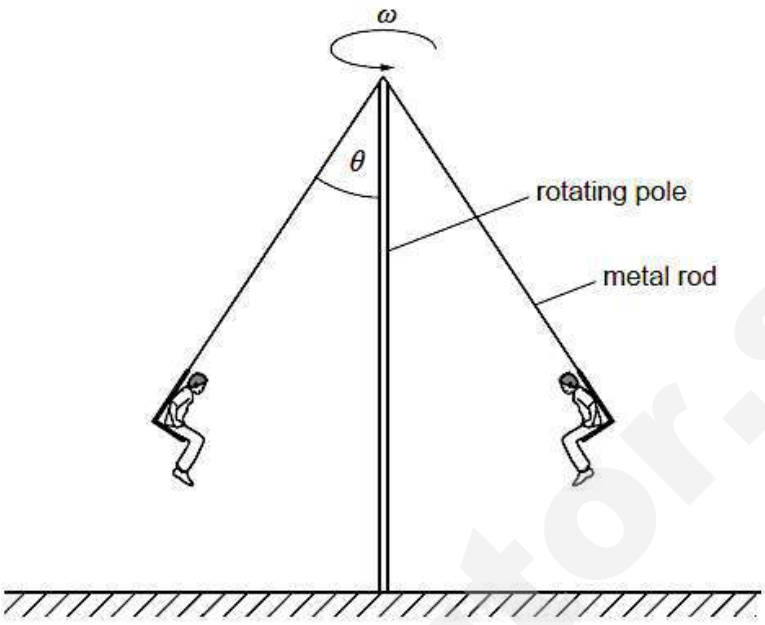


**Fig 4.1**

It is suggested that

$$\cos\theta = \frac{g}{l\omega^2}$$

where *g* is the acceleration of free fall and $l$ is a constant.

Design a laboratory experiment, using a small object to represent an occupied chair, to determine the value of $l$.

You should draw a diagram to show the arrangement of your apparatus and pay particular attention to

(a) the equipment you would use
(b) the procedure to be followed
(c) how you could determine that the angular velocities used
(d) the control of variables
(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

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**Diagram**

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**- END OF PAPER –**

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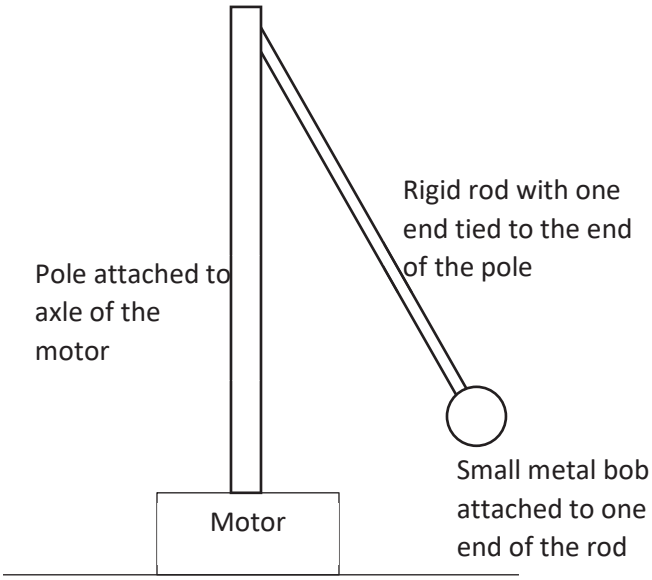


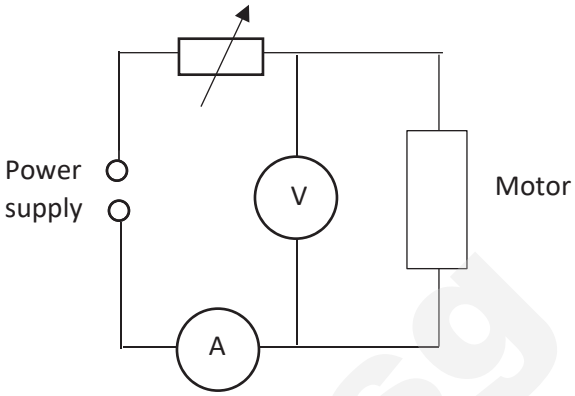


Aim: To determine $l$

Independent variable: angular velocity $\omega$ (*or frequency or period of rotation*)

Dependent variable: angle between rigid rod and pole, $\theta$

Fixed variables: length of rod (ignore reference to mass)

**Procedure**

1. Set up the apparatus as shown above.
2. Measure the length $x$ of the rigid rod with a metre rule.
3. Measure the height $h_0$ of the top end of the pole from the bench with a metre rule.
4. Switch on the motor.
5. The metal bob will start to turn. Allow the metal bob to stabilize at a fixed height.
6. Use a metre rule to measure the height $h$ of the metal bob from the bench.
7. Angle $\theta$ can be found using the following equation: $cos\theta = \frac{h_0 - h}{x}$
8. Count a fixed number of revolutions n made by the metal bob and use the stopwatch to record the time t taken for n revolutions.
9. The period T is t/n.
10. The angular velocity $\omega = \frac{2\pi}{T}$.
11. Adjust the power to motor by changing the resistance of the variable resistor to change the angular velocity of the motor and repeat steps 6 to 8 for 10 readings

**Analysis**

1. Tabulate $h, cos\theta, T, \omega$ and $1/\omega^2$
2. Plot a graph of $cos\theta$ against $1/\omega^2$.
3. A straight line passing close to the origin should be obtained, where the gradient = $\frac{g}{l}$ and $l$ can then be calculated from the gradient.

**Safety Precautions**

1. Use a protective screen in case mass detaches from the pole.
2. Ensure speed of mass is not too fast such that it flies off the pole.

**Additional Details**

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1. Preliminary experiment could be conducted to ensure there is a large motor speed to produce a measurable $\theta$.
2. Projection method, slow motion freeze frame video, camera with detail, i.e. what to measure using these methods to obtain $\theta$
3. $cos\theta = \frac{h_0 - h}{x}$ or equivalent trigonometric method
4. Use set-square (or other methods) to check pole is vertical
5. Wait for motion to be stable before measurements
6. When measuring angular velocity, at least 10 rotations should be used or timing of rotations should be long enough.
7. When counting rotations, a mark or light gates perpendicular to the motion of objects can be used to assist with the counting and increase accuracy of the timing t.
8. Repeated measurements of timing t could be taken to increase accuracy.

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H

**NATIONAL JUNIOR COLLEGE**
**SENIOR HIGH 2 Preliminary Examination**
Higher 2

| | | | |
|---|---|---|---|
| CANDIDATE NAME | | | |
| SUBJECT CLASS | | REGISTRATION NUMBER | |

# PHYSICS

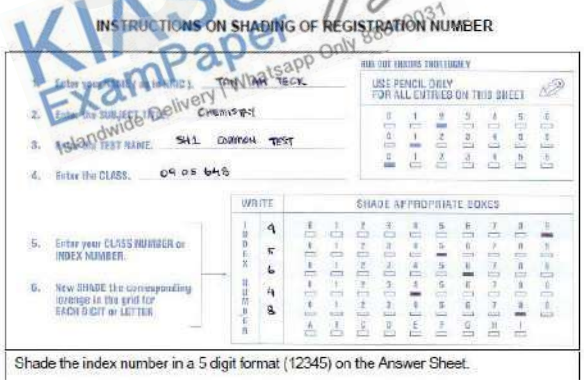
**9749/01**

Paper 1 Multiple Choice

Additional Materials: Multiple Choice Answer Sheet

**19 September 2019**
**1 hour**

**READ THE INSTRUCTION FIRST**
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.
There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.
**Read the instructions 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.



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.

**This document consists of <u>21</u> printed pages.**

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## Data

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

## 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 | $\phi = -GM/r$ |
| temperature | $T/K = T/℃ + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \cdots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{ln2}{t_{\frac{1}{2}}}$ |

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# RIVER VALLEY HIGH SCHOOL
## JC2 PRELIMINARY EXAMINATIONS

# H2 PHYSICS 9749 / 1
# PAPER 1
25 SEPTEMBER 2019

**1 HOUR**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CANDIDATE NAME** | | | | | | | | | |
| **CENTRE NUMBER** | S | | | | | **INDEX NUMBER** | | | | |
| **CLASS** | 1 | 8 | J | | | | | | |

**INSTRUCTIONS TO CANDIDATES**

**DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.**

**Read these notes carefully.**
*Write your name, centre number, index number and class above.*

*There are **thirty** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C** and **D**.*

*Choose the **one** you consider correct and record your choice in **soft pencil** on the separate **Answer Sheet**.*

**Read the instructions on the Answer Sheet very carefully.**

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done on the Question Paper.
The use of an approved scientific calculator is expected where appropriate.

The total number of marks for this paper is **30**.

This Question Paper consists of **17** printed pages and **1** blank page.


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**Data**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
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| temperature | $T$ / K = $T$ / °C + 273.15 |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m., | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m., | $v = v_0 \cos \omega t$<br>$= \pm \omega\sqrt{(x_0^2 - x^2)}$ |
| electric current, | $I = Anvq$ |
| resistors in series, | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel, | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential, | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage, | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire, | $B = \frac{\mu_0 I}{2\pi d}$ |
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| radioactive decay, | $x = x_0 \exp(-\lambda t)$ |
| decay constant, | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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For each question, there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider correct and shade your choice in **soft pencil** on the separate **Answer Sheet**.

**1** A cylindrical tube rolling down a slope of inclination $\theta$ moves a distance $L$ in time $T$. The equation relating these quantities is

$$L(3 + \frac{a^2}{P}) = QT^2 \sin\theta$$

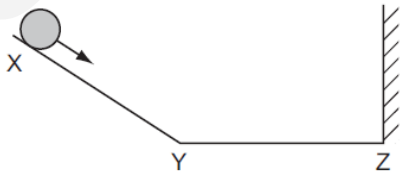
where $a$ is the internal radius of the tube and $P$ and $Q$ are constants.

Which line gives the correct units for $P$ and $Q$?

| | $P$ | $Q$ |
|---|---|---|
| **A** | $m^2$ | $m^2\ s^{-2}$ |
| **B** | $m^2$ | $m\ s^{-2}$ |
| **C** | $m^2$ | $m^3\ s^{-2}$ |
| **D** | $m^3$ | $m\ s^{-2}$ |

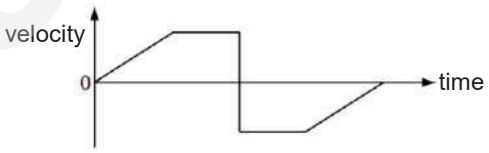
**2** A ball is released from rest on a smooth slope XY.

It moves down the slope, along a smooth horizontal surface YZ and rebounds inelastically at Z. Then it moves back to Y and comes to rest momentarily somewhere on XY.

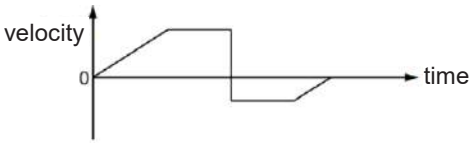



Which velocity-time graph represents the motion of the ball?

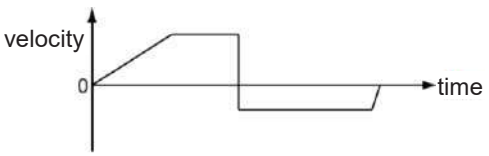
**A**



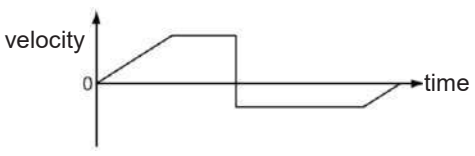

**B**




**C**




**D**

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**3** A particle X, with kinetic energy $E_k$, is about to collide with a stationary particle Y. Both particles have the same mass.

After colliding, X and Y travel onwards together as a single larger particle.

How much kinetic energy is lost in the collision?

**A** zero

**B** $\frac{E_k}{4}$

**C** $\frac{E_k}{2}$

**D** $\frac{3E_k}{4}$

**4** Forces of 3 N, 4 N and 5 N act at one point on an object. The angles at which the forces act can vary.

What is the value of the **minimum** resultant force of these forces?

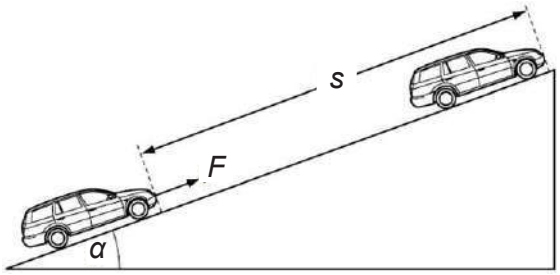
**A** 0

**B** between 0 and 2 N

**C** 2 N

**D** between 2 N and 4 N

**5** A constant force $F$, acting on a car of mass $m$, moves the car up the slope through a distance $s$ at constant velocity $v$. The angle of the slope to the horizontal is $\alpha$.




Which expression gives the efficiency of the process?

**A** $\frac{mgs\sin\alpha}{Fv}$

**B** $\frac{mv}{Fs}$

**C** $\frac{mv^2}{2Fs}$

**D** $\frac{mg\sin\alpha}{F}$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**6** A 10 m long, hollowed concrete cylinder of outer radius 0.30 m and inner radius 0.15 m, with uniform density $2.0 \times 10^3$ kg m$^{-3}$ is lifted 5.0 m vertically by a crane.

What is the change in potential energy of the hollowed concrete cylinder?

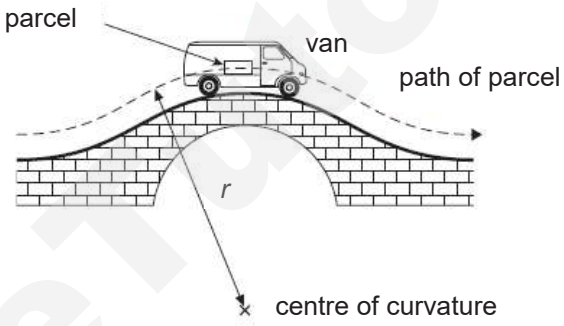
**A** 69 kJ

**B** 140 kJ

**C** 210 kJ

**D** 280 kJ

**7** A 12 kg parcel containing fragile contents is placed on the floor of a delivery van that is passing over a hump-backed bridge on the straight section of a road. The radius of curvature of the bridge is 23 m.




What is the maximum speed that the van can travel at the top of bridge so that the parcel does not lift off the floor of the van?

**A** 4.3 m s$^{-1}$

**B** 15 m s$^{-1}$

**C** 23 m s$^{-1}$

**D** 52 m s$^{-1}$

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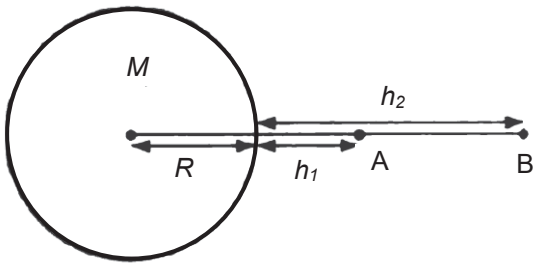
**8** An object of mass $m$ located at A at a height $h_1$ from the Earth's surface is brought to position B at a height $h_2$ measured with respect to the Earth's surface.




If $h_1$ and $h_2$ are of same order of magnitude as the radius $R$ of the Earth, what is the expression for the increase in gravitational potential energy in this process?

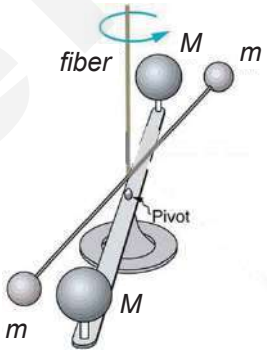
**A** $mg(h_2 - h_1)$

**B** $GMm\left(\frac{1}{R+h_1} - \frac{1}{R+h_2}\right)$

**C** $GMm\left(\frac{1}{h_1} - \frac{1}{h_2}\right)$

**D** $-\frac{GMm}{R+h_2}$

**9** The 1798 Cavendish's experiment, similar to the set-up shown, investigated Newton's law by measuring the gravitational force between two unequal uniform lead spheres. The radius of the larger sphere was 100 mm and that of the smaller sphere was 25 mm.




Given that the density of lead is $11.3 \times 10^3$ kg m$^{-3}$, what is the gravitational force between a pair of larger and smaller spheres when their surfaces were in contact?

**A** $1.5 \times 10^{-7}$ N

**B** $2.0 \times 10^{-7}$ N

**C** $1.9 \times 10^{-8}$ N

**D** $3.2 \times 10^{-9}$ N

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**10** A fixed mass of ideal monoatomic gas at low temperature is trapped in a container at constant pressure. The gas is then heated and the volume of the container changes so that the pressure stays at $1.00 \times 10^5$ Pa. When the gas reaches a temperature of 0.0 °C, the volume is $2.20 \times 10^{-3}$ $m^3$.

What is the total internal energy of the gas at a temperature of 50.0 °C?

**A** 60 J

**B** 130 J

**C** 330 J

**D** 390 J

**11** An electrical heater is placed in an insulated container holding 100 g of ice at a temperature of –14.0 °C. The heater supplies energy at a rate of 98 W. After 30 s, all the ice has reached a temperature of 0.0 °C.

What is the specific heat capacity of ice?

**A** 900 J $kg^{-1}$ $K^{-1}$

**B** 1200 J $kg^{-1}$ $K^{-1}$

**C** 2100 J $kg^{-1}$ $K^{-1}$

**D** 4200 J $kg^{-1}$ $K^{-1}$

**12** A horizontal plate is vibrating vertically with simple harmonic motion at a frequency of 20 Hz.

What is the maximum amplitude of vibration so that a mass placed on the plate always remains in contact with it?

**A** $6.2 \times 10^{-4}$ m

**B** $5.0 \times 10^{-2}$ m

**C** $7.8 \times 10^{-2}$ m

**D** $4.9 \times 10^{-1}$ m

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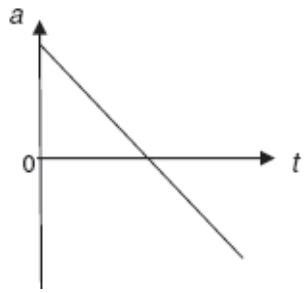
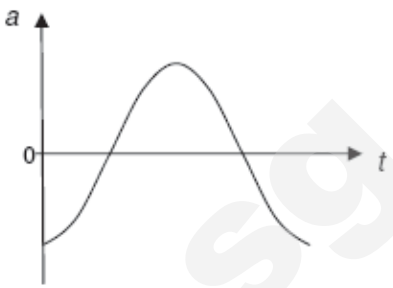
**13** The bob of a simple pendulum moves through its equilibrium position at time $t = 0$ s.

Which of the following graphs best shows the variation of the acceleration $a$ of the bob with time $t$ ?

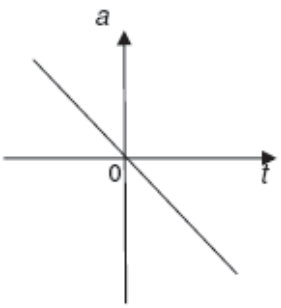
**A**



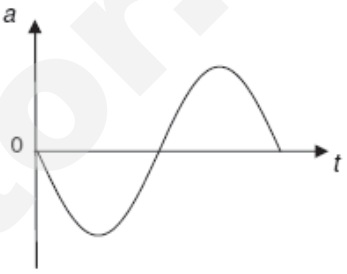

**B**




**C**




**D**




**14** The diagram below is a snapshot of a string as a transverse progressive wave travels along it from left to right.




Which one of the following correctly shows the directions of the velocities of the points 1, 2 and 3 on the string?

| | *1* | *2* | *3* |
|---|---|---|---|
| **A** | → | → | → |
| **B** | → | ← | → |
| **C** | ↑ | ↓ | ↑ |
| **D** | ↓ | ↑ | ↓ |

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**15** Consider a tube of length 32.8 cm which is open at both ends. When a vibrating tuning fork is held close to one end of the tube, a loud sound is detected.

Given the velocity of sound in air is 345 m $s^{-1}$, what is the frequency of vibration of the fork?

**A** 789 Hz

**B** 526 Hz

**C** 263 Hz

**D** 175 Hz

**16** A microwave transmitter of frequency, *f*, is placed several metres away from a metal plate deflector. A microwave receiver, connected to a microammeter, is used to detect nodes and antinodes along the normal from the source to the plate. The microwave receiver is moved from one node through 10 antinodes to another node, over a distance of *L*.

What is the speed of the microwave?

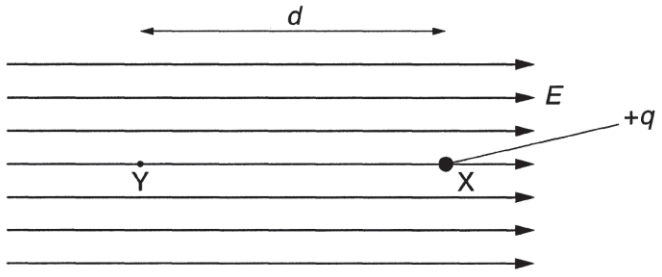
**A** 0.16*fL*

**B** 0.18*fL*

**C** 0.20*fL*

**D** 0.25*fL*

**17** The diagram below shows a charge +q at X in a uniform electric field of electric field strength E.




The charge at X is moved to Y through a distance *d*.

What is the work done on the charge?

**A** $+\frac{qE}{d}$ **B** $-\frac{qE}{d}$

**C** $+qEd$ **D** $-qEd$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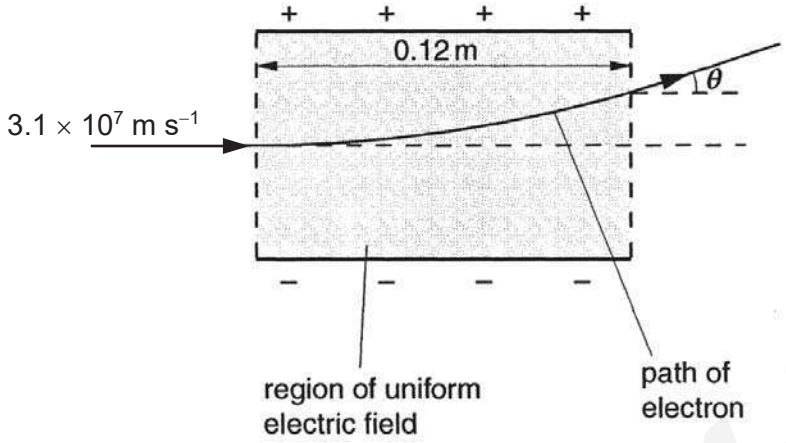
**18** The diagram below shows a beam of electrons travelling at a speed of $3.1 \times 10^7$ m s$^{-1}$ in a uniform electric field created by two charged parallel plates.




When an electron is in this field, it experiences a constant force of $3.2 \times 10^{-15}$ N towards the positive plate.

The length of each parallel plate is 0.12 m. The electron emerges from the electric field region at an angle $\theta$.

What is the angle $\theta$?

**A** 0°

**B** 24°

**C** 66°

**D** 90°

**19** An iron wire has length 8.0 m and diameter 0.50 mm. The wire has resistance $R$. A second iron wire has length 2.0 m and diameter 1.0 mm.

What is the resistance of the second wire?

**A** $\frac{R}{16}$ **B** $\frac{R}{8}$

**C** $\frac{R}{2}$ **D** $R$

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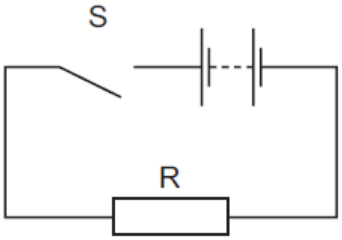
**20** The diagram shows a simple circuit.




Which statement is correct?

**A** When switch S is closed, the e.m.f. of the battery falls because work is done against the internal resistance of the battery.

**B** When switch S is closed, the e.m.f. of the battery falls because work is done against the resistance R.

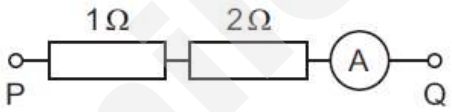
**C** When switch S is closed, the potential difference across the battery falls because work is done against the internal resistance of the battery.

**D** When switch S is closed, the potential difference across the battery falls because work is done against the resistance R.

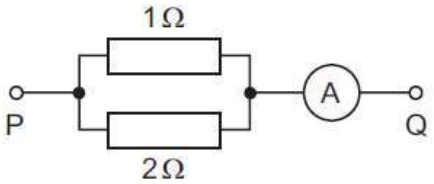
**21** In each arrangement of resistors, the ammeter has a resistance of 2 Ω.

Which arrangement gives the largest reading on the ammeter when the same potential difference is applied between points P and Q?

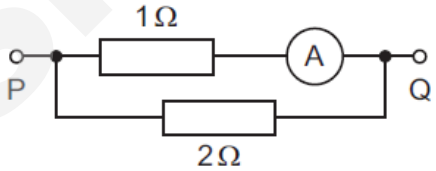
**A**



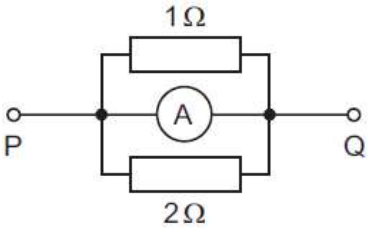

**B**




**C**




**D**

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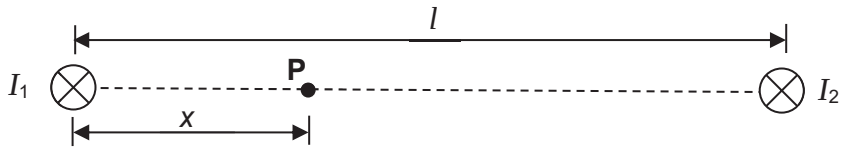
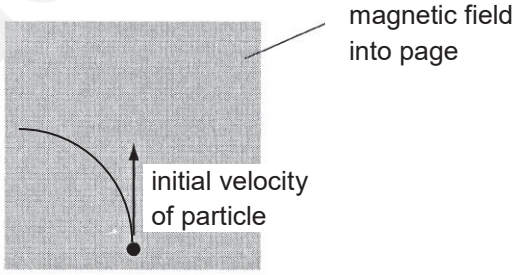
**22** Two long parallel wires, separated by a distance $l$, carry currents $I_1$ and $I_2$ where $I_1 > I_2$ and both currents flow into the plane of the paper as shown in the diagram below.




What is the resultant magnetic field at point **P** at distance *x* from the wire carrying current $I_1$?

| | magnitude | direction |
|---|---|---|
| **A** | $\frac{\mu_0}{2\pi}\left(\frac{I_1}{x}-\frac{I_2}{l}\right)$ | down |
| **B** | $\frac{\mu_0}{2\pi}\left(\frac{I_1}{x}-\frac{I_2}{l-x}\right)$ | down |
| **C** | $\frac{\mu_0}{2\pi}\left(\frac{I_1}{x}-\frac{I_2}{l}\right)$ | up |
| **D** | $\frac{\mu_0}{2\pi}\left(\frac{I_1}{x}-\frac{I_2}{l-x}\right)$ | up |

**23** At one instant, a charged particle carrying +*q* is moving with velocity v towards the top of the page. A magnetic field of strength *B* is directed at right angles to its path into the paper.




The particle will describe the arc of a circle of radius *r* towards the left.

Which combination of factors will change the direction of the particle to the right?

| | ***B*** | ***v*** | ***q*** |
|---|---|---|---|
| **A** | into paper | towards top of page | negative |
| **B** | into paper | towards bottom of page | negative |
| **C** | out of paper | towards top of page | negative |
| **D** | out of paper | towards bottom of page | positive |

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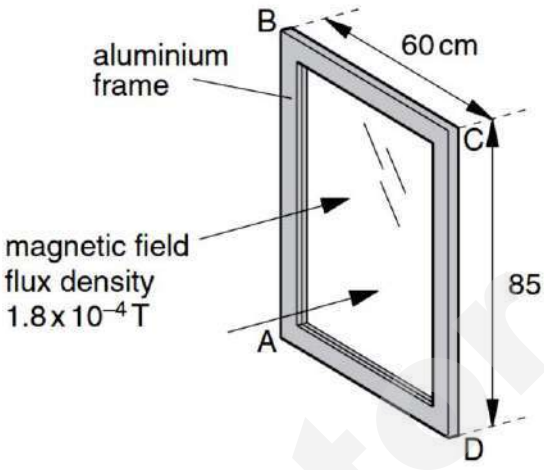
**24** The aluminium frame ABCD of a window measures 85 cm × 60 cm, as shown below.
The window is hinged along the edge AB.
The Earth's magnetic field, of flux density $1.8 \times 10^{-4}$ T, is normal to the window when it is closed.
When open, the plane of the window is parallel to the Earth's magnetic field.




If the closed window is now opened in a time of 0.20 s, what is the average e.m.f. induced in side CD?

**A** $1.4 \times 10^{-4}$ V

**B** $4.6 \times 10^{-4}$ V

**C** 1.4 V

**D** 4.6 V

**25** When a light bulb is connected across a sinusoidal alternating current source of peak voltage 170 V, the mean power dissipated is 40 W. Two such light bulbs are now connected in series to the electrical mains of 220 $V_{r.m.s.}$.

What would be the total mean power dissipated?

**A** 34 W

**B** 67 W

**C** 80 W

**D** 130 W

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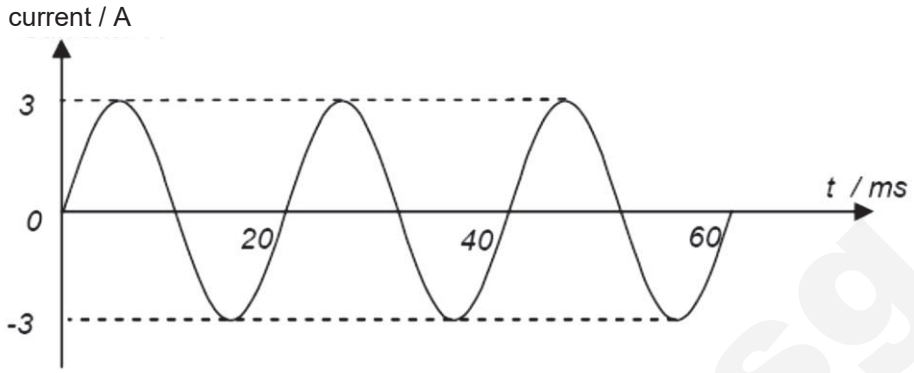
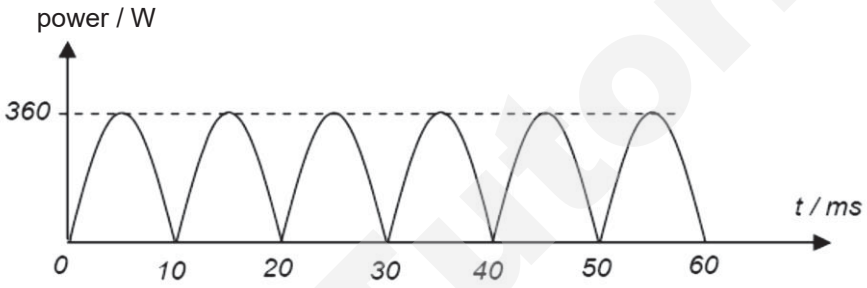
**26** A sinusoidal alternating current as shown below flows through a resistor of 80 Ω.

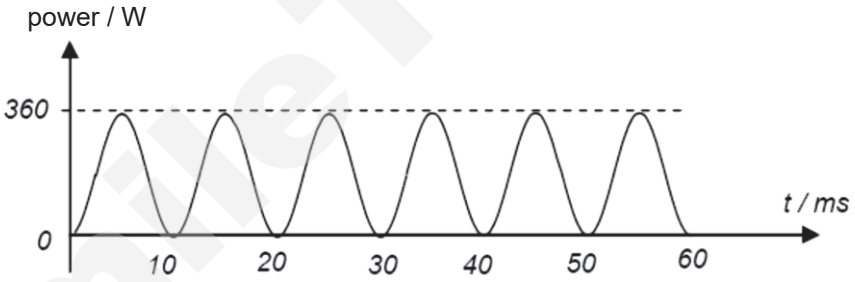



The power dissipated in the resistor is given by

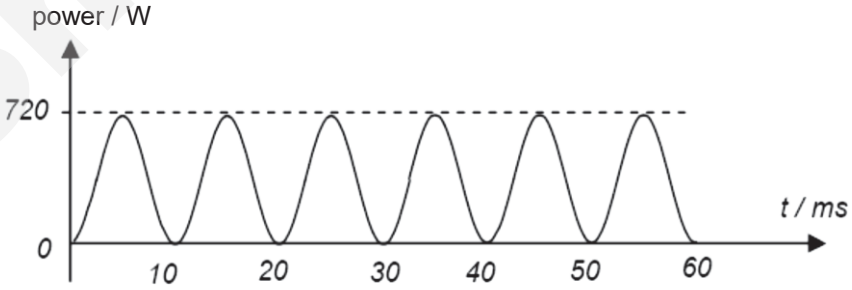
**A**



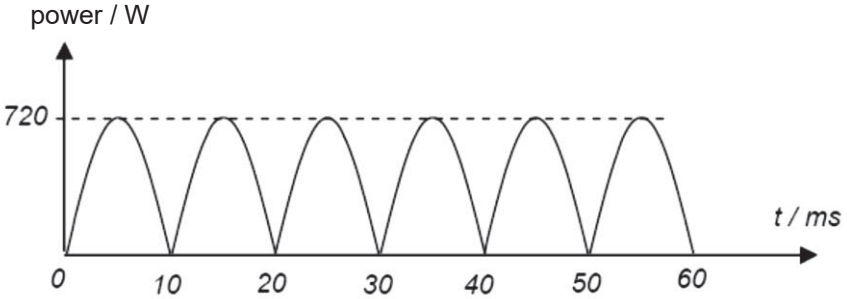

**B**




**C**




**D**

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**27** In an experiment to investigate photoelectric effect, a clean metal plate is illuminated with monochromatic light of wavelength $\lambda$ and intensity $I$. Consequently, a steady photoelectric current $I_e$ is observed to reduce to zero at negative potential $V_s$.

Then another source of monochromatic light of wavelength $\frac{1}{2}\lambda$ and same intensity $I$ is shone upon the same plate simultaneously.

Which of the following changes in $I_e$ and $V_s$ occur?

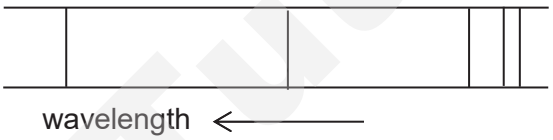
**A** Both $I_e$ and $V_s$ are not doubled.

**B** Both $I_e$ and $V_s$ are doubled.

**C** $I_e$ is doubled but $V_s$ is not doubled.

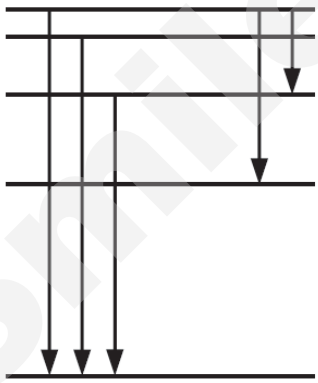
**D** $V_s$ is doubled but $I_e$ is not doubled.

**28** The emission spectrum of a gas is shown below.

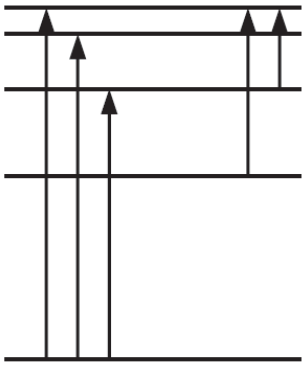



The wavelength increases to the *left*.

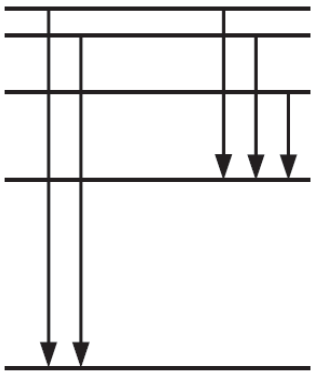
**A**



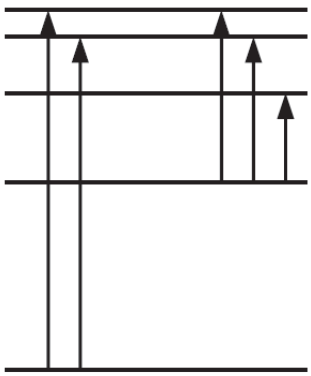
**B**



**C**



**D**



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**29** When an isotope of boron, $^{10}_{5}B$ captures a slow neutron, it splits into lithium $^{7}_{3}Li$ and an alpha particle. An emission of $\gamma$-ray occurs during this reaction.

The nuclear binding energies of the reactants and products are

$^{10}_{5}B$ : 64.94 MeV
$^{7}_{3}Li$ : 39.25 MeV
$^{4}_{2}He$ : 28.48 MeV

If the total kinetic energies of the products produced is 2.31 MeV, what is the energy of the $\gamma$-ray emitted?

**A** 0.48 MeV

**B** 2.79 MeV

**C** 10.77 MeV

**D** 25.69 MeV

**30** Which of the statements regarding binding energy is true?

**A** Nuclei with low mass numbers tend to undergo nuclear fusion.

**B** Nuclei undergo fission or fusion in an attempt to reduce the binding energy per nucleon.

**C** Nuclei in the middle of the graph of binding energy against mass number tend to be the least stable.

**D** The greater the mass defect of a substance, the greater its binding energy will be and hence the substance is more stable.

**END OF PAPER**

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# RIVER VALLEY HIGH SCHOOL
## JC 2 PRELIMINARY EXAMINATIONS

# H2 PHYSICS 9749 / 2
# PAPER 2
16 SEPTEMBER 2019

**2 HOURS**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CANDIDATE NAME** | | | | | | | | | |
| **CENTRE NUMBER** | S | | | | | **INDEX NUMBER** | | | | |
| **CLASS** | 1 | 8 | J | | | | | | |

**INSTRUCTIONS TO CANDIDATES**

**DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.**

**Read these notes carefully.**
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

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

*Answer **all** questions.*

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

| FOR EXAMINERS' USE | |
|---|---|
| **Paper 2** | |
| **1** | **/ 8** |
| **2** | **/ 7** |
| **3** | **/ 15** |
| **4** | **/ 11** |
| **5** | **/ 5** |
| **6** | **/ 8** |
| **7** | **/ 6** |
| **8** | **/ 20** |
| **Deduction** | |
| **Paper 2** | **/ 80** |

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


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**Data**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -GM/r$ |
| temperature | $T/\text{K} = T/°\text{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m., | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m., | $v = v_0 \cos \omega t$<br>$= \pm \omega\sqrt{(x_0^2 - x^2)}$ |
| electric current, | $I = Anvq$ |
| resistors in series, | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel, | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential, | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage, | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire, | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil, | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid, | $B = \mu_0 nI$ |
| radioactive decay, | $x = x_0 \exp(-\lambda t)$ |
| decay constant, | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** During the medieval ages, when defending a castle, rocks were thrown from the top of the castle at invaders.

Fig. 1.1 shows the path of a rock thrown horizontally from a height of 30 m, at a target, positioned on the edge of a 10 m high ridge, 50 m away.

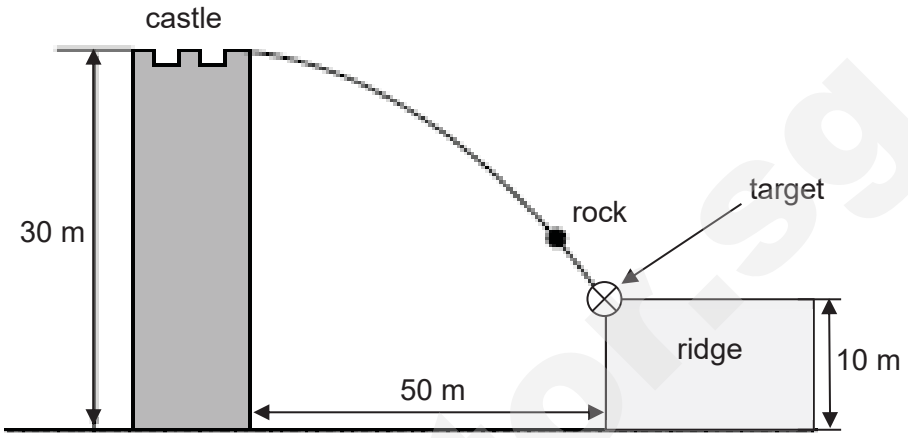


**Fig. 1.1**

**(a)** Calculate the time *t* taken from when the rock is thrown to when it hits the target. Assume air resistance is negligible.

*t* = …… s [2]

**(b)** The target is an invading soldier.

Suggest and explain if the rock is likely to have a direct hit on the soldier.

……..

……..

……..

…… [2]

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**(c)** Determine the magnitude and direction of the velocity of the rock when it just hits the target.

magnitude = …… m $s^{-1}$

direction = …….. [4]

**2** **(a)** Explain what is meant by *the linear momentum of a body*.

…….

…….

……. [1]

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**(b)** Deep space probes often carry modules which may be ejected from them by an explosion. A space probe of total mass 800 kg is travelling in a straight line through free space at 165 m $s^{-1}$ when it ejects a capsule of mass 170 kg explosively, releasing energy. Immediately after the explosion, the empty probe continues to travel in the original direction but at 235 m $s^{-1}$, as shown in Fig. 2.1.

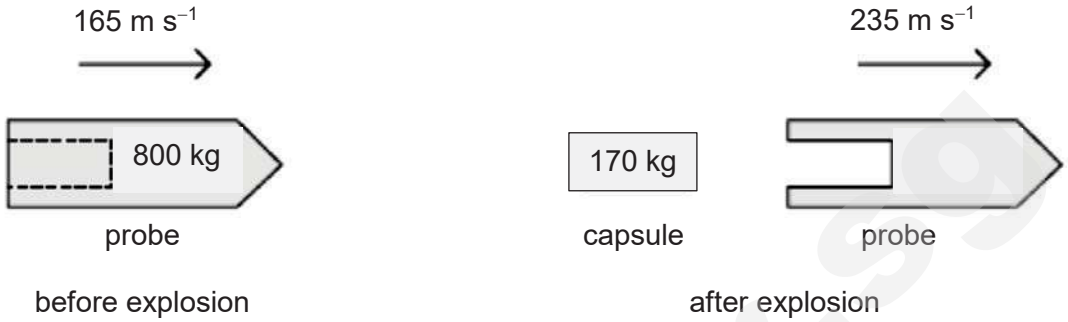


**Fig. 2.1**

**(i)** Calculate the magnitude and direction of the velocity of the capsule immediately after the explosion.

magnitude = …… m $s^{-1}$

direction = …….. [3]

**(ii)** Determine the total amount of energy given to the probe and capsule by the explosion.

total energy = …… J [3]


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**3** The orbit of the Earth, mass $6.0 \times 10^{24}$ kg, may be assumed to be a circle of radius $1.5 \times 10^{11}$ m with the Sun at its centre, as illustrated in Fig. 3.1.

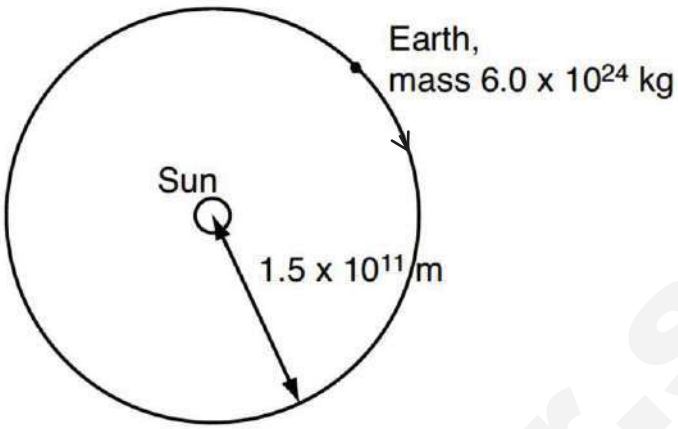


**Fig. 3.1**

**(a)** **(i)** Show that the time taken for one orbit is $3.15 \times 10^7$ s.

[1]

**(ii)** Calculate the magnitude of the angular velocity of the Earth about the Sun.

angular velocity = …….. rad $s^{-1}$ [2]

**(b)** **(i)** Hence, or otherwise, calculate the magnitude of the gravitational force on the Sun due to the Earth.

gravitational force = …….. N [3]

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**(ii)** Draw an arrow on Fig. 3.1 and label it S to represent the gravitational force on the Sun. [1]

**(iii)** Calculate the mass of the Sun.

mass of the Sun = ..... kg [2]

**(c)** **(i)** Calculate the orbital speed of the Earth.

orbital speed = ..... km $s^{-1}$ [2]

**(ii)** Hence, deduce the total energy of the Earth.

total energy = ..... J [3]

**(d)** Sketch on Fig. 3.1 a possible subsequent path of the Earth if the Sun were to disappear and label the path E. [1]

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**4** **(a)** State the two conditions under which a real gas can be approximated to be ideal.

……

……

……

…… [2]

**(b)**

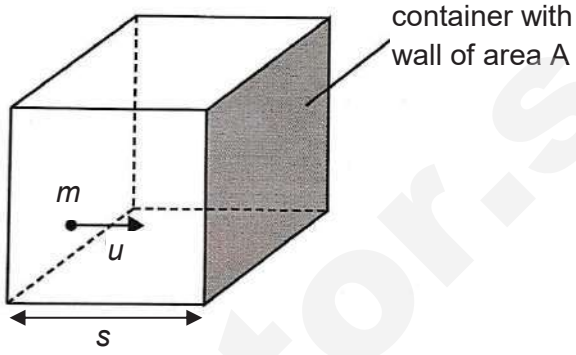


**Fig. 4.1**

By considering one molecule, of mass *m* with initial velocity *u*, of a gas within a container of length *s*, as shown in Fig. 4.1, explain how its molecular movement causes the average pressure exerted, in the derivation of the kinetic theory of gases. Define all additional symbols used.

[3]

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**(c)** A cylinder, shown in Fig. 4.2, fitted with a gas-tight piston contains an ideal gas at a constant temperature of 20 °C. When the pressure $p$ in the cylinder is 0.20 MPa the volume $V$ is $0.50 \times 10^{-3}$ m$^3$.

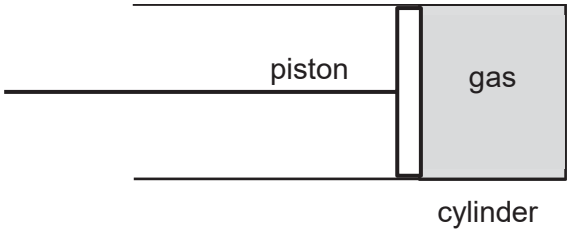


**Fig. 4.2**

An experiment is conducted and the data is plotted in Fig. 4.3.

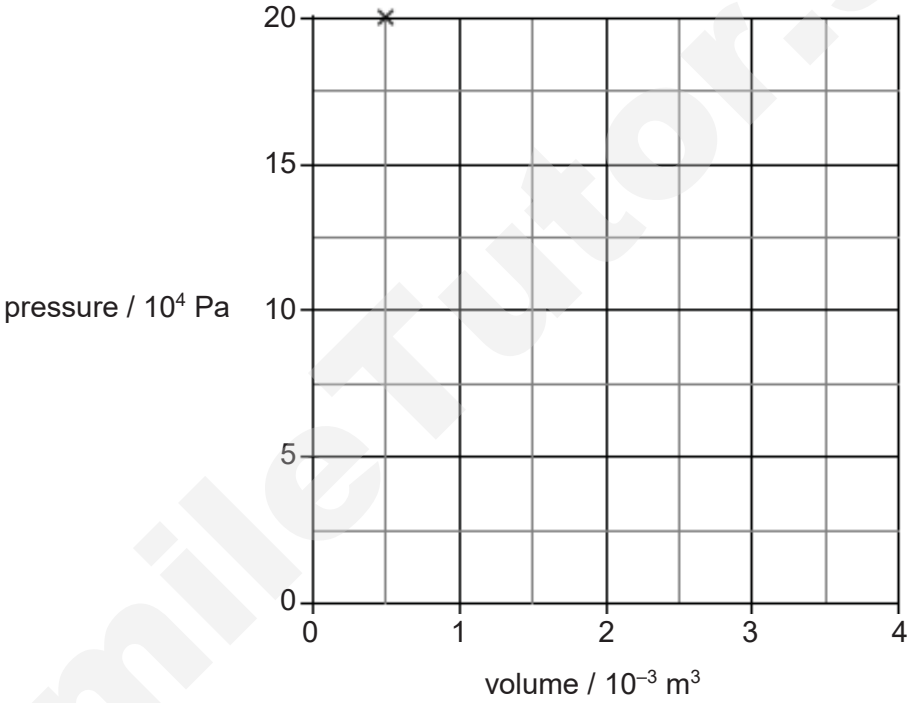


**Fig. 4.3**

**(i)** By plotting two additional points, draw a graph on the axes given in Fig. 4.3 to show the relationship between $p$ and $V$ as the piston is slowly pulled out such that the temperature of the gas remains constant.

[2]

**(ii)** Calculate the number of gas molecules in the cylinder.

number of gas molecules = …….. [2]

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**(iii)** Determine the total kinetic energy of the gas molecules.

total kinetic energy = …….. J [2]

**5** A string, tied to a sinusoidal oscillator at P and running over a support at Q, is stretched by a block of mass *m* as shown in Fig. 5.1. The amplitude of the motion at P is small enough for that point to be considered a node. A node also exists at Q.




**Fig. 5.1**

**(a)** Explain how stationary waves are formed along the string.

……

……

……

…… [2]

**(b)** The frequency of the oscillator is set at 120 Hz. A stationary wave is formed when the length *L* is 1.20 m. The maximum displacement of the antinode is 0.80 cm. The length is slowly increased and the stationary wave disappears. The stationary wave is formed again when *L* is increased by 0.30 m.

**(i)** Determine the velocity of the wave in the string.

velocity = …….. m $s^{-1}$ [2]


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**(ii)** Point X is at one of the antinodes when $L$ is 1.50 m. Point Y is at a distance $\lambda/8$ away from point X, where $\lambda$ is the wavelength of the wave.

Determine the phase difference between the two points.

phase difference = …….. rad [1]

**6** **(a)** Explain what is meant by *electromotive force of a source* and *potential difference between two points of a circuit*.

……

……

……

…… [2]

**(b)** The circuit in Fig. 6.1 consists of three fixed resistors, each of which has a safe power rating of 0.80 W.

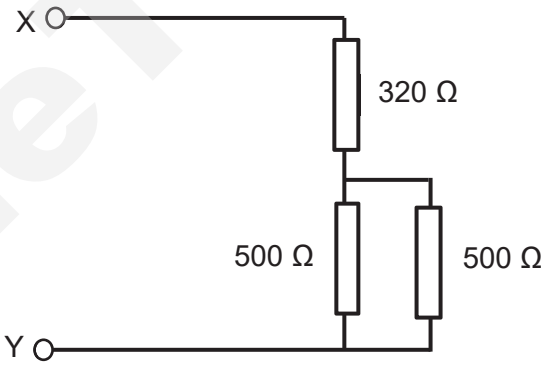


**Fig. 6.1**

**(i)** Determine the *maximum safe* current through each resistor.

current in 320 Ω = …… A

current in 500 Ω = …… A [3]

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**(ii)** Determine the maximum potential difference that can be applied between X and Y without damage to any of the resistors.

maximum potential difference = ..... V [3]

**7** A step-up transformer near a power plant increases the plant's output root-mean square (r.m.s) voltage from 12.0 kV to 240 kV. Step-down transformers near the consumers reduce the r.m.s voltage to 240 V.

The power station produces 20.0 MW of power. The total resistance of the transmission cables is $200\,\Omega$.

**(a)** Explain what is meant by *root-mean-square voltage* when applied to a sinusoidal alternating voltage.

.....

.....

..... [2]

**(b)** **(i)** Determine the turns ratio of the transformer that is located near the power plant.

turns ratio = ..... [1]

**(ii)** Determine the peak power lost during transmission.

peak power = ..... kW [3]


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**8** Among the 2500 known *nuclides*, fewer than 300 are stable. Most of them are unstable and will decay to form other nuclides by emitting particles and electromagnetic radiation. The time scale of these processes can range from a small fraction of a microsecond to billions of years. This is due to different nuclides having different *decay constants*.

The measurements of the *activity* from a sample of radioactive substance are given in Fig. 8.1.

| time elapsed, $t$ / h | activity, $A$ / $s^{-1}$ | $\log_{10}$ ($A$ / $s^{-1}$) |
|---|---|---|
| 0 | 7500 | 3.8751 |
| 0.5 | 4120 | 3.6149 |
| 1.0 | 2570 | 3.4099 |
| 1.5 | 1790 | 3.2529 |
| 2.0 | 1350 | 3.1303 |
| 2.5 | 1070 | 3.0294 |
| 3.0 | 872 | 2.941 |
| 4.0 | 596 | 2.776 |
| 5.0 | 414 | 2.617 |
| 6.0 | 288 | 2.459 |
| 7.0 | 201 | 2.303 |
| 8.0 | 140 | 2.146 |
| 9.0 | 98 | |
| 10.0 | 68 | |
| 12.0 | 33 | |

**Fig. 8.1**

**(a)** Define the terms that have been italicised in the passage above.

**(i)** *nuclides*

……

…….. [1]

**(ii)** *activity*

……

…….. [1]

**(iii)** *decay constant*

……

…….. [1]

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**(b)** **(i)** Complete Fig. 8.1 for $t$ = 9.0 h, 10.0 h and 12.0 h. [2]

**(ii)** Fig. 8.2 is a graph of some of the data of Fig. 8.1.

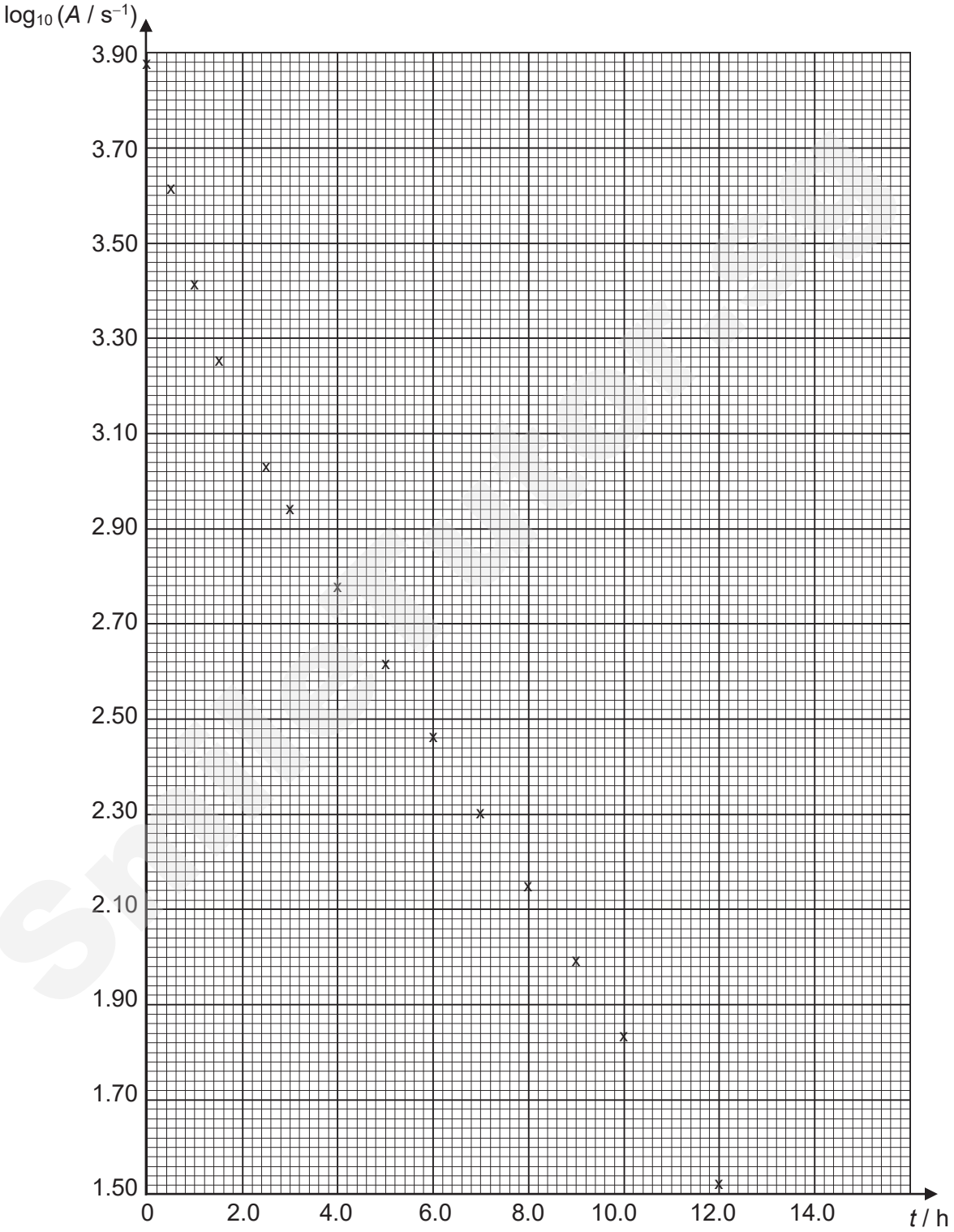


**Fig. 8.2**


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On Fig. 8.2,

1. plot the point corresponding to $t$ = 2.0 h, and

2. draw a line of best fit for the points from $t$ = 4.0 h to 12.0 h and label it R.

[2]

**(iii)** Suggest the significance of the fact that the trend of the points does not give a straight line with constant gradient.

……

…….. [1]

**(iv)** Determine the gradient of the line R drawn in Fig. 8.2 and provide the appropriate units.

gradient = ……. [2]

**(v)** Hence explain what the gradient of R found in **(b)(iv)** represents.

…….. [1]

**(c)** **(i)** Explain why food are sometimes irradiated by exposing them to radioactive substances like cobalt-60 purposefully.

……

…….. [1]

**(ii)** Cobalt-60 decays via beta decay into stable nickel-60 and releases gamma rays in the process.

Complete the nuclear equation for the reaction

$$^{60}_{27}\text{Co} \rightarrow ^{60}_{\ldots\ldots}\text{Ni} + ^{\ldots\ldots}_{\ldots\ldots}\text{e}$$

[1]


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**(iii)** Radioactive samples like those used in **(c)(i)** have shelf-lives. Just after it has been manufactured in a nuclear reactor, the activity of a sample of cobalt-60 is 50000 Ci. When its activity falls below 35000 Ci, it is considered too weak a source to be used.

One such sample was manufactured on 16$^{th}$ September 2014, it is now 16$^{th}$ September 2019.

Given that 1 Ci = $3.7 \times 10^{10}$ Bq and that the half-life of cobalt-60 is 5.271 years, explain quantitatively whether the source is still usable.

……

…….. [3]

**(iv)** Determine the initial mass of a sample of cobalt-60.

mass = ……. g [4]

**END OF PAPER**


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# RIVER VALLEY HIGH SCHOOL
## JC 2 PRELIMINARY EXAMINATIONS

# H2 PHYSICS 9749 / 3
# PAPER 3
19 SEPTEMBER 2019

**2 HOURS**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CANDIDATE NAME** | | | | | | | | | |
| **CENTRE NUMBER** | S | | | | | **INDEX NUMBER** | | | | |
| **CLASS** | 1 | 8 | J | | | | | | |

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

Section A
Answer all questions.

Section B
Answer **one** question only.

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

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

This document consists of **24** printed pages.

| FOR EXAMINERS' USE | |
|---|---|
| **Section A – do all questions** | |
| **1** | **/ 8** |
| **2** | **/ 7** |
| **3** | **/ 10** |
| **4** | **/ 10** |
| **5** | **/ 15** |
| **6** | **/ 10** |
| **Section B – do ONE question only** | |
| **7** | **/ 20** |
| **8** | **/ 20** |
| **Deduction** | |
| **TOTAL** | **/ 80** |

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

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## Section A

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

**1** **(a)** Explain what is meant by the *moment of a force*.

……..

……..

……..

……..… [2]

**(b)** A ladder of length 5.0 m rests in equilibrium on rough ground against a smooth wall as shown in Fig. 1.1. The base of the ladder is 3.0 m from the wall.

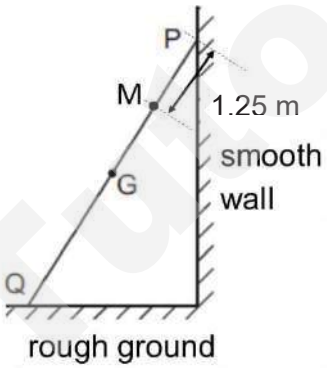


**Fig. 1.1**

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. A painter of weight *M* stands on the ladder, 1.25 m from the top of the ladder.

**(i)** Show that *Q* is given by the expression $\sqrt{P^2 + (W + M)^2}$.

[3]

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**(ii)** Hence, using the principle of moments, determine the value of $Q$ if the maximum friction provided by the rough ground is 920 N and the weight of the ladder is 500 N.

[3]

**2** **(a)** A 300 kg cart at a fun fair rolls from A to B along a track, with an initial speed of 5.0 m $s^{-1}$. At B, its potential energy is 35 kJ less than at A, as shown in Fig. 2.1.

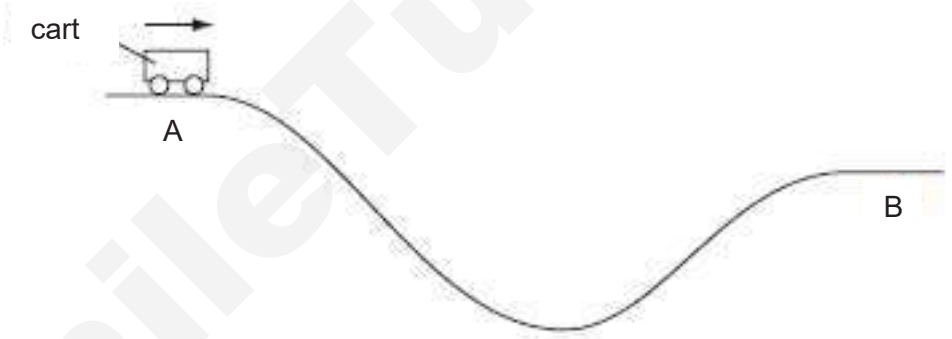


**Fig. 2.1**

Between A and B, the work the cart does against resistive forces is 15 kJ.

Determine the speed of the cart at B.

speed at B = …… m $s^{-1}$ [3]

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**(b)** A force $F$ is applied on a mass $m$ on a surface over a displacement of $s$. The mass has an initial velocity of $u$ and a final velocity of $v$, as shown in Fig. 2.2.

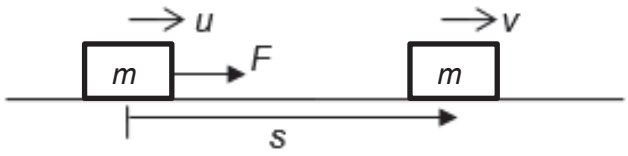


**Fig. 2.2**

Starting with the definition of work done and using the equations of motion, show that the kinetic energy of $m$ after displacement $s$ is $\frac{1}{2} mv^2$.

State an assumption necessary for the derivation.

Assumption:

……

……

…… [4]

**3** **(a)** State what is meant by *simple harmonic motion*.

……

……

…… [2]

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**(b)** A small frictionless trolley is attached to a fixed point **P** by means of a spring. A second spring is used to attach the trolley to a variable frequency oscillator, as shown in Fig. 3.1.

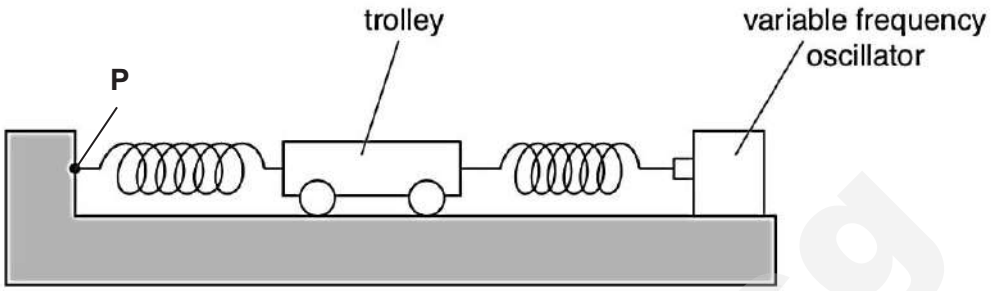


**Fig. 3.1**

Both springs remain extended within their limits of proportionality. Initially, the oscillator is switched off. The trolley is displaced horizontally along the line joining the two springs and is then released. The variation with time $t$ of the velocity $v$ of the trolley is shown in Fig. 3.2.

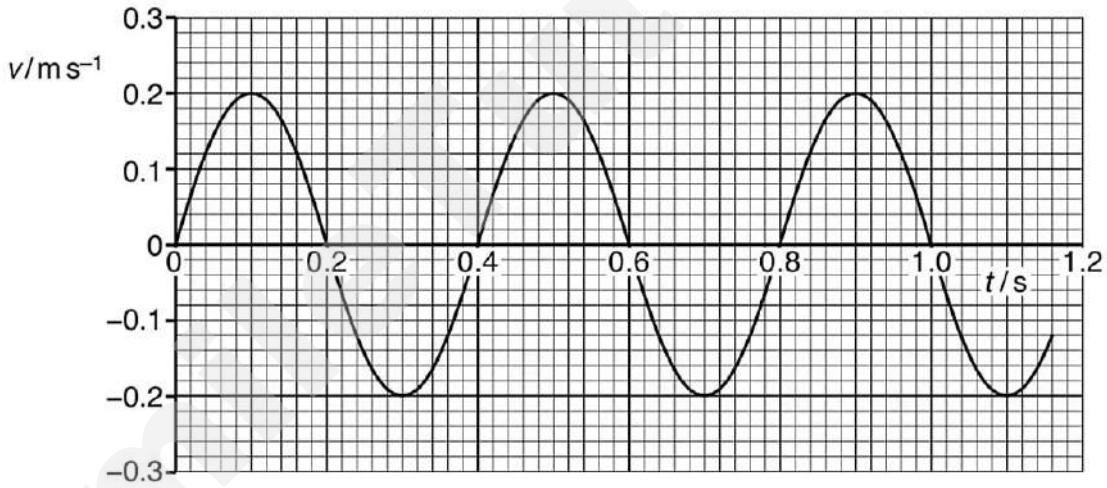


**Fig. 3.2.**

**(i)** Using Fig. 3.2, state two different times at which

**1.** the displacement of the trolley is zero,

time = ..... s and ..... s [1]

**2.** the acceleration in one direction is maximum.

time = ..... s and ..... s [1]

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**(ii)** Determine the frequency of oscillation of the trolley.

frequency = …… Hz [1]

**(iii)** The variation with time of the displacement of the trolley is also sinusoidal.

State the phase difference between the displacement and the velocity.

phase difference = …… ° [1]

**(c)** The oscillator is now switched on. The amplitude of the oscillator is constant. The frequency *f* of vibration of the oscillator is varied. The trolley is forced to oscillate by means of vibrations of the oscillator.

**(i)** Distinguish between *free oscillations* and *forced oscillations*

……

……

……

…… [2]

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**(ii)** It was observed that the trolley vibrates with different amplitudes as the frequencies of the oscillator changes.

On the axes provided on Fig. 3.3, sketch a possible amplitude-frequency graph for this trolley. [1]




**Fig. 3.3**

**(iii)** State the approximate frequency at which the amplitude is maximum

frequency = …… Hz [1]

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

In your answer, include the equation and unit.

……

……

……

equation for electric field strength is ……

S.I. unit of electric field strength = …….. [2]

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**(b)** In an experimental setup to determine the force exerted by an electric field, a small negatively charged sphere is suspended from a fine glass spring between parallel horizontal metal plates, as shown in Fig. 4.1.

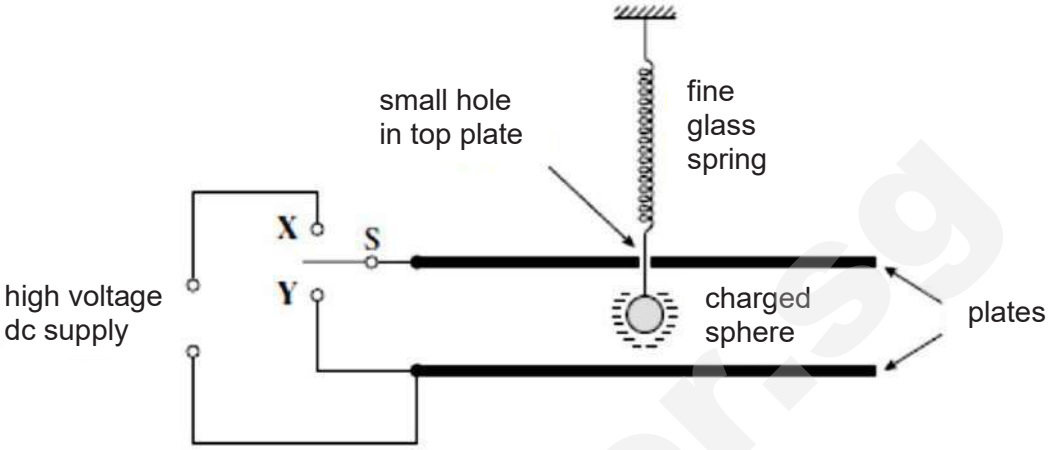


**Fig. 4.1**

Initially the plates are uncharged. When switch S is set to position X, a high voltage dc supply is connected across the plates. This causes the sphere to move vertically upwards so that eventually it comes to rest 18 mm higher than its original position.

**(i)** State the direction of the electric field between the plates.

……..……... [1]

**(ii)** The spring constant of the glass spring is 0.24 N $m^{-1}$.

Calculate the force exerted on the sphere by the electric field.

force = ……..…… N [2]

**(iii)** The potential difference applied across the plates is 5.0 kV. If the charge on the sphere is $-4.1 \times 10^{-8}$ C, determine the separation of the plates.

separation of the plates = …….. m [3]


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**(b)** Switch S is now moved from position X to Y.

State and explain the effect of this on the electric field between the plates.

……

……

……

……

…… [2]

**5** A metal wire is held taut between the poles of a permanent magnet, as illustrated in Fig. 5.1.

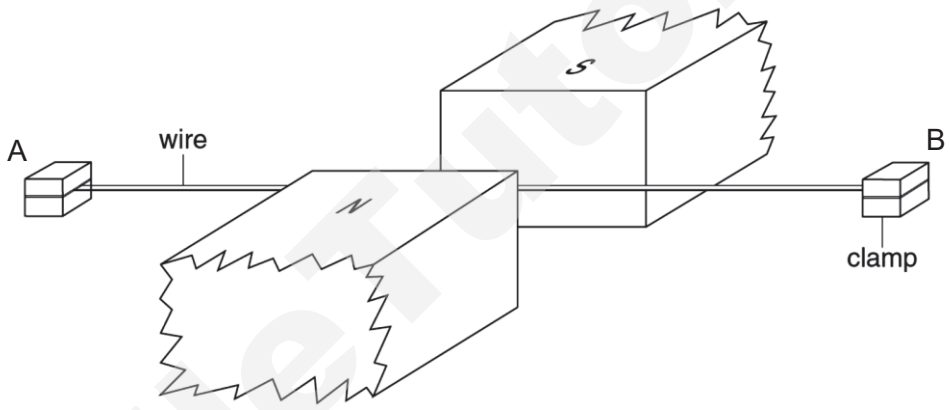


**Fig. 5.1**

A cathode-ray oscilloscope (c.r.o.) is connected between the ends of the wire. The Y-plate sensitivity is adjusted to 1.0 mV $cm^{-1}$ and the time base is 0.5 ms $cm^{-1}$.

The wire is plucked at its centre. Fig. 5.2 shows the trace seen on the c.r.o.

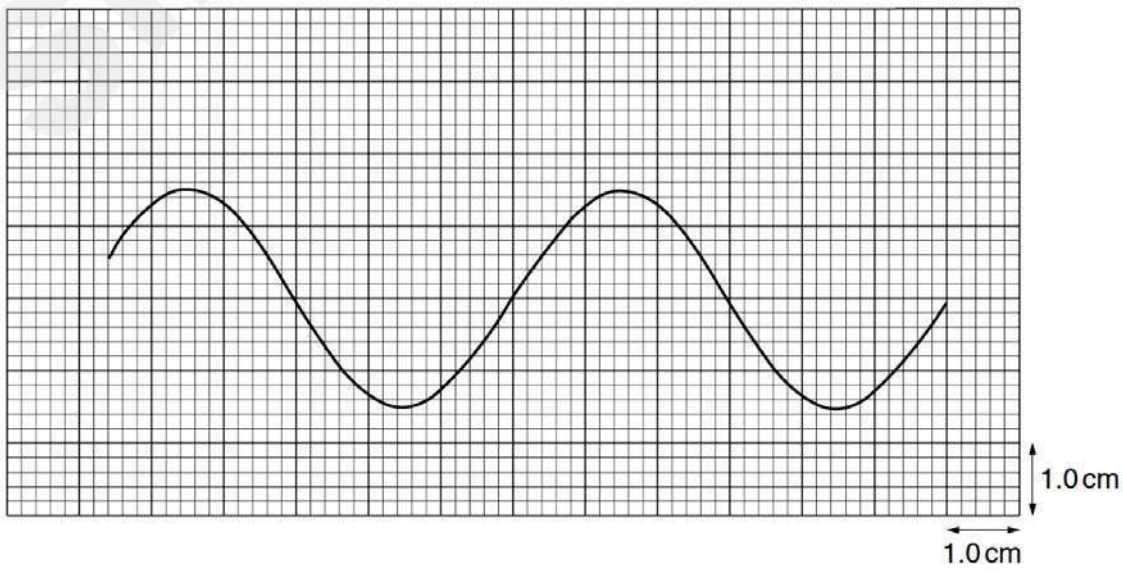


**Fig. 5.2**


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**(a)** With reference to the laws of electromagnetic induction, explain why

**(i)** an e.m.f. is induced in the wire,

……

……

……

…….. [2]

**(ii)** the e.m.f. is alternating.

……

……

……

…….. [2]

**(b)** **(i)** Use Fig. 5.2 and the c.r.o. settings to determine the equation representing the induced alternating e.m.f.

[4]

**(ii)** Mark any two points on Fig. 5.2 with crosses × and label both points with the letter Z to indicate two instances in time when the displacement of the wire is zero.

[1]

**(iii)** Deduce the direction of the motion of the wire at the instant when the electric potential of A is higher than the potential of B.

…….. [1]

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**(c)** **(i)** Given the resistance of the wire is 6.0 Ω and the c.r.o. is replaced with a microammeter, derive the equation representing the induced current.

[2]

**(ii)** Hence or otherwise, calculate the maximum induced magnetic field strength due to the induced current at a separation of 2.0 μm from the wire.

magnetic field strength = …… T [1]

**(iii)** State the direction of the induced current **and** its consequent magnetic field at the instant when the electric potential of A is higher than the potential of B.

……... [1]

**(d)** After a while, the wire stops moving. Explain why this occurs, ignoring friction and air resistance.

……..

……. [1]

**6** **(a)** A decay sequence for a radioactive atom of radon-219 to a stable lead-207 atom is as shown in Fig. 6.1.

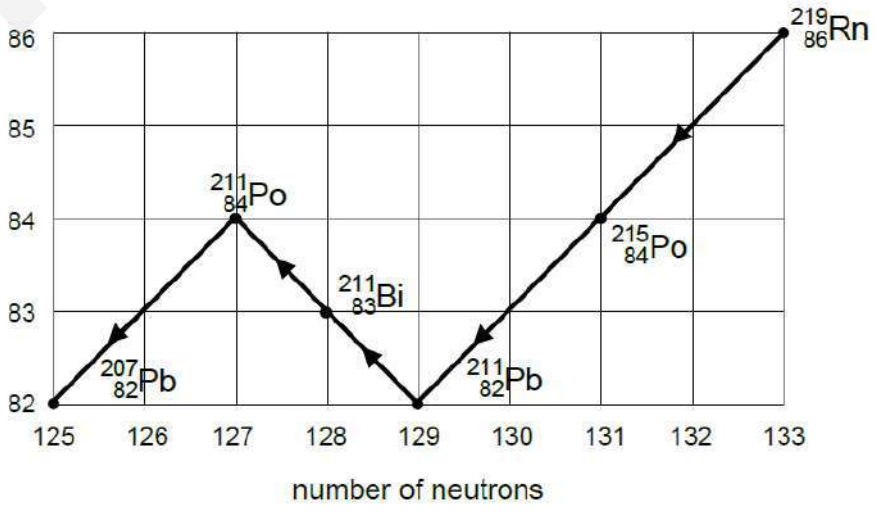


**Fig. 6.1**


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**(i)** Explain what the values on the vertical axis represent.

……..…….. [1]

**(ii)** State what particle is emitted when $^{211}_{83}Bi$ decays.

……..…….. [1]

**(iii)** Explain what happens within the nucleus to cause this decay.

……

……

……..…….. [1]

**(iv)** The particle mentioned in **(b)(ii)** is emitted with a range of energies, state what did this predict.

……..…….. [1]

**(b)** Explain whether the following statements made by two students with regards to the decay series in Fig. 6.1 are correct.

**(i)** Student A: "We can increase the production rate of alpha particles from $^{219}_{86}Rn$ by subjecting the sample to higher temperature and pressure"

……

……

……

……..…….. [1]

**(ii)** Student B: "If I start with 1.000 mol of atoms of radioactive substance $^{219}_{86}Rn$ which has a half-life of 3.96 seconds, there will be exactly 0.500 mol of $^{219}_{86}Rn$ left after one half-life has passed."

……

……

……

……..…….. [2]

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**(c)** A device called a bubble chamber uses liquid hydrogen to visualise radiation, under a uniform magnetic field. Radiation produced from nuclear decays leave bubble tracks, which can be photographed as shown in Fig. 6.2.

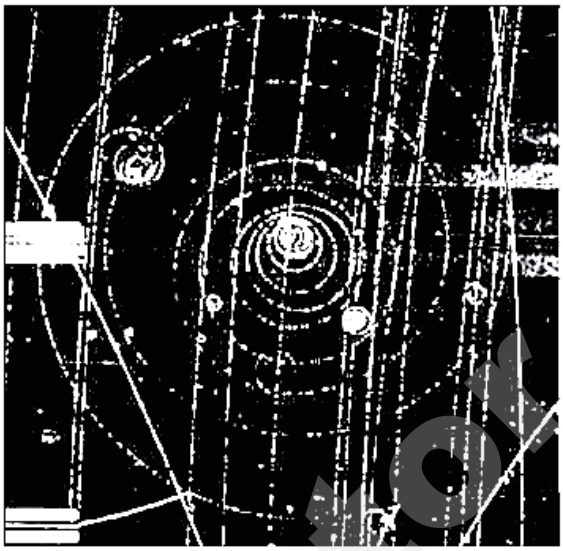

**Fig. 6.2**

**(i)** Explain why the shape of the tracks are spirals rather than circles.

……

……

……

…… [2]

**(ii)** Explain why it is less likely to observe gamma radiations using the bubble chamber as opposed to alpha or beta radiation.

……

……

……

…… [1]

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## Section B

Answer **one** question in this section in the spaces provided.

**7** **(a)** A plane wave passes through an aperture.

State and explain the effect of the width of aperture on the diffraction of the wave.

……

……

……

…….. [2]

**(b)** A diffraction grating is illuminated normally by a monochromatic light source of wavelength $\lambda$ as shown in Fig. 7.1. Light rays from each slit travel a different distance before arriving at a particular point on a screen distance $D$ away. $\theta$ is the angle between the diffracted ray and the normal.

In order to derive an expression for the path difference $x$, the light rays that meet at the same point on the screen can be **approximated** as parallel rays.

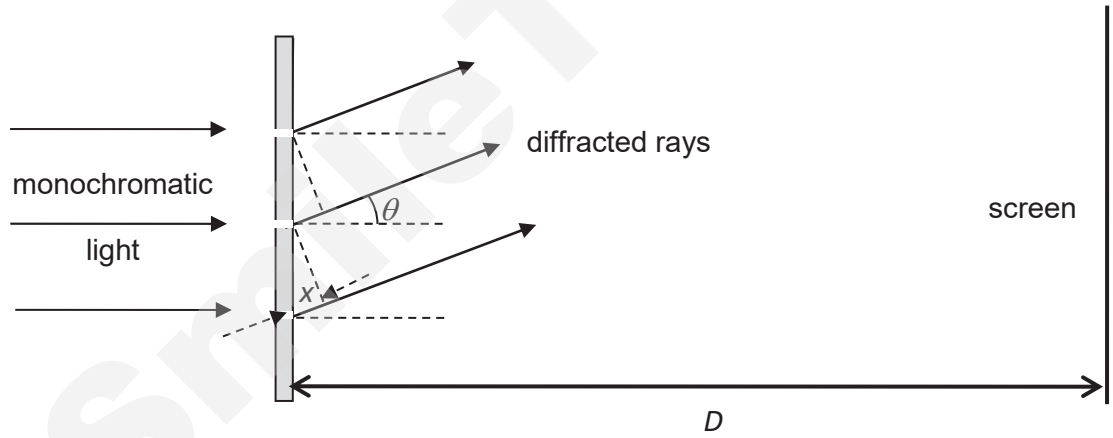


**Fig. 7.1**

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**(i)** State the condition where the rays can be assumed to be parallel.

……

…….. [1]

**(ii)** Derive an expression for the path difference $x$ between adjacent rays in terms of $p$ and $\theta$, where $p$ is the number of lines per unit length of the grating. [2]

**(iii)** Hence, derive an expression relating $p$ and $\theta$ for the constructive interference of the rays.

Define any additional symbol(s) you use. [2]

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**(c)** A diffraction grating is set up at the centre of a rotating table which completes a revolution every 3.0 s. The grating is illuminated normally by monochromatic light of wavelength $\lambda$ from a source which is also mounted on the table as shown in Fig. 7.2.

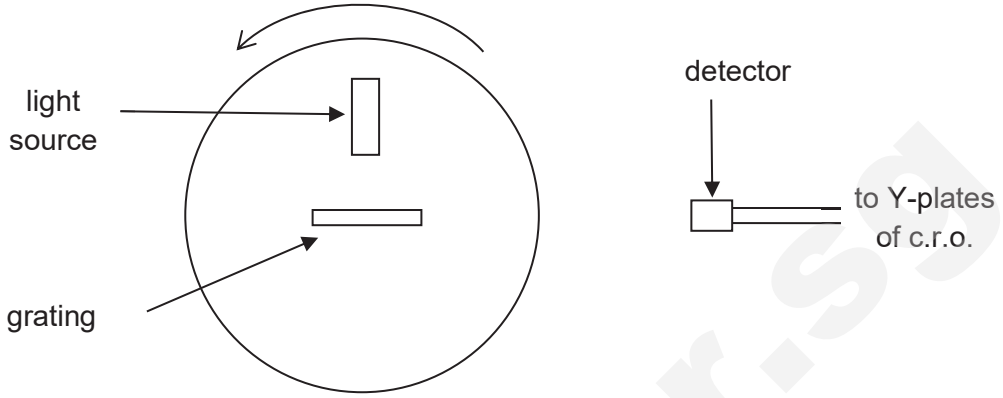


**Fig. 7.2**

The emergent beams of light from the grating are monitored by means of a stationary opto-electrical detector. The output from the detector is displayed on a cathode ray oscilloscope (c.r.o.). With the time-base set at 0.10 s $cm^{-1}$, the trace obtained is shown in Fig. 7.3. The relative positions of the peaks are as indicated.

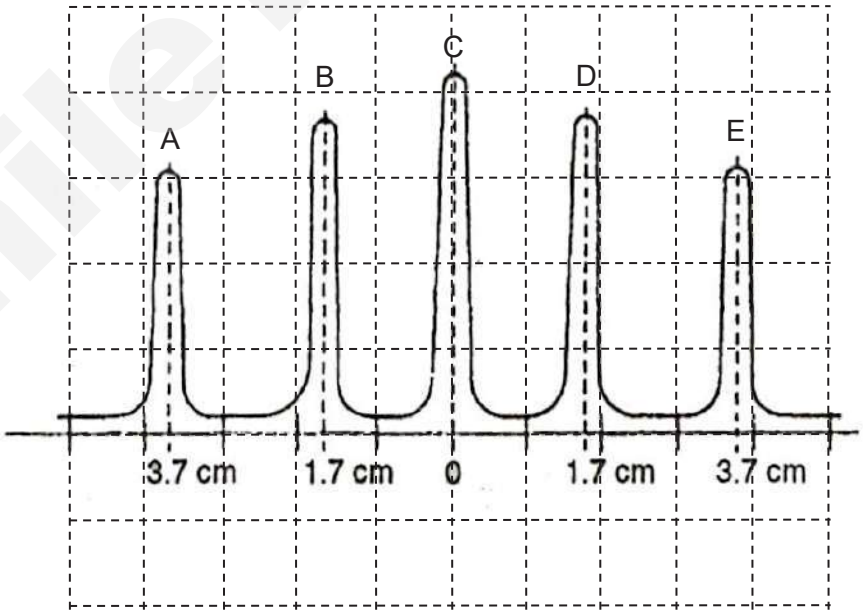


**Fig. 7.3**

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**(c)** **(i)** Calculate the angular speed of rotation of the grating.

angular speed = …….rad $s^{-1}$ [1]

**(ii)** Explain the appearance of the trace in Fig. 7.3 by stating the order of diffraction of the peaks and the variation in heights.

……

……

……

……

…….. [2]

**(iii)** Show that the angle $\theta$ in radians, for peak D is 0.36 rad and hence find the angle for peak E.

$\theta$ for E = …… radians [3]

**(iv)** Using peak E, calculate the wavelength of the light if the grating has 550 lines per mm.

wavelength = …….. nm [2]

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**(v)** Explain why it is preferable to calculate the wavelength using peak E rather than peak D.

……

……

…….. [1]

**(vi)** Sketch in Fig. 7.4, what will be observed on the c.r.o. display, if the diffraction grating is replaced by a double slit of the same slit separation as the diffraction grating. [2]

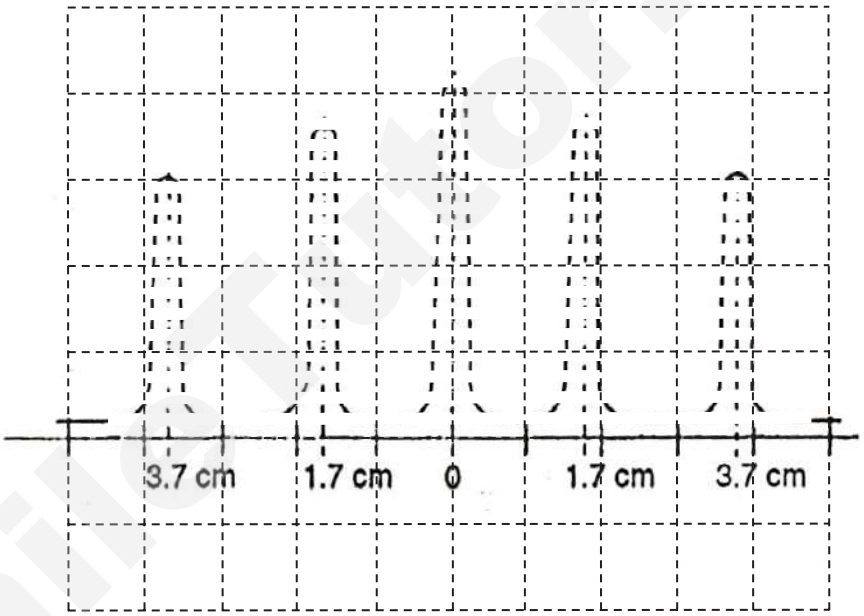


**Fig. 7.4**
(The original display from the grating is shown in dotted lines.)

**(vii)** Explain the appearance and the changes (if any) of the trace in Fig. 7.4.

……

……

……

…….. [2]

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**8** **(a)** A photomultiplier tube (PMT) can be used to detect high-energy charged particles. Fig. 8.1 shows a diagram of a particular photomultiplier tube.

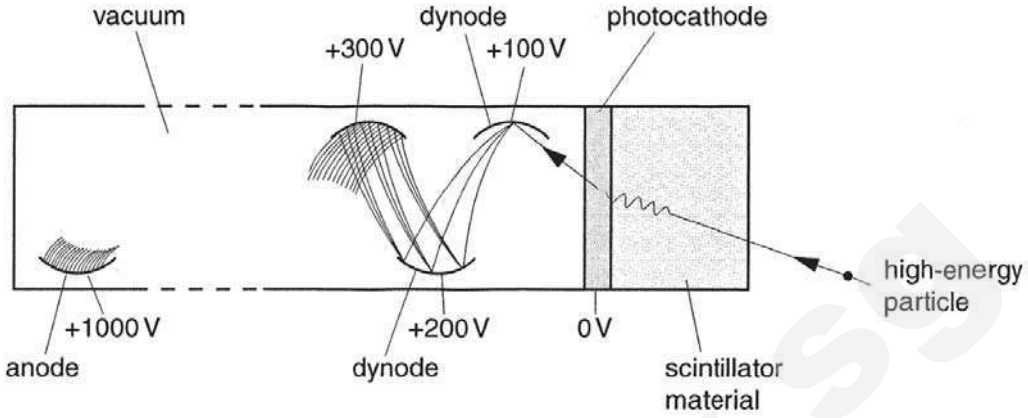


**Fig. 8.1**

The incoming charged particle strikes the scintillator material and produces a short burst of visible light. When this light reaches the photocathode, it removes some of the surface electrons due to the *photoelectric effect*. These electrons are then accelerated towards the first positive dynode because of the 100 V potential difference between it and the cathode.

The kinetic energy of one such electron is sufficient to liberate, on average, 3 'secondary' electrons from a 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 one particular case, a proton of kinetic energy 0.70 MeV produces 550 photons of light of wavelength 410 nm in the scintillator material. For a PMT with 9 dynodes, a single electron emitted from the photocathode produces a pulse of charge lasting $2.3 \times 10^{-8}$ s at the anode. The work function energy of the material of the photocathode is $3.5 \times 10^{-19}$ J.

**(i)** Explain what is meant by the *photoelectric effect*.

……

…… [1]

**(ii)** For a single electron emitted from the photocathode, determine the number of electrons striking the anode.

number of electrons = ……. [1]

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**(iii)** If the current at the anode is 7.2 μA, deduce the rate of electrons emitted at the photocathode.

rate of photoelectrons = …….…… $s^{-1}$ [4]

**(iv)** Calculate the energy of a single photon of light of wavelength 410 nm.

energy of photon = …… J [2]

**(v)** Hence, calculate the maximum kinetic energy of the electrons emitted from the photocathode.

maximum kinetic energy = …… J [2]

**(vi)** Hence, calculate the maximum possible speed of the electrons arriving at the first dynode (+100 V as shown in Fig. 8.1)

maximum possible speed = …….. m $s^{-1}$ [2]

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**(b)** Fig. 8.2 shows a cooler region of hydrogen gas surrounding a hot gas cloud emitting white light.

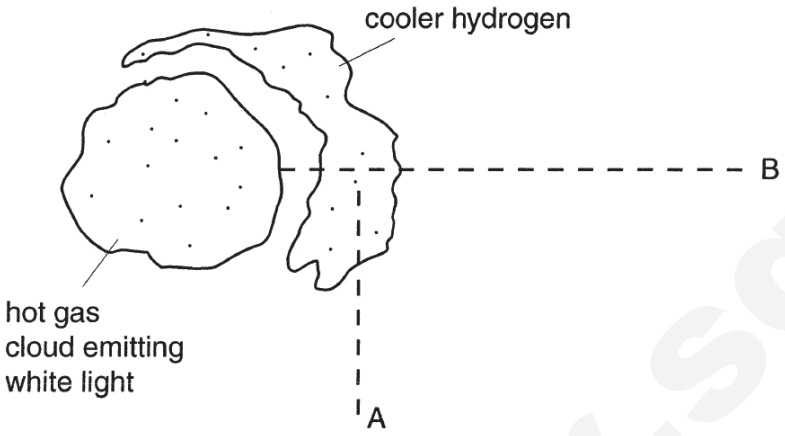


**Fig. 8.2**

**(i)** State the type of hydrogen spectrum observed from

**1.** point A

…… [1]

**2.** point B

…… [1]

**(ii)** Fig. 8.3 shows some of the energy levels of a hydrogen atom.

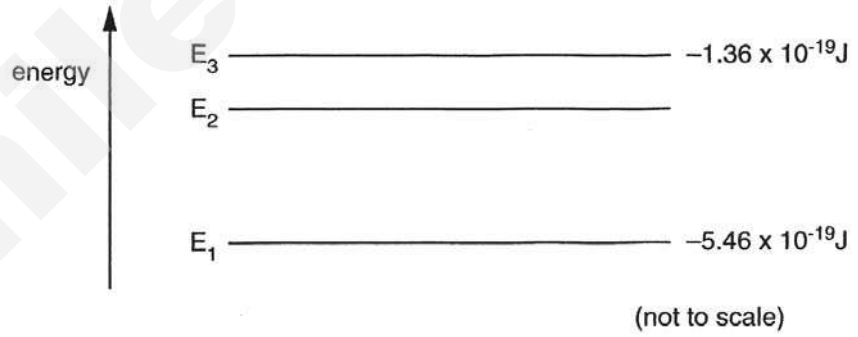


**Fig. 8.3**

**1.** The frequency of radiation emitted when an electron makes a transition between energy levels $E_3$ to $E_2$ is $1.60 \times 10^{14}$ Hz.

Determine the wavelength of the electromagnetic radiation when an electron makes a transition between energy levels $E_2$ and $E_1$.

wavelength = …….. nm [3]

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**2.** Determine the shortest wavelength of the electromagnetic spectrum that can be emitted when an electron makes a transition between any two energy levels shown in Fig. 8.3.

shortest wavelength = ..... nm [2]

**3.** State the colour of this shortest wavelength.

..... [1]

**END OF PAPER**

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# RIVER VALLEY HIGH SCHOOL
## JC2 PRELIMINARY EXAMINATION

# H2 PHYSICS 9749
# PAPER 4
28 AUG 2019

## 2 HOURS 30 MINUTES

**NAME** _____

**CLASS** 18J (  )

**INDEX NO.** _____

**INSTRUCTIONS TO CANDIDATES**

**DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.**

**Read these notes carefully.**
*Write your name, class and index number above.*

Candidates answer on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

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

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

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

| SHIFT |
|---|
| |
| **LABORATORY** |
| |

| FOR EXAMINERS' USE | |
|---|---|
| 1 | / 21 |
| 2 | / 14 |
| 3 | / 8 |
| 4 | / 12 |
| TOTAL | / 55 |

This document consists of **15** printed pages.


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**1** An Atwood Machine is a basic physics laboratory device often used to demonstrate basic principles of dynamics and acceleration. Using a modified Atwood machine, you will investigate the motion of two connected cases as the mass inside each of the cases is changed.

**(a)** Clamp two hooks about 80 cm above the bench using stands and clamps. The hooks have been screwed into corks for ease of clamping. The arrangement is shown in Fig. 1.1.

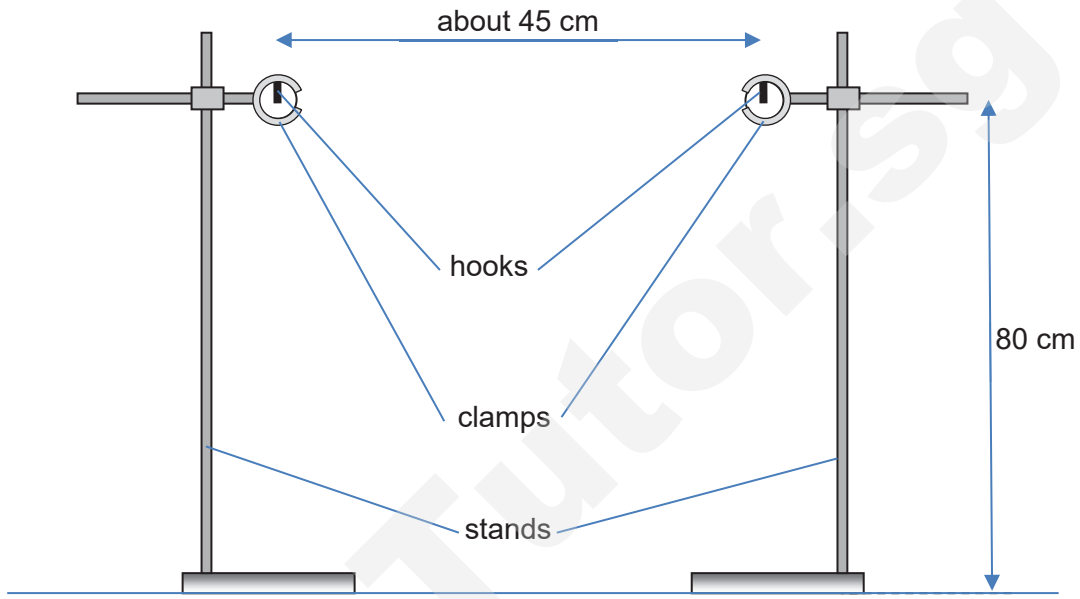


**Fig. 1.1**

**(b)** You are supplied with two paper cases labelled A and B which are joined by a length of thread. Pass the thread over both hooks so that A rests on the bench as shown in Fig. 1.2.

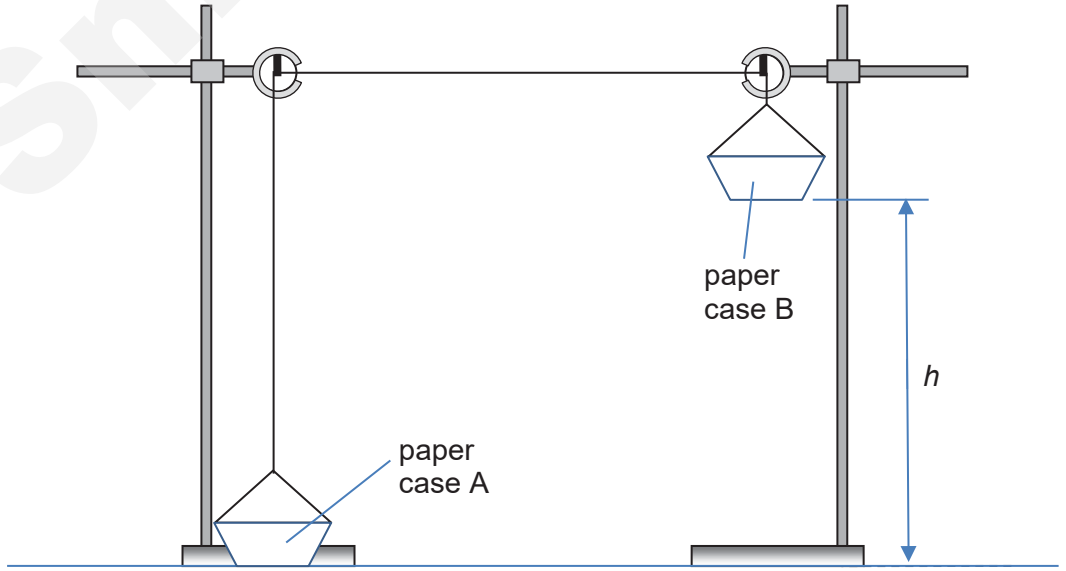


**Fig. 1.2**

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**(i)** The thread between the 2 hooks should be horizontal. Do not disturb the hooks from their positions or change the value of $h$ for the rest of the experiment.

Measure and record $h$.

$h$ = ……. [1]

**(ii)** Estimate the percentage uncertainty in $h$.

percentage uncertainty = ……. [1]

**(iii)** Place 30 paper clips into each plastic case. Gently transfer plastic clips, one by one, from A into B, until B begins to fall smoothly. Case A may need to be held down during this transfer.

**(iv)** Measure and record the time $t$ for B to fall from rest through the distance $h$.

Record the number of clips $N_A$ and $N_B$ in A and B respectively.

Note that only timings that are lesser than 5.0 s should be accepted and recorded.

$N_A$ = ……..

$N_B$ = ……..

$t$ = ……. [1]

**(v)** Estimate the percentage uncertainty in $t$.

percentage uncertainty = ……. [1]

**(vi)** Restore B to its original position, while keeping A held at the bench. Increase the number of plastic clips in B by transferring another paper clip from A to B.


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**(vii)** Repeat steps **(a)(iv)** and **(a)(vi)** to obtain further sets of readings for $t$, $N_A$, $N_B$.

[7]

**(c)** Theory suggests that $t$ , $N_A$ and $N_B$ are related by an expression of the form

$$\frac{1}{t^2} = \frac{P}{h}(N_B - N_A) + Q$$

where $P$ and $Q$ are constants.

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

$P$ = .....

$Q$ = ..... [4]


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[3]


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

……

…… [1]

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

……

…… [1]

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

……

…… [1]

**[Total: 21 marks]**

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**2** In this experiment, you will compare the diameters of objects seen through air with their apparent diameters seen through water and glass.

**(a)** The external diameter $d_1$ of the test-tube is shown in Fig. 2.1.

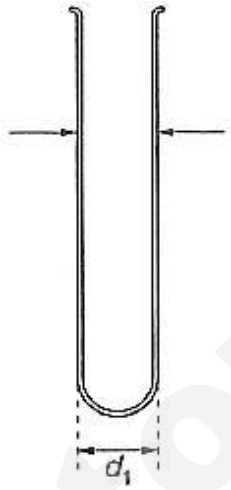


**Fig. 2.1**

Measure and record $d_1$, in the table using the 30cm plastic ruler, the vernier caliper and the micrometer screw gauge.

30cm plastic ruler, $d_1$ = .....

vernier caliper, $d_1$ = .....

micrometer screw gauge, $d_1$ = ..... [3]

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**(b) (i)** Fill the beaker with water to about the half way mark and stand the test-tube upside down in the **centre** of the beaker of water as shown in Fig. 2.2.

Look through the glass and water at the test-tube.

The external diameter $d_2$ of the test-tube as **seen through the water and glass** is shown in Fig. 2.2.

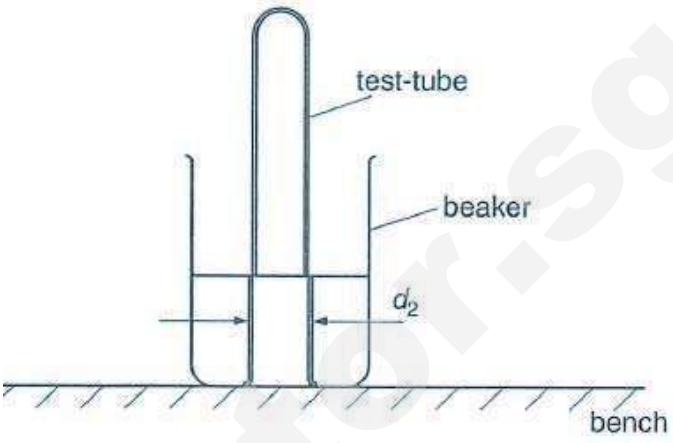


**Fig. 2.2**

**(ii)** 1. Measure and record $d_2$ using only **one** of the measuring instruments.

$d_2$ = …… [1]

2. Justify which measuring instrument you used to measure $d_2$.

……...

…… [1]

**(iii)** Remove the test-tube from the beaker and place the test-tube back into the basket.

**(c) (i)** Use **one** of the measuring instruments to measure and record the external diameter of $d_1$ of the measuring cylinder.

$d_1$ = ……

**(ii)** Place the measuring cylinder upright into the beaker, and measure and record $d_2$ using the same measuring instrument as in **(b) (ii)**.

$d_2$ = …… [1]


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**(iii)** Determine the percentage uncertainty in your value of $d_2$ for the measuring cylinder.

percentage uncertainty in $d_2$ = ..... [1]

**(d)** A student suggested that $d_1$ and $d_2$ are related by the expression

$$d_2 = kd_1$$

where $k$ is a constant.

**(i)** Use your values from **(a)**, **(b)(ii)**, **(c)(i)**, and **(c)(ii)** to determine two values of $k$.

first value of $k$ = .....

second value of $k$ = ..... [1]

**(ii)** Do the results of your experiment support the suggested relationship? Justify your answer by referring to your value in **(c)(iii).**

.....

.....

..... [2]

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**(e)** The external diameter $d_2$ of the test-tube as seen through the water and glass is thought to be larger than the external diameter $d_1$ as seen through air. The magnification factor, $k$ is proposed as,

$$k = \frac{d_2}{d_1}$$

It is suggested that the magnification factor of the setup in Fig. 2.2 depends on the internal diameter of the beaker of water.

Plan an investigation to determine the internal diameter of the beaker for which the magnification factor equal to 2.

You are provided with several beakers, each with uniform internal diameter.

Your account should include:

- your experimental procedure
- the table of measurements with appropriate units,
- how you determine the internal diameter of the beaker for which the magnification factor is 2.

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…… [4]

**[Total: 14 marks]**

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**3** In this experiment, you will investigate the resistance of a wire coil.

**(a)** You have been provided with a coil as shown in Fig. 3.1.

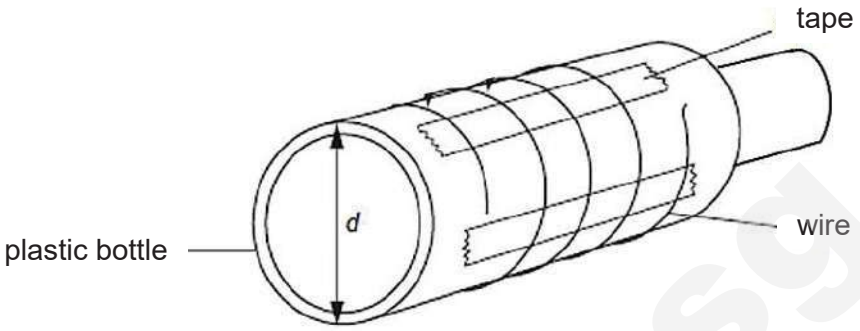


**Fig. 3.1**

**(i)** Measure and record the diameter *d* of the plastic bottle.

*d* = ..... [1]

**(ii)** Estimate the absolute uncertainty in your value of *d*.

uncertainty of *d* = ..... [1]

**(iii)** Estimate the length *x* of wire in a single turn.

*x* = ..... [1]

**(b)** Set up the circuit as shown in Fig. 3.2, and clip the contacts at both ends of the coil. Set the ammeter to 10 A DC and the voltmeter to 20 V DC.

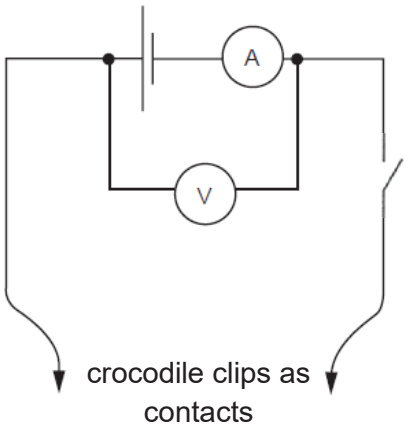


**Fig. 3.2**

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**(i)** Record the number of turns $n$ between the contacts.

Close the switch. Measure and record voltage $V$ and current $I$.

$n$ = .....

$V$ = .....

$I$ = ..... [2]

**(ii)** Determine the resistance $R$ between the contacts.

$R$ = ..... [1]

**(ii)** The resistance per metre $\mu$ of the wire is given by

$$\mu = \frac{R}{xn}$$

Use your results to determine a value for $\mu$.

$\mu$ = ..... [2]

**[Total: 8 marks]**

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**4** Fig. 4.1 shows a coil (coil X) tightly wound around a tube.

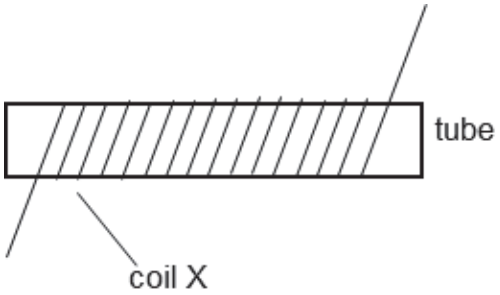


**Fig. 4.1**

A student winds up another coil (coil Y) tightly around coil X.

The student just learned in the topic of Electromagnetic Induction that a changing e.m.f. in coil X induces an e.m.f in coil Y.

The student wishes to investigate how the e.m.f. $V$ in coil Y depends on the frequency $f$ of the current in coil X and the number of turns, $N$, of coil X.

It is suggested that

$$V = k f^{p} N^{q}$$

where $k$, $p$ and $q$ are constants.

An alternating current power supply is provided and you may use any other equipment usually found in a Physics laboratory.

Design an experiment to determine the values of $k$, $p$ and $q$.

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 coils would be constructed,
**(d)** how the frequency of the current would be measured,
**(e)** any precautions that would be taken to improve the accuracy and safety of the equipment.

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**[Total: 12 marks]**

**END OF PAPER**



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# RVHS JC2 H2 Physics Preliminary Examinations Paper 1 Solutions

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

**1 Ans: B**

Units on LHS: $[m] + [m][m^2][P^{-1}]$
Units on RHS: $[Q][s^2]$
Since equation must be dimensionally constant throughout,

$[P]$ has to be $[m^2]$ and $[Q]$ has to be $[m\ s^{-2}]$

**2 Ans: D**

Ball accelerates constantly down XY upon release due to weight-component down the slope, hence velocity increases uniformly. Once travelling on YZ, ball travels with constant velocity. Inelastic collision at Z means a reduction in KE (i.e. lower speed) and since ball travels in reversed direction now, velocity is now in negative region. When the ball travels up in YX direction before coming to rest momentarily, the ball is again under constant retardation due to weight-component down the slope. Hence the velocity-time gradient at the final segment should be the same as the gradient of the initial motion.

**3 Ans: C**

Nature of collision is inelastic, hence total KE is not conserved.
By C.O.M.
$mu_x = 2mv_{xy} \rightarrow v_{xy} = mu_x/2m = ½\ u_x$
initial KE = $½\ mu_x^2 = E_k$ =
loss KE = $½\ mu_x^2 – ½\ mv_{xy}^2 = E_k – ½\ (2m)(½\ u_x)^2 = E_k – ½\ E_k = ½\ E_k$


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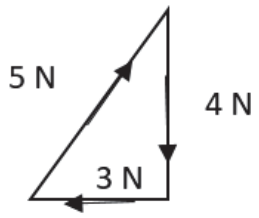
**4 Ans: A**




**5 Ans: D**

Constant velocity → no acceleration, i.e. net force = zero
Work done by car against gravity = mgsinα
Input energy = Fs
Output energy = mgs sinα
Efficiency is ratio of output energy/input energy = mg sinα/F

**6 Answer: C**

Volume of cylinder = πr2h
Volume of hollowed cylinder = $\pi h(R^2 - r^2)$
Mass of concrete hollowed cylinder = ρV
Therefore change in PE of hollowed concrete cylinder = ρVgΔh
$= (2.0 \times 10^3)(\pi)(10)(0.30^2 - 0.15^2)(9.81)(5.0) = 208$ kJ ~ 210 kJ

**7 Answer: B**

Fc = W – N
For N = 0
$mv^2/r = mg \rightarrow v^2 = (23)(9.81) \rightarrow v = 15$

**8 Answer: B**

At A, GPE = $U_A = -\frac{GMm}{(h_1+R)}$
At B, GPE = $U_B = -\frac{GMm}{(h_2+R)}$
The increase in GPE = $U_B - U_A = GMm\left(\frac{1}{R+h_1} - \frac{1}{R+h_2}\right)$

**9 Ans: A**

m of larger sphere = ρV = $(11.3 \times 10^3)(4/3)(\pi)(0.1)^3 = 47.3$
m of smaller sphere = 0.74

F = $G(47)(0.74)\left(\frac{1}{0.125^2}\right) = 1.5 \times 10^{-7}$

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**10** **Ans: D**

$pV = NkT \rightarrow N = (1.00 \times 10^5)(2.20 \times 10^{-3})/kT_0$
microscopic KE = 3/2 kT

Total internal energy = $3/2\ N(kT_{50}) = 3/2\ (1.00 \times 10^5)(2.20 \times 10^{-3})(T_{50}/T_0) = 390$ J

**11** **Ans: C**

$Q = mc\Delta T$
$30 \times 98 = 0.100 \times c \times 14$

$c = 2100$

**12** **Ans : A**

To remain in contact at all times, acceleration of plate $\leq g$
$\omega^2 x_0 \leq g \Rightarrow (2\pi f)^2 x \leq g$

maximum amplitude, $x_0 = 9.81 / (2\pi \times 20)^2 \Rightarrow x_0 = 6.2 \times 10^{-4}$ m

**13** **Ans: D**

Starting from $x = x_0 \sin \omega t$ and $a = -\omega^2 x$

$a = -x_0 \sin \omega t$

**14** **Ans: D**




**15** **Answer: B**

$\frac{1}{2}\lambda = 0.328$ m $\Rightarrow \lambda = 0.656$ m

From $v = f\lambda \Rightarrow f = 345 / 0.656 = 526$ Hz

**16** **Answer: C**

From one node through 10 antinodes to another node = $5\lambda = L$

$\Rightarrow \lambda = L / 5$

From $v = f\lambda = f(L / 5) = 0.20fL$

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**17 Answer: C**

electric field strength $E = \Delta V/d$
work done on charge by electric force = $q\Delta V = (+q)(Ed)$

**18 Answer: B**

$v_{\square} = u_{\square} = 3.1 \times 10^7$ m s$^{-1}$
$s_{\square} = u_{\square} t$
$t = 0.12 / 3.1 \times 10^7 = 3.8710 \times 10^{-9}$

$a_{\square} = F / m = 3.2 \times 10^{-15} / (9.11 \times 10^{-31}) = 3.5126 \times 10^{15}$
$v_{\square} = u_{\square} + a_{\square} t = 0 + (3.5126 \times 10^{15})(3.8710 \times 10^{-9})$
$v_{\square} = 1.3597 \times 10^7$ m s$^{-1}$

tan $\theta = v_{\square} / v_{\square}$
$\theta = 24°$

**19 Answer: D**

$R = \rho L/A = \rho L/(\pi r^2) = \rho(8)/(\pi(0.00025)^2) = 128 \times 10^6\ \rho/\pi$
$R_2 = \rho(2)/(\pi(0.0005)^2) = 128 \times 10^6\ \rho/\pi$
$\rightarrow R_2 = R$

**20 Answer: C**

Energy is consumed to overcome the internal resistance of the battery.

**21 Answer: D**

Effective resistance between PQ has to be lowest
A: 5 Ω
B: 2.67 Ω
C: 1.2 Ω
D: 0.5 Ω

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**22 Ans: B**

At **P**, $B_1$ due to $I_1$ = $\frac{\mu_0}{2\pi}\left(\frac{I_1}{x}\right)$ downwards but $B_2$ due to $I_2$ = $\frac{\mu_0}{2\pi}\left(\frac{I_2}{l-x}\right)$ upwards

Since $I_1 > I_2$ , so net $B = B_1 - B_2$.

**23 Ans: A**

Using Fleming's Left-hand Rule

**24 Ans: B**

average e.m.f. = $BA / t = (1.8 \times 10^{-4})\ (0.85 \times 0.60) / 0.20 = 4.6 \times 10^{-4}$ V

**25 Ans: B**

Peak power = $V^2 / R \Rightarrow 2 \times 40 = (170)^2 / R$
R = 361.25 Ω
With two such light bulbs connected in series,
the total mean power dissipated = $V^2 / 2R = (220)^2 / (2 \times 361.25) = 67.0$ W

**26 Ans: C**

Peak power = $(3)^2\ 80 = 720$ W

**27 Ans: A**

$eV_S = hf + \phi$ ➔ $\phi = eV_S - hf$

$\lambda$ *is halved* ➔ *f is doubled.*
$eV_S' = h(2f) + \phi$
$eV_S' = h(2f) + (eV_S - hf)$
$eV_S' = eV_S + hf$

$\lambda$ *is halved* ➔ *f is doubled*
*but* $I$ *is kept constant*
*so N/t is halved for this source.* $I$ *= (N/t) hf/A*

*so total current* □ *total N/t due to both sources = 1.5 N/t = 1.5* $I_e$

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**28 Ans: A**

The higher frequency lines are clustered together.

**29 Ans: A**

Difference in binding energies of products and reactants = Gain in kinetic energies of products + Energy of gamma ray

(39.25 + 28.48 – 64.94) = 2.31 + E

E = 0.48 MeV

**30 Ans: A**

Stability of a nucleus depend on the binding energy per nucleon. The greater the binding energy per nucleon, the more stable the nucleus is. Hence low mass nucleus undergo fusion and heavy mass nucleus undergo fission to produce products that have an increased binding energy per nucleon.

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**RVHS JC2 H2 Physics Preliminary Examinations Paper 2 Solutions**

1 (a) $S_y = u_y t + ½ at^2$
$20 = 0 + ½ (9.81)t^2$
$t = 2.02$ s

(b) No. As the time duration is larger than human reaction time, which is about 0.3 s.
or
No. As the rock reaches the intended target in more than 2.0 s time, the soldier would have moved away sufficiently far, assuming a speed of 1 m s⁻1, i.e. 2 m away.
or
No. Air resistance will render the horizontal distance travelled to be lesser than 50 m.

(c) $S_x = u_x t$
$50 = u_x(2.02) \rightarrow u_x = v_x = 24.752$
$v_y = u_x + (9.81)(2.02) \rightarrow v_y = 19.816$
$v = (v_x^2 + v_x^2)^{½} = 31.7$ m s$^{-1}$ ~ 32 m s$^{-1}$
$\tan\theta = 19.816/24.752$
$\theta = 38.7° \sim 39°$
39° below the horizontal

2 (a) The linear momentum of a body is the product of the mass and its velocity. The linear momentum is in the same direction as its velocity.

2 (b) (i) By C.O.M.
$mu = m1v1 + m2v2 \rightarrow (800)(165) = (170)(v1) + (630)(235)$
$v1 = -94.4$ m s$^{-1}$
magnitude of $v1 = 94.4$ m s$^{-1}$
direction: in the opposite horizontal direction as larger fragment (or to the left, or backward)

(ii) Initial KE = ½ (800) $(165)^2$ = 10.890 MJ
Final KE = ½ (170) $(94.4)^2$ + ½ (630) $(235)^2$ = 18.153 MJ
Energy released by explosion = final KE – initial KE
= 7.26 x $10^6$ J


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3

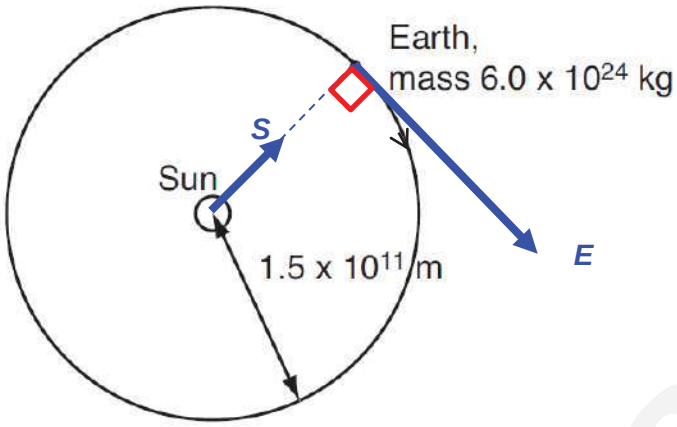


**Fig. 3.1**

**(a)** **(i)** T = 1 year = 365 × 24 × 60 × 60 = 31536000 ≈ 3.15 × $10^7$ s [1]

**(ii)** ω = 2π / T = 1.99 × $10^{-7}$ rad $s^{-1}$ [1], [1]

**(b)** **(i)** By Newton's 3rd law,
gravitational force by Sun on Earth = –gravitational force by Earth on Sun
gravitational force by Sun on Earth provides the centripetal force on Earth [1]
= $m_E r\omega^2$
= (6.0 × $10^{24}$)( 1.5 × $10^{11}$)(1.99 × $10^{-7}$)$^2$ [1]
= 3.6 × $10^{22}$ N [1]

**(ii)** Refer to Fig. 3.1 [1]

**(ii)** $F_G = GM_{Earth}M_{Sun} / r^2$ = 3.6 × $10^{22}$ [1]
$M_{Sun}$ = 2.0 × $10^{30}$ kg [1]

**(c)** **(i)** v = rω or v = 2πr / T [1]
v = 30 km $s^{-1}$ [1]

**(ii)** KE = ½ m $v^2$ [1]
KE = 2.6856 × $10^{33}$
GPE = $–GM_{Earth}M_{Sun} / r$ [1]
GPE = –5.336 × $10^{33}$
Total energy = GPE + KE = –2.7 × $10^{33}$ J [1]

Alternatively:
$F_G$ provides $F_C$.
$GM_{Earth}M_{Sun} / r^2 = mv^2 / r$
$GM_{Earth}M_{Sun} / 2r$ = ½ $mv^2$ = KE [1]

GPE = $–GM_{Earth}M_{Sun} / r$

Total energy = GPE + KE
= $–GM_{Earth}M_{Sun} / r + GM_{Earth}M_{Sun} / 2r$ [1]
= –2.7 × $10^{33}$ J [1]

**(d)** Refer to Fig. 3.1 [1]

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4 (a) High temperature, Low pressure

(b) Considering a single molecule colliding elastically against the container walls, which do not move upon collision, the molecule's impulse is equal to $\Delta p$, where $p$ is the momentum of molecule. $\Delta p = mv - mu = -2mu$, where $v$ is the velocity after collision = $-u$.

For constant velocity, the time interval, $\Delta t$, between collisions against a wall is $\Delta t = 2s/u$.
Using impulse-momentum theorem, the average force, $F_{av}$, that one molecule experiences due to the wall is given by

$$F_{av} = \frac{\Delta p}{\Delta t} = -\frac{mu^2}{s}$$

By N3L, the average force the molecule exerts on the wall

$$F_{molecule\ on\ wall} = -F_{av} = +\frac{mu^2}{s}$$

By definition of pressure, $P$ = Force/Area. As the container has cross-sectional area A and side $s$, average pressure exerted by one molecule is given by

$$P = \frac{\left(\frac{mu^2}{s}\right)}{A} = \frac{mu^2}{V}$$

where the volume of container, $V$ = As

(c)

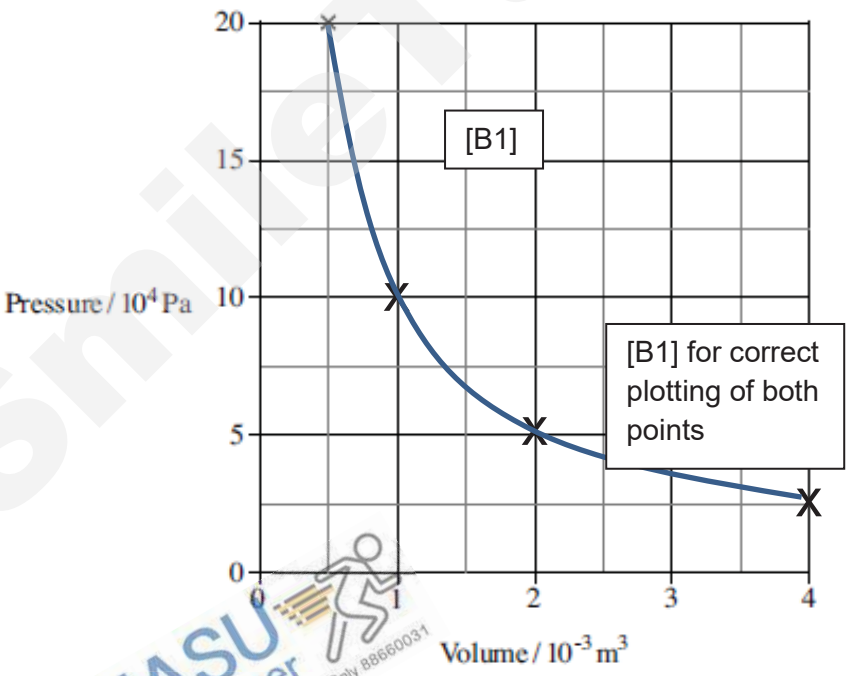


Fig. 4.2

(ii) $pV = NkT \rightarrow N = (20 \times 10^4)(0.5 \times 10^{-3})/(1.38 \times 10^{-23})(293.15)$
n = 0.3411 moles
$N = 2.47 \times 10^{22}$

(iii) Microscopic KE = 3/2 kT = $6.068 \times 10^{-21}$ J
Total KE = 3/2 NkT = $2.47 \times 10^{22} \times 6.068 \times 10^{-21}$
= 149.9 J ~ 150 J

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**5** **(a)** Formed due to superposition/interference of the incident wave from oscillator and reflected wave from Q. 1

The two waves have the same speed, wavelength/frequency, same amplitude and travel in opposite directions along the same line (string) 1

**(b)** **(i)** ½ λ = 0.30 m

λ = 0.60 m [1] 1

v = f λ

= 120 (0.60) = 72 m $s^{-1}$ [1] 1

**(ii)** Within the same segment - phase difference is zero. 1

**6** **(a)** Electromotive force of a source is defined as the **energy converted per unit charge from other forms of energy into electrical energy** when the charge is driven through the source round a complete circuit. 1

Potential difference between two points of a circuit **is the amount of electrical energy converted per unit charge into other forms of energy** when the charge moved from one point to the other. 1

**(b)** **(i)** Using $P = I^2 R$ 1

320 Ω : current = $\sqrt{\frac{0.8}{320}} = 0.050$ A 1

500 Ω : current = $\sqrt{\frac{P}{R}} = \sqrt{\frac{0.8}{500}} = 0.040$ A 1

**(ii)** Max current in parallel branch = 2 x 0.040 = 0.080 A

But the 320 Ω resistor will be damaged first.

Hence, maximum current in circuit = 0.050 A 1

1 mark for recognizing the maximum current or the resistor which will be damaged first.

Maximum safe p.d = 0.050 (320 + 250)= 28.5 V

1 mark for total resistance 1

1 mark for determining the maximum safe potential difference. 1

**7** **(a)** ***The root-mean-square (r.m.s.)*** voltage of an alternating current is defined as the ***steady direct voltage*** which converts electrical energy to other forms of energy in a given resistance **at the same rate as the a.c.** [2]

**(b)** **(i)** Turns Ratio [1]


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$$\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{240 \times 10^3}{12.0 \times 10^3}$$
$$= 20$$

**(ii)**

$$\text{Transmitting current} = \frac{\text{power}}{\text{voltage}} = \frac{20 \times 10^6}{240 \times 10^3}$$
$$= 83.3 \text{ A}$$ 1

Power lost = $I^2R = (83.3)^2(200) = 1387778$ W
=1390 kW 1

peak power = 2 x mean power = 2800 kW 1

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**8** **a** **i** A species of nucleus with a specific value of proton and neutron number. 1

**ii** Number of nuclei disintegrating per unit time / rate of nuclear disintegration 1

**iii** Nucleus' probability of decay per unit time. 1

**b** **i**

| | | |
|---|---|---|
| 9.0 | 98 | **1.99** |
| 10.0 | 68 | **1.83** |
| 12.0 | 33 | **1.52** |

Correct values 1
Correct precision 1

**ii** 1. Point correctly plotted with precision of half the smallest square (2, 3.13) 1
2. Line of best fit. 1

**iii** The substance contains a mixture of elements with different decay constants. 1

**iv** Correct gradient calculations with coordinates read correctly 1

Correct units $h^{-1}$ 1

**v** It represents the decay constant of one of the elements within the mixture multiplied by lg e 1

**c** **i** To kill the bacteria on the food thus allowing them to last longer. 1

**ii** $^{60}_{27}Co \rightarrow ^{60}_{28}Ni + ^{0}_{-1}e^{-}$ (+ $\bar{\upsilon_e}$ + γ) optional 1

**iii** $A = A_0 e^{-\lambda t}$

$A = 50000e^{-\frac{ln2}{5.271}5}$ 1

$= 25900$ Ci (25906.99) 1

Since the activity now is lesser than 35000, it is too weak a source and unusable 1

**iv** $$A = \lambda N = \frac{ln2}{t_{1/2}}N$$ 1

$$N = \frac{50000 \times 3.7 \times 10^{10}}{\frac{ln2}{5.271 * 365 * 24 * 60 * 60}} = 4.4366 \times 10^{23}$$ 1

Total mass = N * mass of 1 cobalt atom = N * 60 u = $4.4366 \times 10^{23} \times 1.66 \times 10^{27} * 1000$ 1

Total mass = 44.2 g 1

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## RVHS JC2 H2 Physics Preliminary Examinations Paper 3 Solutions

**1 (a)** Moment is the turning effect of a force.
The moment of a force is equal to the product of the force and the perpendicular distance of the line of action of the force from a pivot.

**(b) (i)** $\sum F_X = 0,\ Q_H = P$
$\sum F_Y = 0,\ Q_V = W + M$
$Q = \sqrt{Q_H^2 + Q_V^2}$
$= \sqrt{(P^2 + (W+M)^2)}$ (shown)

**(ii)** Moment about P, $(M)\left(\frac{1}{4}\right)(3) + (W)(1.5) + (Q_H)(4) = (Q_V)(3)$
$\left(\frac{3}{4}\right)(M) + (150) + (4200) = (3)(M+W)$
M = 1302 ~ 1300 N
Substituting back into expression from (b)(i),
Q= $\sqrt{(920^2 + (500+1302)^2)} = 2023\ N$ ~ 2000 N

**2 (a)** By C.O.E.
$KE_A + GPE_A = WD_{Friction} + KE_B + GPE_B$
$\frac{1}{2}(300)(5.0^2) + 35kJ = 15kJ + \frac{1}{2}(300)(v_B^2)$
$= 12.6\ m\,s^{-1}$

**(b)** From N2L, F = ma and WD by a constant force F, W = F.s = mas
From equations of motion, $v^2 = u^2 + 2as$
$as = \frac{1}{2}(v^2 - u^2)$
$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ (final KE – initial KE)
Assuming body starts from rest, i.e. $\frac{1}{2}mu^2 = 0$
$W = \frac{1}{2}mv^2$ (derived)

Assumption:
Constant force F
No energy loss / smooth surface
No initial KE / starts from rest

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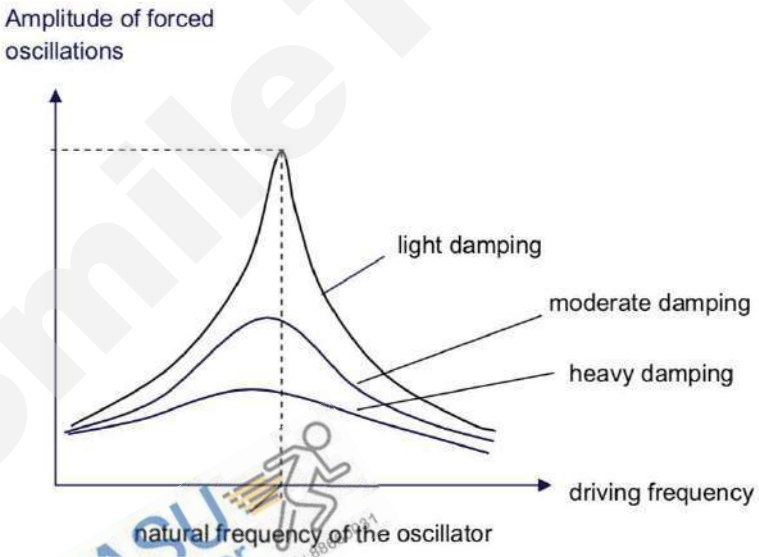
| | | |
|---|---|---|
| **3(a)** | Acceleration / force proportional to displacement (from a fixed point)<br>either<br>acceleration and displacement in opposite directions<br>or<br>acceleration always directed towards a fixed point | 1<br><br>1 |
| **3(b)(i)1.** | 0.10 s, 0.30 s, 0.50 s, etc (any two) | 1 |
| **3(b)(i)2.** | either **0.0 s, 0.40 s, 0.80 s, 1.20 s**<br>or **0.20 s, 0.60 s, 1.00 s** (any two) | 1 |
| **3(b)(ii)** | period = 0.40 s<br>frequency = 2.5 Hz | 1 |
| **3(b)(iii)** | phase difference = 90° | 1 |
| **3(c)** | Free oscillation: object oscillates at its natural frequency without external forces applied. (without any loss of energy / no resistive forces )<br><br>Forced oscillation: object made to oscillates at the frequency of an external periodic driving force. (continuous energy input / driving oscillator) | 1<br><br>1 |
| **(d)(i)** |  <br>Any of these shapes and max peak at natural frequency | 1 |
| **3(d)(ii)** | frequency = 2.5 Hz | 1 |

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**4** **(a)** Electric field strength at a point is defined as the electric force per unit positive charge that acts on a stationary charge placed at that point.

$E = F/q$

N $C^{-1}$ or V $m^{-1}$ (question asked for SI units. NOT base SI units)

**(b)** **(i)** (vertically) downwards
(or top to bottom, or down the page)

**(ii)** Force on sphere $F = kx = 0.24 \times 18 \times 10^{-3}$
$= 4.32 \times 10^{-3}$

**(iii)** $E = F/q = 4.32 \times 10^{3}/4.1 \times 10^{-8}$
$E = V/d = (4.32 \times 10^{3}/4.1 \times 10^{-8}) = 5.0 \times 10^{3}/d$
$d = 4.76 \times 10^{-2}$

**(c)** Electric field becomes zero (or ceases to exist)
Flow of charge (or electrons) from one plate to the other (or plates discharge)
Potential difference across plates becomes zero (or no pd across plates, or plates at same potential)

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**5** **(a)** **(i)** wire cuts magnetic field 1

e.m.f induced when there is cutting of flux 1

**(ii)** induced e.m.f. may produce an effect which 'opposes' change causing it 1

as direction of movement changes, so does induced e.m.f. 1

**(b)** **(i)** $x_0 = 1.5$ mV 1

$\omega = 2\pi / T = 2\pi / (3 \times 10^{-3})$ 1 (for formula/method)

$= 2090$ rad $s^{-1}$ 1

$x = 0.0015 \sin 2090t$ 1 (for expression)

or $x = 0.0015 \cos 2090t$

**(ii)** any two max or –max 1

**(iii)** moving upwards 1

**(c)** **(i)** $I_0 = V_0/R = 1.5 / 6.0 = 0.25$ mA 1

$I = 0.0025 \sin 2090t$ 1

or $I = 0.0025 \cos 2090t$

**(ii)** $B = \mu_0 I / 2\pi d$

$= 2.5 \times 10^{-5}$ T 1

**(iii)** induced current flows from B to A and induced B-field direction according to Right-hand grip rule is anticlockwise as viewed from point A or clockwise as viewed from point B. 1

**(d)** The magnetic field of the induced current generates a magnetic force which acts to slow the motion of the wire. 1

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| | | | | |
|---|---|---|---|---|
| **6** | **a** | **i** | Number of protons in the nucleus | 1 |
| | | **ii** | A high-speed electron | 1 |
| | | **iii** | An neutron in the nucleus decays to form a proton and an electron with the latter being ejected out of the nucleus. | 1 |
| | | **iv** | The existence of the neutrino to conserve energy and momentum in the decay. | 1 |
| | **b** | **i** | Radioactive decay is a spontaneous process. It is not affected by external temperature or pressure. | 1 |
| | | **ii** | Radioactive decay is a random process. | 1 |
| | | | Half life is the average time taken for half the amount of nuclei to decay, hence it is likely that there will be 0.5 mol left but not definitely.<br><br>If the experiment is repeated a lot of time, the average amount left will tend to 0.5 mol. | 1 |
| | **c** | **i** | As the particles travel, they lose energy and slow down. | 1 |
| | | | Since the radius of the circular path is proportional to the velocity of the particles, the radius of the path gets smaller as they travel. | 1 |
| | | **ii** | Gamma radiations are weakly ionizing hence they do not produce much bubbles | 1 |

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**7** **a** When the wavelength of the wave is comparable to slit width, 1
diffraction is most significant. 1

**b** **i** Distance *D* must be much longer than distance between two adjacent slits of the grating 1

**ii** Slit separation, $d = 1/p$ 1

path difference $x = d \sin\theta = 1/p \sin\theta$ 1

**iii** Hence constructive interference occurs when

$1/p \sin\theta = n\lambda$ where $n = 0, 1, 2, \ldots\ldots$ 1

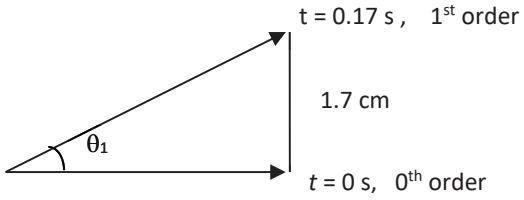
Or $\sin\theta = n\,p\,\lambda$ where $n = 0, 1, 2, \ldots\ldots$

Where *n* is the order of the spectrum and $\theta$ is the angle of diffraction between the diffracted ray and the direction of incident light. 1

**c** **i** Angular speed of grating, $\omega = 2\pi / T = 2\pi / 3.0$ 1
$= 2.09 = 2.1$ rad $s^{-1}$ 1

**ii** Peak C corresponds to the zeroth order of the interference pattern whereas peaks B and D the first order, and Peaks A and E the second order. 1
The higher the order of the peaks, the lower the height of each peak due to the longer distance that it has to travel to reach the screen. 1

**iii** Time taken to shift from zeroth order to the first order through 1.7 cm on the CRO screen is 1.7 x 0.10 s = 0.17s 1




$\theta_1 = (2\pi / 3) \times 0.17$ [1] $= 0.356$ rad $= 0.36$ rad 1

Similarly time from the zeroth order to 2nd order = 3.7 x 0.1 = 0.37 s

$\theta = (2\pi / 3) \times 0.37 = 0.7749$ rad $= 0.77$ rad. 1

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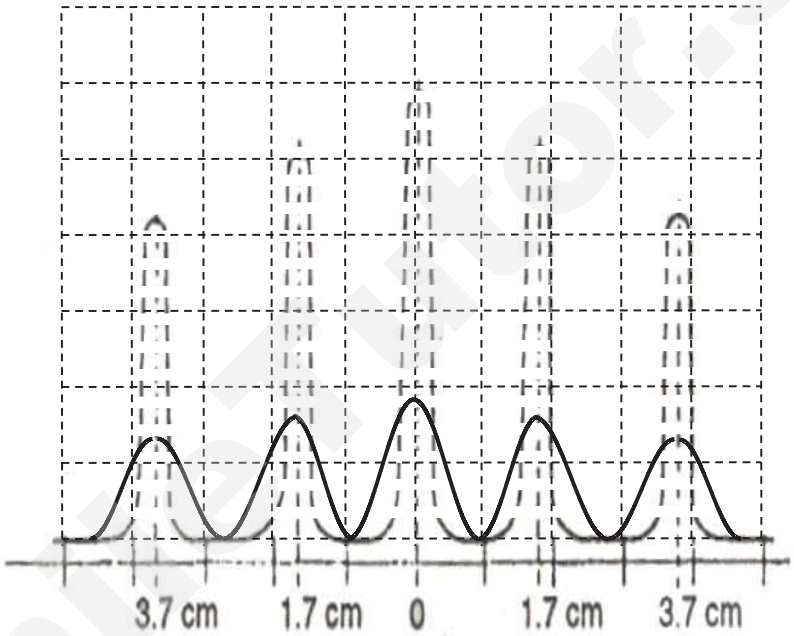
**Iv** Using the grating equation

$\sin \theta_2 = 2 \times 5.5 \times 10^5 \times \lambda$ 1

$\lambda = 636$ nm 1

**V** Peak E is preferred as the angle $\theta$ is larger and the percentage error for calculating the wavelength is smaller. 1




Fringe separation remains the same. [1]
Lower intensity for all peaks [1]

**vii** Since the slit separation remain the same, the fringe separation remains the same. 1

However, the peaks are less intense (poorer contrast) and less sharp (broader and less defined) due to fewer slits that allow light to pass through. 1

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**8** **(a)** **(i)** The emission of electrons when light of sufficient frequency strikes the photocathode. 1

**(ii)** 1 dynode ~ multiply by 3, so 9 dynodes ~ $3^9 = 19683$ 1

**(iii)** Let n be number of photoelectrons.
$I = (n/t)e$ 1
$7.2 \times 10^{-6} = n/t\ (1.60 \times 10^{-19})$
At the ANODE, $n/t = 4.5 \times 10^{13}$ 1

AT the PHOTOCATHODE,
$n/t = 4.5 \times 10^{13} / 19683$ 1
$= 2.286 \times 10^{9}$ 1

**(iv)** $E = hf = hc/\lambda$ 1
$= (6.63 \times 10^{-34})(3.00 \times 10^{8}) / (410 \times 10^{-9}) = 4.85 \times 10^{-19}$ J 1

**(v)** $KE_{max}$ of electrons emitted at photocathode = $hf - \phi$ 1
= (iv) - $3.5 \times 10^{-19}$
$= 1.35 \times 10^{-19}$ J 1

**(vi)** gain in KE = WD by p.d. 1
$½\ mv^2 - (v) = eV$
$v^2 = [(1.60 \times 10^{-19})\ (100) + 1.35 \times 10^{-19}] / (½\ 9.11 \times 10^{-31})$
$v = 5.95 \times 10^{6}$ m $s^{-1}$ 1

**(b)** **(i)** **1.** emission line spectrum 1

**2.** absorption line spectrum 1

**(ii)** **1.** $E_3 - E_2 = hf$ 1
$-1.36 \times 10^{-19} - E_2 = (6.63 \times 10^{-34})(1.60 \times 10^{14})$
$E_2 = -2.4208 \times 10^{-19}$ 1

$E_2 - E_1 = hf = hc/\lambda$
$-2.4208 \times 10^{-19} - (-5.46 \times 10^{-19}) = (6.63 \times 10^{-34})(3.00 \times 10^{8}) / \lambda$
$\lambda =$ 54 nm 1

**2.** $E_3 - E_1 = hf = hc/\lambda$ 1
$-1.36 \times 10^{-19} - -5.46 \times 10^{-19} = (6.63 \times 10^{-34})(3.00 \times 10^{8}) / \lambda$
$\lambda = 485$ nm 1

**3.** blue / indigo / violet / purple 1

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**RVHS JC2 Preliminary Examination Paper 4 suggested solutions**

| Q1 | Answer | Marks |
|---|---|---|
| (b)(i) | **MMO**<br>value of $h$ to the nearest 0.1 mm with unit<br>$h$ should be at least 55 cm if students follow instructions. | 1 |
| (b)(ii) | **ACE**<br>Percentage uncertainty in $h$ calculated correctly using sensible value of $\Delta h$ (e.g. 0.2 or 0.3 mm) to indicate uncertainty in holding rule vertical and reading to bottom of plastic cup accurately. | 1 |
| (b)(iv) | **MMO**<br>$N_A$, $N_B$ and $t$ measured to the correct precision with unit. | 1 |
| (b)(v) | **ACE**<br>Percentage uncertainty in $t$ calculated correctly using sensible value of $\Delta t$ (e.g. 0.2 ~ 0.5 s) to indicate human reaction time | 1 |
| (b)(vii) | **MMO**<br>Evidence of repeat readings.<br>**MMO**<br>**MMO**<br>• Award 2 marks if candidate has successfully collected 6 or more sets of data ($N_A$, $N_B$ and $t$) without assistance / intervention.<br>• Award 1 mark if candidate has successfully collected 5 sets of data ($N_A$, $N_B$ and $t$) without assistance / intervention.<br>• Award zero mark if candidate has successfully collected 4 or fewer sets of data ($N_A$, $N_B$ and $t$) without assistance / intervention.<br>• Deduct 1 mark if candidate requires some assistance / intervention but has been able to do most of the work independently.<br>• Deduct 2 marks if candidate has been unable to collect data without assistance / intervention.<br>**PDO**<br>Layout: column headings (raw data and calculated quantities: $N_A$, $N_B$, $t$, $1/t^2$ and $(N_A - N_B)$). Each column heading must contain a quantity and unit.<br>**PDO**<br>All values of e.g. $N_A$, $N_B$ and $t$ to the correct precision.<br>**PDO**<br>For each calculated value of e.g. $1/t^2$ and $(N_A - N_B)$, the number of s.f. should be the same or one more than the number of s.f. in the raw data.<br>**ACE**<br>Correctly calculated values of calculated quantity. | 7 |
| (c) | **ACE**<br>Linearising equation.<br>**PDO**<br>Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed.<br>Scales must be chosen so that plotted points occupy at least half the graph grid in both x and y directions.<br>Axes must be labelled with the quantity which is being plotted.<br>Axes must be labelled with values every 2 cm. Awkward values (e.g. 1.6, 2.6, etc) are not allowed.<br>**PDO**<br>All observations must be plotted. Work to an accuracy of half a small square. | 7 |

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| | | |
|---|---|---|
| | If student puts a cross at gradient coordinates, it is considered wrong plotting.<br>**PDO**<br>Straight line of best fit - judge by scatter of points about the candidate's line.<br>There must be a fair scatter of points either side of the line.<br>**ACE**<br>y-intercept must be read oft to the nearest half small square or determined from y = mx + c using a point on the line.<br>**ACE**<br>Gradient - the hypotenuse of the I:! must be greater than half the length of the drawn line. Read-ofts must be accurate to half a small square.<br>If student draws a fat dot at gradient coordinates, it is considered obscuring the gradient coordinates such that the marker cannot verify and mark, and cannot be credited.<br>**ACE**<br>Values of *P* and *Q* calculated correctly with units. | |
| **(d)** | **MMO**<br>Anomalous data/results, if any, must be identified. Appropriate justification must be given. Otherwise comment on absence of anomalous data. | 1 |
| **(e)(i)** | **ACE**<br>Relevant points (with appropriate elaboration) might include:<br>• As *t* measured gets progressively less as $N_B - N_A$ increases, the percentage uncertainty of *t* will increase significantly.<br>• Friction between the hooks and thread prevents the cases from moving smoothly, leading to incorrect *t* being measured.<br>As % error in *h* is significantly smaller than % error in *t*, discussion of any error in *h* is not considered creditworthy. | 1 |
| **(e)(ii)** | **ACE**<br>Relevant points (with appropriate elaboration) might include:<br>• Increase the height *h* through which case B falls to increase the time *t* OR use data logger with light gates to reduce the uncertainty in the experiment.<br>• Use a fishing line instead of the thread or a pulley instead of the hook to reduce friction or other similar arguments. | 1 |
| **(c)** | **P**<br>Use pulleys instead of hooks<br><br>**P**<br>Use slotted masses instead of paper clips<br><br>**P**<br>Use light gates connected to datalogger instead of stopwatch | 3 |

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**2** In this experiment, you will compare the diameters of objects seen through air with their apparent diameters seen through water and glass.

**(a)** The external diameter $d_1$ of the test-tube is shown in Fig. 2.1.

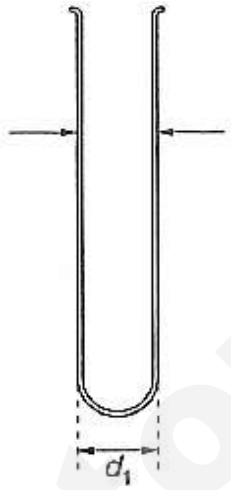


**Fig. 2.1**

Measure and record $d_1$, in the table using the 30cm plastic ruler, the vernier caliper and the micrometer screw gauge.

**Solution:**

**Range accepted : 1.5 ≤ $d_1$ ≤ 1.7 cm**

30cm plastic ruler, $d_1$ = ……**1.6 cm (1 d.p.)**……

**Range accepted : 1.50 ≤ $d_1$ ≤ 1.70 cm**

vernier caliper, $d_1$ = ……**1.62 cm (2 d.p.)**……

**Range accepted : 15.00 ≤ $d_1$ ≤ 17.00 mm**

- Include unit

micrometer screw gauge, $d_1$ = ……**16.05 mm (2 d.p.)**…… [3]

**(b) (i)** Fill the beaker with water to about the half way mark and stand the test-tube upside down in the **centre** of the beaker of water as shown in Fig. 2.2.

Look through the glass and water at the test-tube.

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The external diameter $d_2$ of the test-tube as **seen through the water and glass** is shown in Fig. 2.2.

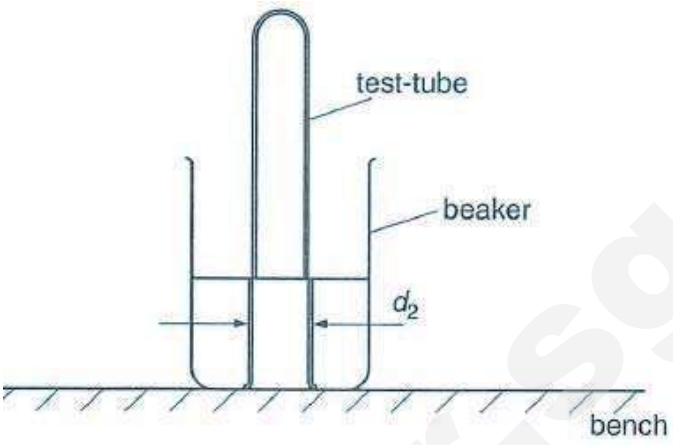


**Fig. 2.2**

**(ii)** 1. Measure and record $d_2$ using only **one** of the measuring instruments.

**Marking point:**

- Acceptable range between 1.8 cm to 2.2 cm
- Include unit
- $d_2$ larger than $d_1$

$d_2$ = ..... **2.0 cm (1 d.p.)** ..... [1]

2. Justify which measuring instrument you used to measure $d_2$.

**The 30 cm plastic ruler because the uncertainty in this measurement is more than 0.1 cm.**

..... [1]

**(iii)** Remove the test-tube from the beaker and place the test-tube back into the basket.

**(c) (i)** Use **one** of the measuring instruments to measure and record the external diameter of $d_1$ of the measuring cylinder.

- Can use any **one** of the measuring instruments to measure $d_1$.
  - Acceptable range between 2.8 cm to 3.2 cm
  - Include unit and appropriate d.p.

$d_1$ = ..... **3.1 cm** .....


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**(ii)** Place the measuring cylinder upright into the beaker, and measure and record $d_2$ using the same measuring instrument as in **(b) (ii)**.

**Solution:**

- Use **30 cm plastic ruler** to measure $d_2$
- Testing on the skill of using appropriate instrument for measurements.

**Marking Point:**

- Acceptable range between 3.5 cm to 4.3 cm
- Same precision as b(ii) and $d_2$ larger than $d_1$

$d_2$ = ..... **4.0 cm** ..... [1]

**(iii)** Determine the percentage uncertainty in your value of $d_2$ for the measuring cylinder.

**Solution:**

$\Delta d_2 = 0.2$ to $0.4$ cm ( 0.1 cm is too small)

$$\% \text{ uncertainty} = \frac{0.2}{4.0} \times 100\% = 5.0\ \% \text{ to } 10\ \%$$

**Marking Point**

- **$\Delta d_2 \geq 0.2$ cm (ecf from (c)(ii) for 0.02 cm for vernier caliper or 0.02 mm for micrometer screw gauge.)**
- **Final answer to 1 or 2 s.f.**

percentage uncertainty in $d_2$ = ..... **5.0 %** ..... [1]

**(d)** A student suggested that $d_1$ and $d_2$ are related by the expression

$$d_2 = kd_1$$

where $k$ is a constant.

**(i)** Use your values from **(a)**, **(b)(ii)**, **(c)(i)**, and **(c)(ii)** to determine two values of $k$.

**Solution:**

$$d_2 = kd_1$$

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$$k = \frac{d_2}{d_1}$$

First value of *k*,

$$k_1 = \frac{2.0}{1.6} = 1.25$$

Second value of *k*

$$k_2 = \frac{4.0}{3.1} = 1.29$$

first value of *k* = ..... **1.25** .....

second value of *k* = ..... **1.29** ..... [1]

**(ii)** Do the results of your experiment support the suggested relationship? Justify your answer by referring to your value in **(c)(iii).**

**Solution:**

The percentage difference between the two values of *k*,

$$\% = \frac{k_2 - k_1}{k_1} \times 100\% = \frac{1.29 - 1.25}{1.25} \times 100\% = 3.2\%$$

Since the percentage difference of the two values of *k* obtained is 3.2 % which is less than the **percentage uncertainty in (c)(iii),** the two values of *k* obtained are similar within experimental confidence. As such, my results support the suggested relationship.

.....

..... [2]

**(e)** The external diameter $d_2$ of the test-tube as seen through the water and glass is thought to be larger than the external diameter $d_1$ as seen through air. The magnification factor, *k* is proposed as,

$$k = \frac{d_2}{d_1}$$

It is suggested that the magnification factor of the setup in Fig. 2.2 depends on the internal diameter of the beaker of water.

Plan an investigation to determine the internal diameter of the beaker for which the magnification factor equal to 2.

You are provided with several beakers, each with uniform internal diameter.

Your account should include:

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- your experimental procedure
- the table of measurements with appropriate units,
- how you determine the internal diameter of the beaker for which the magnification factor is 2.

**Solution:**

1. Measure the **internal diameter *s* of the beaker using the back end of a vernier caliper [1]** and take repeated measurements.
2. Fill the beaker with the smallest internal diameter with water until it is half full.
3. Perform the same experiment as per (a) and (b)(i),(ii) to measure the external diameter of a test tube in the first beaker with the smallest internal diameter. **Measure $d_1$ and $d_2$ using a 30 cm plastic ruler [1]** as per (a) and (b)(i)(ii).
4. Calculate the magnification factor by k = $d_2$ / $d_1$.
5. Repeat steps 1 to 3 using the several beakers with different internal diameter for at least 5 more sets of *s* and *k*.
6. **The table of measurements are as follow: [1]**

| $s_1$ / cm | $s_2$ / cm | <s> / cm | $d_1$ / cm | $d_2$ / cm | *k* (no units) |
|---|---|---|---|---|---|
| | | | | | |

7. **Plot a graph of internal diameter <s> against *k*.**
8. **Read off the position where *k* is equal to 2 and identify the internal diameter of the beaker that gives the result. [1]**

**Do not accept by trial and error to get the diameter. Use a graphical method to determine.**

……

……

…… [4]

**[Total: 14 marks]**

**3** In this experiment, you will investigate the resistance of a wire coil.

**(a)** You have been provided with a coil as shown in Fig. 3.1.

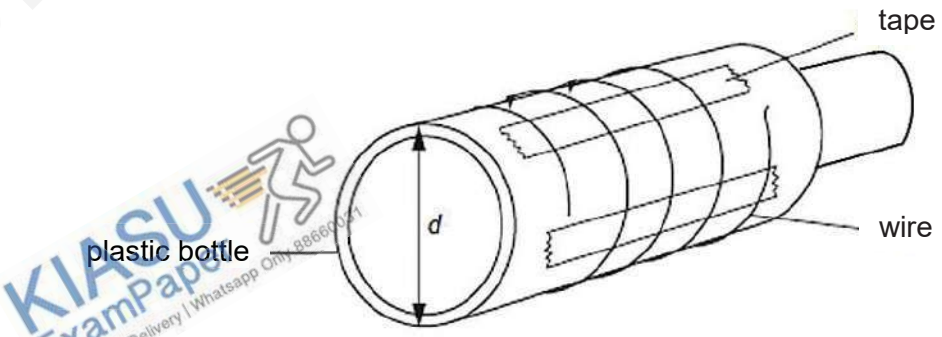


**Fig. 3.1**

**(i)** Measure and record the diameter *d* of the plastic bottle.

- Repeat readings, *d* = (2.66 + 2.65 + 2.65) / 3 = 2.65 cm
- Acceptable range between 2.45 cm to 2.75 cm
- Correct units and 2 to 3 d.p. in cm

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$d$ = **2.65 cm (2 d.p.)** [1]

**(ii)** Estimate the absolute uncertainty in your value of $d$.

- Acceptable range between 0.01 cm to 0.04 cm

uncertainty of $d$ = **0.02 cm** [1]

**(iii)** Estimate the length $x$ of wire in a single turn.

$x = \pi d = \pi \times 2.65 = 8.33$ cm

$x$ = **8.33 cm** [1]

**(b)** Set up the circuit as shown in Fig. 3.2, and clip the contacts at both ends of the coil. Set the ammeter to 10 A DC and the voltmeter to 20 V DC.

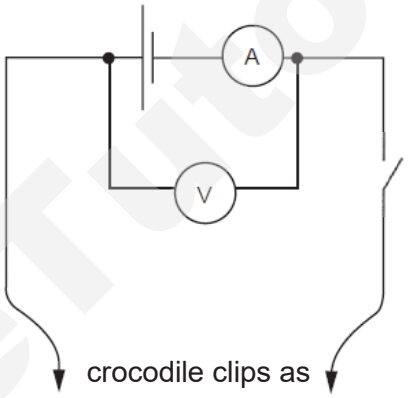


**Fig. 3.2**

**(i)** Record the number of turns $n$ between the contacts.

Close the switch. Measure and record voltage $V$ and current $I$.

**Range accepted : 1.95 V ≤ $V$ ≤ 2.20 V**

**Range accepted : 0.28 A ≤ $I$ ≤ 0.35 A**

$n$ = **4**

$V$ = **2.14 V (2 d.p.)**

$I$ = **0.31 A (2 d.p.)** [2]

**(ii)** Determine the resistance $R$ between the contacts.

$R = V / I = 2.14 / 0.31 = 6.9\ \Omega$

- Acceptable range between 5.6 Ω to 7.9 Ω


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$R$ = **6.9 Ω** ..... [1]

**(ii)** The resistance per metre $\mu$ of the wire is given by

$$\mu = \frac{R}{xn}$$

Use your results to determine a value for $\mu$.

$\mu$ = 6.9 / (0.0833 × 4) = 20.7 Ω m$^{-1}$

- Acceptable range between 17.0 Ω m$^{-1}$ to 24.0 Ω m$^{-1}$

$\mu$ = **20.7 Ω m$^{-1}$** ..... [2]

**[Total: 8 marks]**

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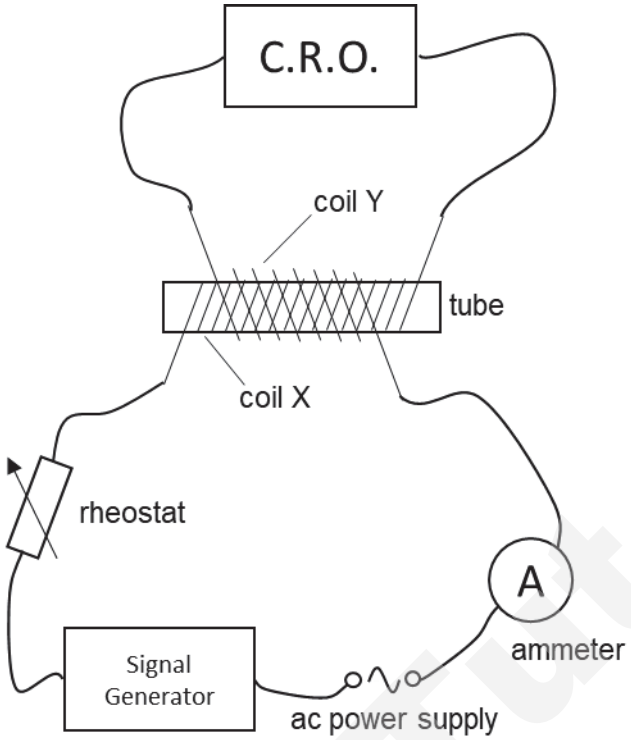
| 4 | Suggested answer | Max. Mark |
|---|---|---|
| | **Suggested diagram:**<br>  <br> | |
| | **Design**<br>**A1** labelled diagram with workable arrangement: CRO, ammeter, ac power supply, signal generator, rheostat, coil X and coil Y<br>**A2** coil X connected to rheostat, signal generator, ac power supply, ammeter in series, and coil Y connected to CRO in series | 2 |
| | **Procedure**<br>**B1 Construction of coils X and Y**<br>1. Measure out a fixed length of wire and wind tightly around an insulating core. Leave sufficient length of wire at both ends of coil to serve as contact leads. This is coil X.<br>2. Measure out another fixed length of wire and wind tightly around coil X. Leave sufficient length of wire at both ends of coil to serve as contact leads. This is coil Y.<br>3. Connect both coil X and Y as described above **(Design)**.<br>**B2 Determination of raw data**<br>4. Increase current passing through coil X slowly to obtain preliminary readings to ensure induced emf in coil Y is sufficiently large to be recorded on CRO<br>5. Use CRO to determine period/frequency or read off signal generator<br>6. Keep current constant in coil X, by adjusting signal generator/use of rheostat.<br>**B3 Workable procedure**<br>7. For effect of *f* on *V*, fixed length and number of turns of wire for coil X, but vary the frequency through a signal generator. (Frequency of ac current should not be varied directly from ac power supply) Repeat to obtain six different sets of *V* and *f*<br>**B4 Workable procedure** | 4 |

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| | | |
|---|---|---|
| | 8. For effect of $N$ on $V$, fixed length of wire for coil X (i.e. will have longer contact leads on both ends of coil X), to keep resistance constant, but vary the number of turns. Repeat to obtain six different sets of $V$ and $N$ | |
| | **Safety and Analysis**<br>**C1** Reference to hot coils – switch off when not in use/use gloves/do not touch coils. Must refer to hot coils.<br>**C2** Plot graph of lg $V$ against lg $f$, where $p$ is gradient and lg $k$ + $q$ lg $N$ is vertical intercept.<br>**C3** Plot graph of lg $V$ against lg $N$, where $q$ is gradient and lg $k$ + $p$ lg $f$ is vertical intercept<br>**C4** Determination of k by choosing a set of data from experiment and using lg $k$ = lg $V$ – lg $f$ – $q$ lg $N$ | 4 |
| | **Detail**<br>**D1/2**<br>1. Use insulated wire for coils<br>2. Use of adhesive tapes to keep turns of wire in place<br>3. Use large current in coil X/large number of coils on coil Y (to increase emf)<br>4. Keep coil Y and coil X in same relative positions<br>5. Use iron core (to increase emf)<br>6. Detail on measuring emf e.g. height × y-gain, adjust waveform such that max and min peaks within the screen<br>7. Detail on measuring frequency from CRO to determine period and hence $f$, e.g. width × time base, adjust waveform such that at least one complete cycle can be observed within the screen<br>8. Use of ammeter/ CRO and resistor to check current is constant<br>9. Ammeter to be set at ac function<br>10. Avoid other nearby alternating magnetic fields<br>11. Ensure complete rounds of coil<br>12. Ensure no kinks in coils<br>Other possible good physics suggestions.<br>Do not allow vague computer methods. | 2 |
| | | |

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| Class | Index Number | Name |
|---|---|---|
| 18S | | |

**ST. ANDREW'S JUNIOR COLLEGE**
**JC 2 2019**
**Preliminary Examination**

**PHYSICS, Higher 2** **9749/01**

Paper 1 Multiple Choice **20th September 2019**
**1 hour**

Additional Materials: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil..
Do not use staples, paper clips, glue or correction fluid.
Write your name, index number and Civics Group the Answer Sheet in the spaces provided.

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

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

| For Examiner's Use | |
|---|---|
| Total | / 30 |

This document consists of **15** printed pages including this page.

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## Data

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## Formulae

uniformly accelerated motion, $s = u\,t + \frac{1}{2}\,a\,t^2$

$v^2 = u^2 + 2\,a\,s$

work done on/by a gas, $W = p\,\Delta V$

hydrostatic pressure, $p = \rho\,g\,h$

gravitational potential, $\phi = -\dfrac{Gm}{r}$

temperature, $T/\mathrm{K} = T/{}^{\circ}\mathrm{C} + 273.15$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

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

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

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

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

electric current $I = Anvq$

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

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \dfrac{Q}{4\pi\varepsilon_0 r}$

alternating current/voltage, $x = x_o \sin \omega t$

magnetic flux density due to a long straight wire, $B = \dfrac{\mu_0 I}{2\pi d}$

magnetic flux density due to a flat circular coil, $B = \dfrac{\mu_0 N I}{2r}$

magnetic flux density due to a long solenoid, $B = \mu_0 n I$

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

decay constant, $\lambda = \dfrac{\ln 2}{t_{1/2}}$

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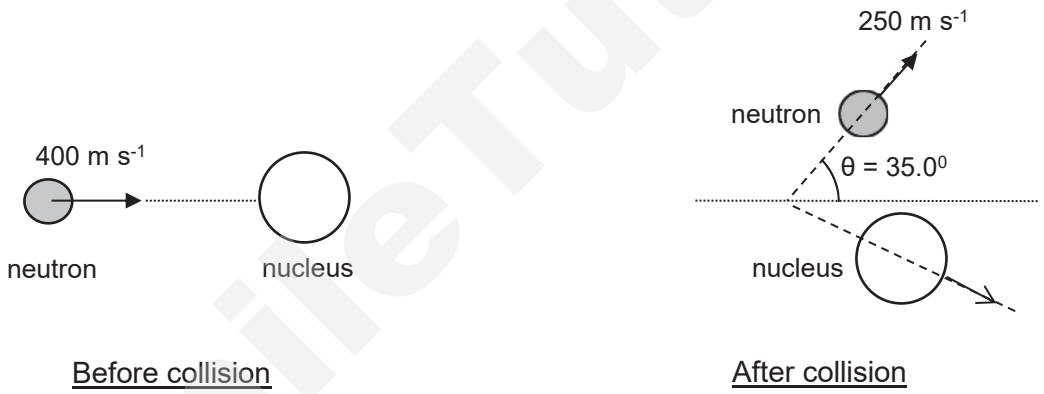
## Answer all questions.

**1** An engine part of mass 0.51 kg is placed on four different balances. For each balance the reading is taken five times. The table shows the values obtained together with the means.

Which balance has the smallest systematic error but is not very precise?

| Set | Reading / kg | | | | | Mean / kg |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| A | 0.51 | 0.51 | 0.52 | 0.54 | 0.52 | 0.518 |
| B | 0.49 | 0.50 | 0.51 | 0.48 | 0.49 | 0.494 |
| C | 0.56 | 0.41 | 0.52 | 0.54 | 0.54 | 0.512 |
| D | 0.44 | 0.49 | 0.46 | 0.43 | 0.41 | 0.446 |

**2** The figure below shows the speed and direction of a neutron just before and after collision with a nucleus.




Before collision

After collision

The magnitude of change in velocity of the neutron in m $s^{-1}$ is

**A** 150 **B** 242 **C** 332 **D** 622

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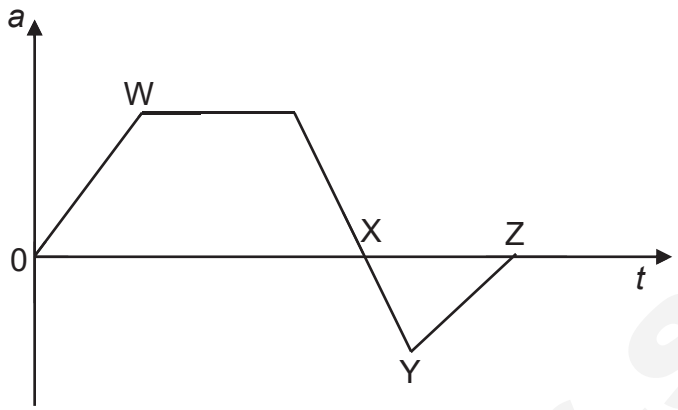
**3** A car is travelling along a straight road. The graph shows the variation with time $t$ of its acceleration $a$ during part of the journey.

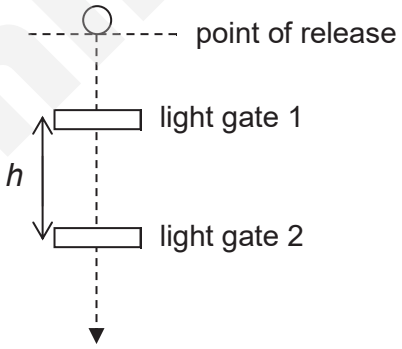



At which points on the graph does the car have its greatest velocity and greatest displacement?

| | Greatest velocity | Greatest displacement |
|---|---|---|
| **A** | W | X |
| **B** | W | Z |
| **C** | X | Y |
| **D** | X | Z |

**4** To determine the acceleration of free fall, a steel ball is dropped above two light gates as shown.

The ball passes light gate 1 and 2 at times $t_1$ and $t_2$ after release.




What is the acceleration of free fall?

**A** $\dfrac{2h}{(t_2 - t_1)}$ **B** $\dfrac{2h}{(t_2 - t_1)^2}$ **C** $\dfrac{2h}{(t_2^2 - t_1^2)}$ **D** $\dfrac{2h}{\left(\dfrac{t_2 + t_1}{2}\right)^2}$

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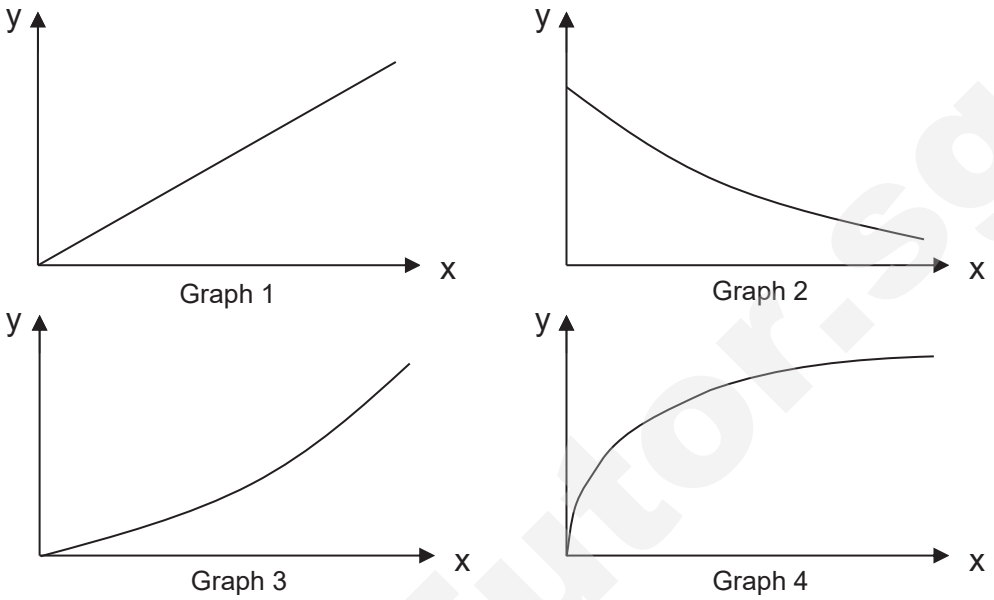
**5** An object is accelerated from rest by a constant force. The process is observed in an experiment.

Which of the following graphs correctly shows the variation of the displacement with time squared, and the variation of the momentum with displacement of the object?




| | displacement vs $(\text{time})^2$ | momentum vs displacement |
|---|---|---|
| **A** | Graph 4 | Graph 1 |
| **B** | Graph 3 | Graph 2 |
| **C** | Graph 2 | Graph 3 |
| **D** | Graph 1 | Graph 4 |

**6** A tennis ball of mass 0.060 kg, initially moving at 45 m $s^{-1}$, is struck by a racket exerting an average force of 95 N in the opposite direction for 70 ms.

What is the speed of the ball just after it leaves the racket?

**A** 9.4 m $s^{-1}$ **B** 36 m $s^{-1}$ **C** 66 m $s^{-1}$ **D** 156 m $s^{-1}$

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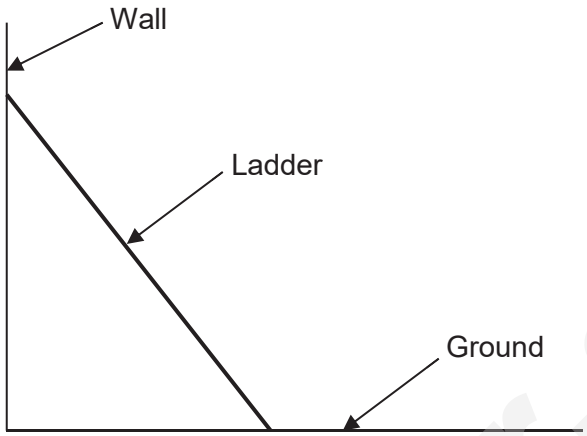
**7** A ladder is placed between a vertical wall and horizontal ground. The wall and ground can be either smooth or rough.



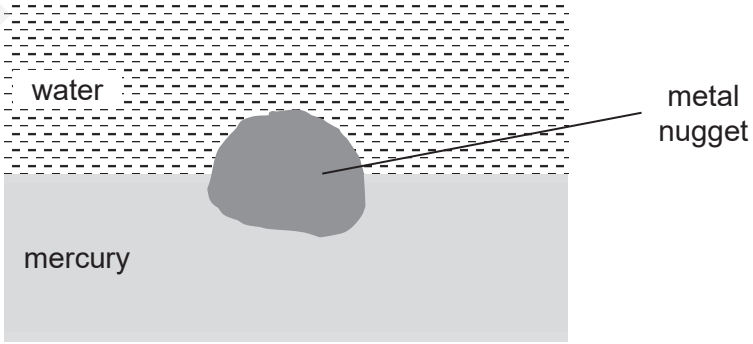

The table below shows the various combinations of roughness and smoothness for the two surfaces.

| | **Wall** | **Ground** |
|---|---|---|
| (i) | Rough | Smooth |
| (ii) | Smooth | Rough |
| (iii) | Rough | Rough |

For which of the options below would the ladder be in static equilibrium?

**A** (iii) only
**B** (i) and (iii) only
**C** (ii) and (iii) only
**D** (i), (ii) and (iii) only

**8** A metal nugget floats in between some water and mercury. The densities of the metal nugget, mercury and water are 7900 kg $m^{-3}$, 13600 kg $m^{-3}$ and 1000 kg $m^{-3}$ respectively.




What is the ratio of the volume of the nugget submerged in water to that in mercury?

**A** 0.541 **B** 0.826 **C** 0.924 **D** 1.21

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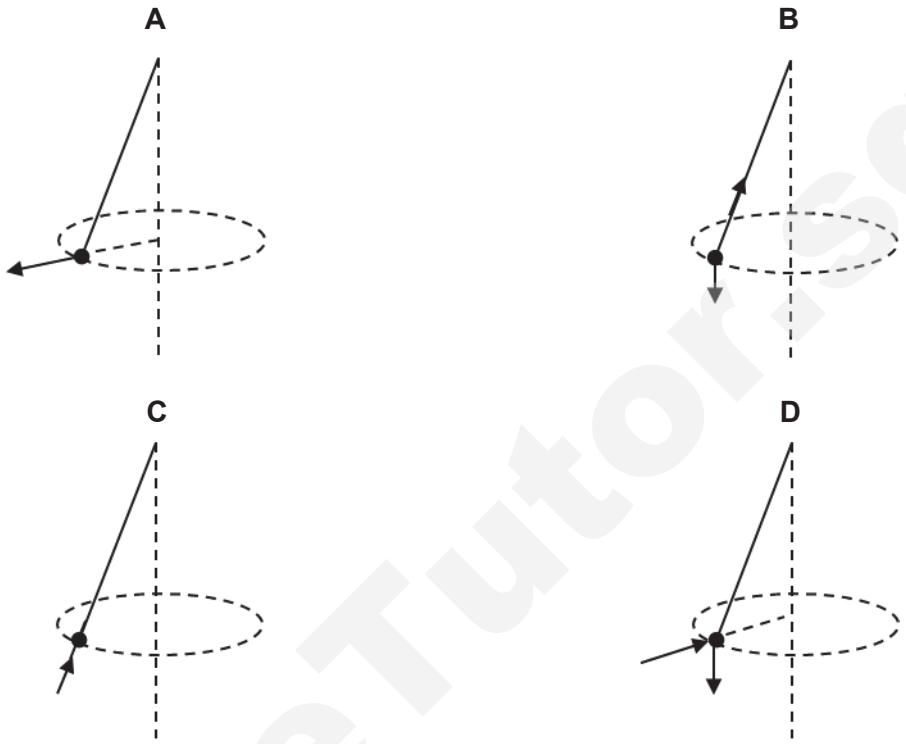
**9** A mass on the end of a string is set in motion such that it describes a uniform circular motion in a horizontal plane.

Which of the four diagrams accurately portrays all the forces, represented by arrows, acting on the mass at an instant in such a motion?




**10** When at the surface of the Earth, a satellite has weight $W$ and gravitational potential energy $U$. It is projected into a circular orbit whose radius is equal to twice the radius of the Earth.

Which of the following shows correctly the changes to the weight of the satellite and to its gravitational potential energy?

| | Weight, $W$ | Gravitational potential energy, $U$ |
|---|---|---|
| **A** | becomes $W/2$ | decreases by $U/2$ |
| **B** | becomes $W/4$ | increases by $U/2$ |
| **C** | remains $W$ | increases by $U$ |
| **D** | becomes $W/4$ | decreases by $U/2$ |

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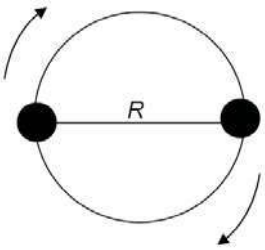
**11** A binary star system, with two stars of the same mass $M$, moves in circular orbit as shown below.




Which expression correctly gives the period of rotation of the system if they have the same mass?

**A** $\sqrt{\frac{4R^3\pi^2}{GM}}$ **B** $\sqrt{\frac{2R^3\pi^2}{GM}}$

**C** $\sqrt{\frac{4R^3\pi^2}{GM^2}}$ **D** $\sqrt{\frac{4R^2\pi^2}{GM}}$

**12** A small piece of metal A, of mass $m$, at 0 ºC, is placed into a hole in a block of metal B, of mass $4m$, at 100 ºC. The equilibrium temperature is 75 ºC.

Assuming that there is no heat loss to the surroundings, the ratio of the specific heat capacity of A to the specific heat capacity of B is

**A** $\frac{1}{4}$ **B** $\frac{1}{3}$ **C** $\frac{3}{4}$ **D** $\frac{4}{3}$

**13** Two containers of volumes 4.0 $m^3$ and 6.0 $m^3$ contain ideal gases at pressures of 100 Pa and 50 Pa respectively. Their temperatures are equal. The containers are joined by a tube of negligible volume so that the molecules can move from one container to the other with no change in temperature.

What is the final pressure of the gases?

**A** 70 Pa **B** 75 Pa **C** 80 Pa **D** 150 Pa

**14** The rise and fall of water level in a harbour is simple harmonic with a period of 12.5 hours. The depth of water varies between 1.0 m at low tide and 3.0 m at high tide. A boat which requires a minimum depth of water of 1.5 m approaches the harbour at low tide.

How long will the boat have to wait before entering the harbour?

**A** 1.0 hours **B** 1.1 hours **C** 2.0 hours **D** 2.1 hours

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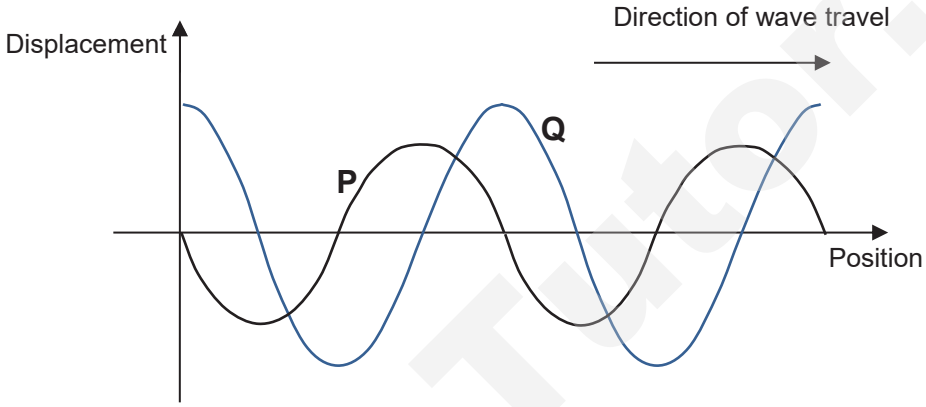
**15** A simple harmonic oscillator has an amplitude of 40.0 mm and a frequency of 120 Hz.

What is the maximum magnitude of acceleration and the maximum speed?

| | Maximum acceleration / m $s^{-2}$ | Maximum speed / m $s^{-1}$ |
|---|---|---|
| **A** | 1.14 x $10^4$ | 30.1 |
| **B** | 1.14 x $10^4$ | 15.1 |
| **C** | 2.27 x $10^4$ | 30.1 |
| **D** | 2.27 x $10^4$ | 15.1 |

**16** Two waves **P** and **Q** are moving towards the right as shown in the figure below.




Which of the following correctly describes the phase difference between the two waves?

**A** **P** lags **Q** by $\frac{\pi}{4}$ radians.

**B** **P** leads **Q** by $\frac{\pi}{4}$ radians.

**C** **P** lags **Q** by $\frac{3\pi}{2}$ radians.

**D** **P** leads **Q** by $\frac{3\pi}{2}$ radians.

**17** A spy satellite orbits the Earth at a height of 200 km and carries out surveillance with a telescopic camera having a lens diameter of 35 cm. If the observations are made using light of wavelength 550 nm, the separation of two small objects on the Earth's surface that are just resolved is

**A** 0.31 m **B** 3.1 m **C** 5.6 m **D** 10.8 m

**18** A beam of monochromatic light of wavelength 600 nm is incident normally on a diffraction grating that has 3.0 x $10^5$ lines per metre. Not counting the 'straight-through' image, the maximum number of diffracted images of the slit visible to the observer is

**A** 5 **B** 6 **C** 10 **D** 11

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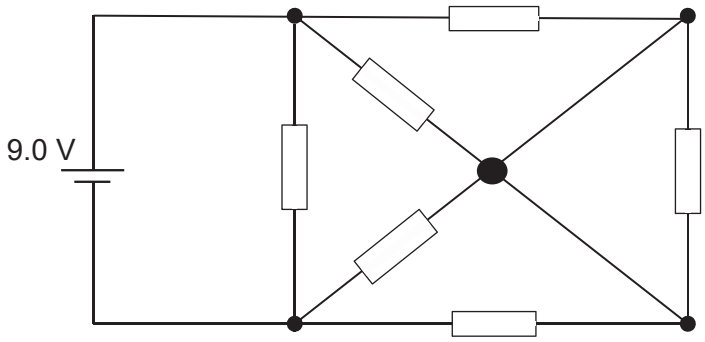
**19** A cell of e.m.f. 9.0 V with negligible internal resistance is connected to 6 identical resistors, each of 10.0 Ω as shown below.

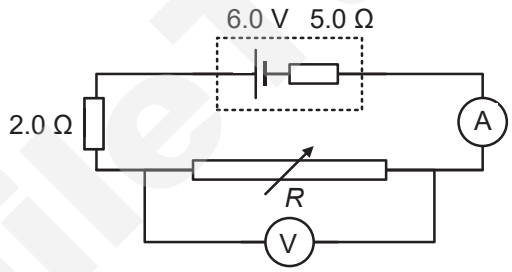



What is the current flowing through the cell in diagram above?

**A** 1.35 A **B** 1.80 A **C** 4.00 A **D** 5.45 A

**20** A battery of e.m.f. 6.0 V, and internal resistance, 5.0 Ω is connected in series to a fixed resistor of 2.0 Ω and a variable resistor *R* which has resistance between 0 Ω and 10 Ω, as shown below. The ammeter and the voltmeter are both ideal.

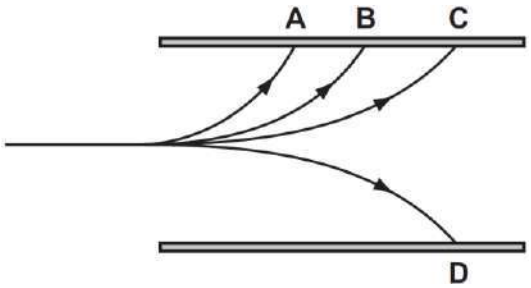
Determine the maximum power delivered to the variable resistor R.




**A** 1.08 W **B** 1.29 W **C** 2.08 W **D** 7.20 W

**21** A single proton travelling with a constant horizontal velocity enters a uniform electric field between two parallel charged plates. In the diagram, **B** shows the path taken by the proton.

Which path is taken by an alpha particle that enters the electric field at the same point but at half the velocity as the proton?

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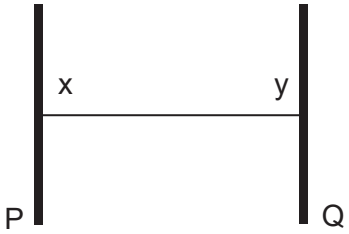
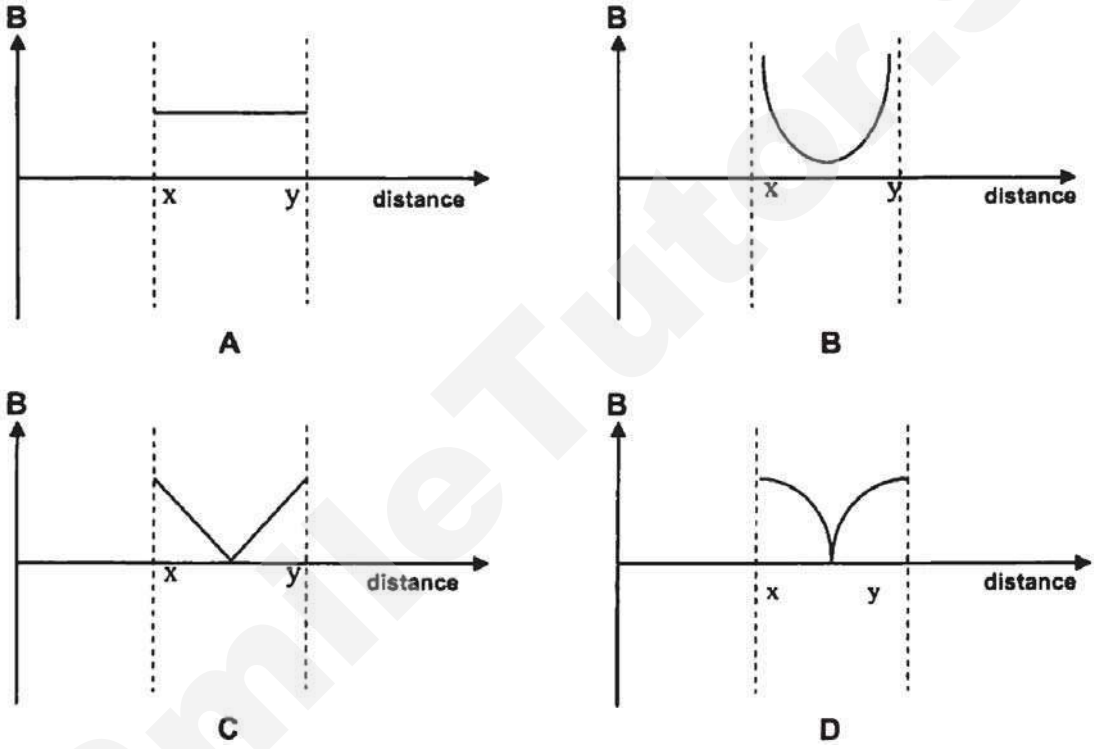
**22** Two long straight parallel wires P and Q carry equal currents in opposite directions as shown. xy is a line perpendicular to the wires.




Which of the graph best shows the variation of the magnitude of the magnetic flux density B along the line xy?

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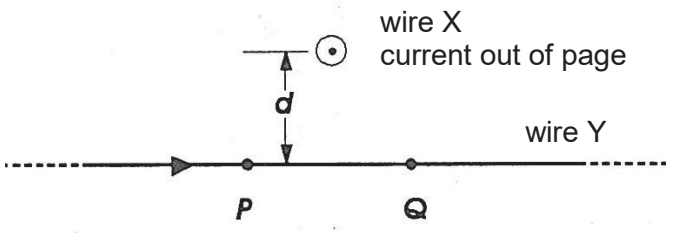
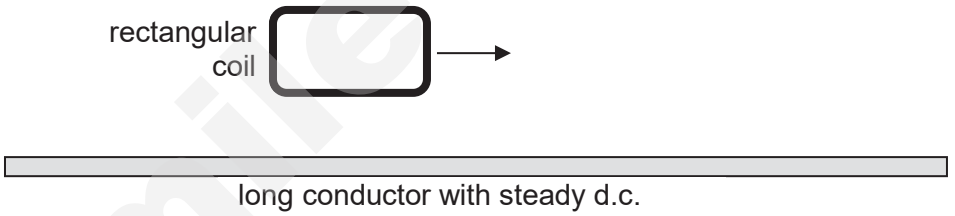
**23** Two long straight wires X and Y are placed perpendicular to each other at a distance *d* apart. A current flows out of the page in wire X while a current flows from left to right in wire Y.

What are the directions of the forces acting on wire Y at points P and Q due to the magnetic field produced by wire X?




| | force at P | force at Q |
|---|---|---|
| **A** | out of page | into page |
| **B** | into page | out of page |
| **C** | towards X | away from X |
| **D** | towards X | towards X |

**24** 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 flows anti-clockwise in the coil.
**D** The magnitude of the induced current in the coil varies proportionally to the speed at which the coil is moving.

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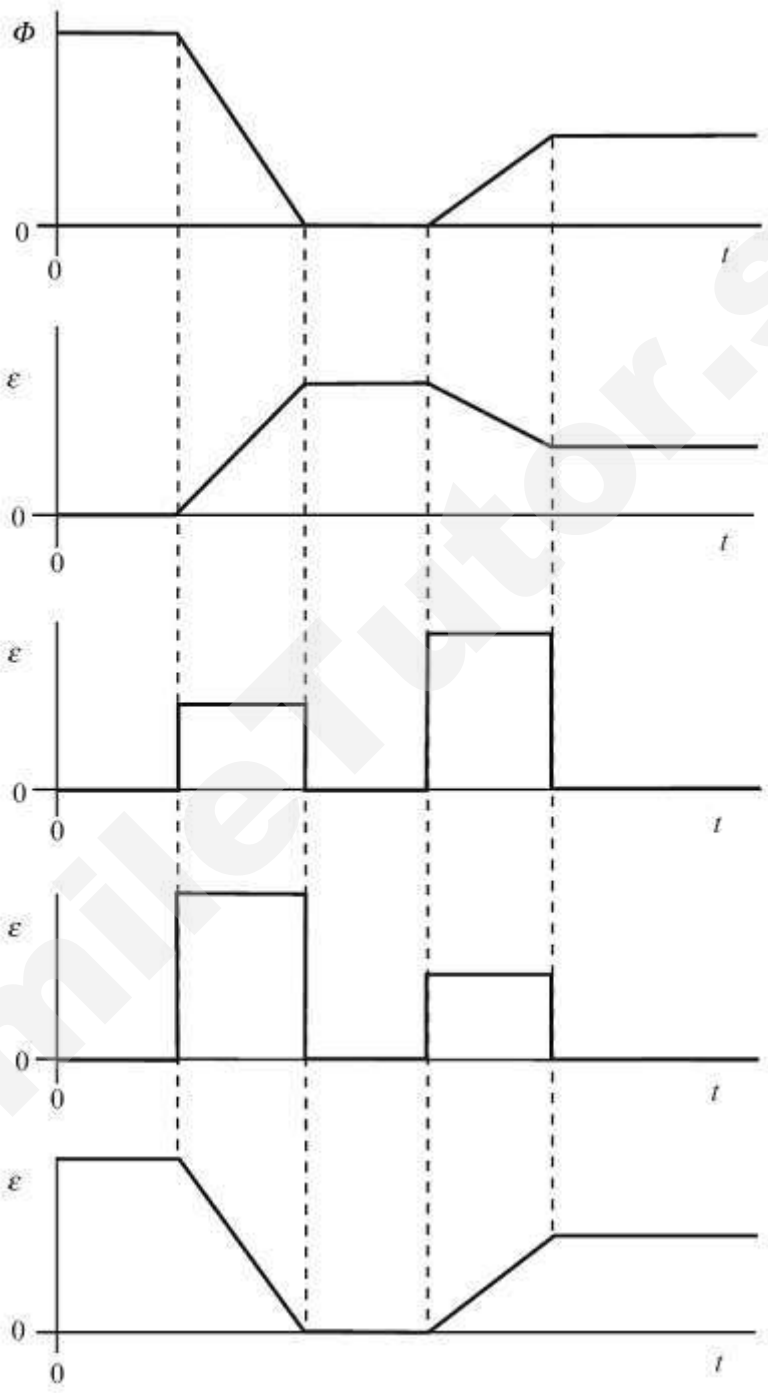
**25** The magnetic flux, $\Phi$, through a coil varies with time, $t$, as shown.

Which one of the following graphs, A to D, best represents how $\varepsilon$, the magnitude of the induced e.m.f. varies with time?

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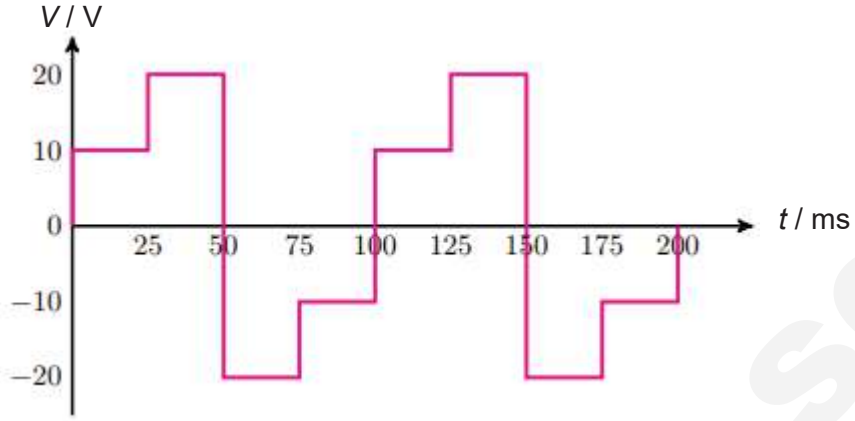
**26** Determine the root-mean-square value of the signal below.




**A** 0 **B** 10.0 **C** 15.8 **D** 18.6

**27** In a photoelectric effect experiment, light of wavelength 450 nm is incident on a material.

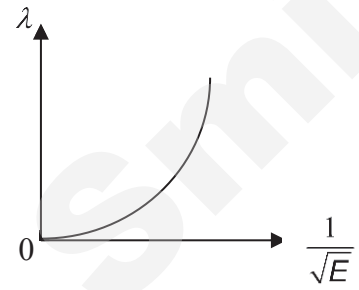
What is the increase in the stopping potential when light of 400 nm is now used?

**A** 0.050 V **B** 0.10 V **C** 0.20 V **D** 0.35 V

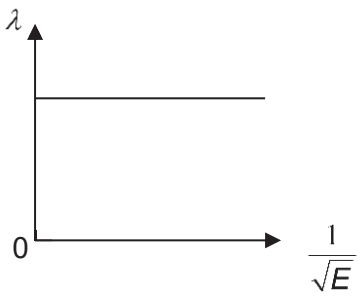
**28** An atom with kinetic energy $E$ has a de Broglie wavelength of $\lambda$.

Which of the following graphs correctly represents the relationship between $\lambda$ and $E$?

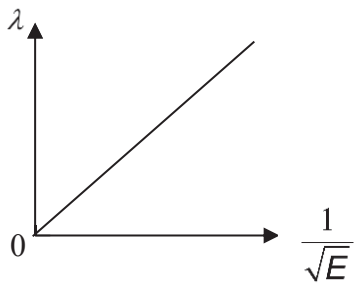
**A**



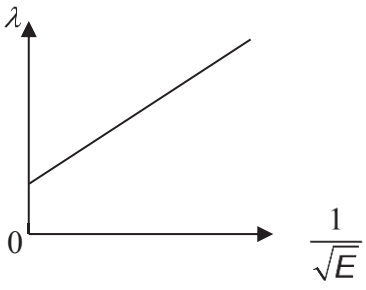

**B**




**C**




**D**

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**29** Which of the following statements is / are true?

Statement 1**:** The greater the binding energy of a nucleus, the more stable it is.

Statement 2: When a stationary nucleus undergoes a $\beta$ decay, the products always move off in opposite directions so as to conserve linear momentum.

Statement 3: Although the half-life of a radioactive substance is unaffected by changes in pressure, temperature and other external factors, we can still change the half-life by allowing the substance to react chemically to produce a new radioactive compound.

**A** 1 only
**B** 1 & 2
**C** All of the statements
**D** None of the statements

**30** In a cancer therapy unit, patients are given treatment from a certain radioactive source. This source has a half-life of 4 years. A particular treatment requires 10 minutes of irradiation when the source is first used.

How much time is required for this treatment, using the same source, 2 years later?

**A** 7 minutes
**B** 10 minutes
**C** 14 minutes
**D** 20 minutes

**End of paper**

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| Class | Index Number | Name |
|---|---|---|
| 18S | | |

**ST. ANDREW'S JUNIOR COLLEGE**
**JC 2 2019**
**Preliminary Examination**

**PHYSICS, Higher 2** **9749/02**

Paper 2 Structured Questions **29th August 2019**
**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.
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 | / 10 |
| 2 | / 10 |
| 3 | / 10 |
| 4 | / 10 |
| 5 | / 10 |
| 6 | / 10 |
| 7 | / 20 |
| Total | / 80 |

This document consists of **20** printed pages including this page.

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## Data

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

work done on/by a gas, $W = p\Delta V$

hydrostatic pressure, $p = \rho g h$

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

temperature, $T/\text{K} = T/^{\circ}\text{C} + 273.15$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

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

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

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

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

electric current $I = Anvq$

resistors in series, $R = R_1 + R_2 + ...$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + ...$

electric potential, $V = \frac{Q}{4\pi\varepsilon_0 r}$

alternating current/voltage, $x = x_o \sin \omega t$

magnetic flux density due to a long straight wire, $B = \frac{\mu_0 I}{2\pi d}$

magnetic flux density due to a flat circular coil, $B = \frac{\mu_0 NI}{2r}$

magnetic flux density due to a long solenoid, $B = \mu_0 nI$

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

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

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**1** A boom can be used to assist a person to move heavy loads. A typical arrangement is shown below.

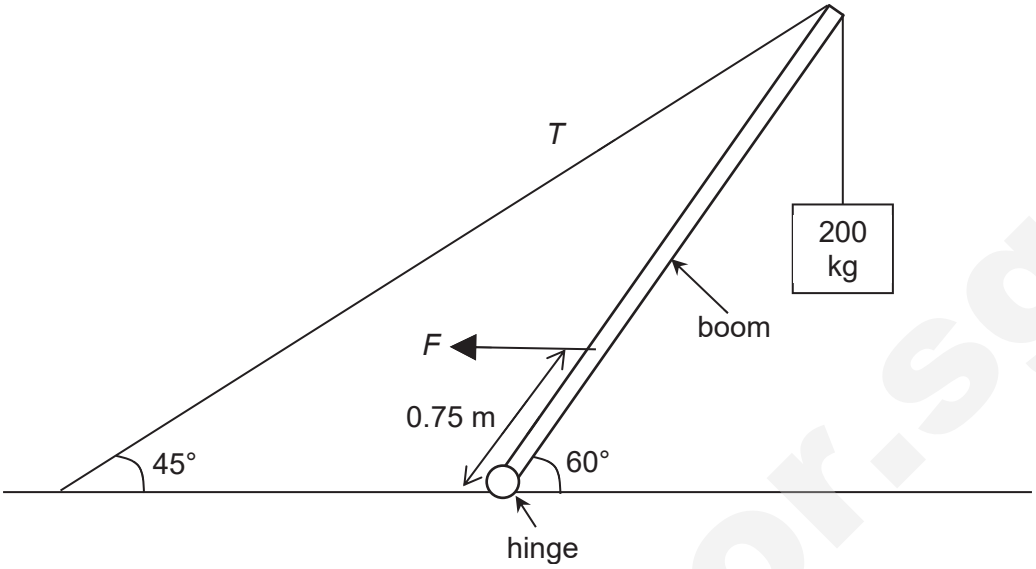


**Fig. 1.1**

The boom is angled at 60° to the horizontal, and a steel cable is attached to the top of the boom and the floor such that the cable makes an angle of 45° to the horizontal, as shown. The uniform boom has a mass of 45 kg and length 3 m.

A human operator exerts a force $F$ = 120 N horizontally at a distance 0.75 m away from the hinge as measured along the boom. The system is in equilibrium.

**(a)** State the conditions for a body to be in static equilibrium.

……..

……. [2]

**(b)** Show that the tension $T$ in the cable connecting from the top of the boom to the floor is 4.1 kN.

[3]

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**(c)** Determine the magnitude and direction of the force exerted by the hinge on the boom.

magnitude of force = …….. N

direction of the force = …… [4]

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**2** **(a)** State Newton's Law of Gravitation.

……

…… [1]

**(b)** Explain why it is incorrect to term $g$ ( = 9.81 N kg$^{-1}$) as 'gravity'.

……

……

…… [2]

**(c)** Determine the Earth's gravitational field strength at a height of 0.12 x $10^6$ m above the Earth's surface. The Earth's radius is taken to be 6.38 x $10^6$ m.

gravitational field strength = …….. N kg$^{-1}$ [3]

**(d)** Explain briefly why an astronaut in a satellite orbiting the Earth at this altitude may be described as weightless.

……

……

…… [2]

**(e)** Explain why the magnitude of the apparent weight of a person is smaller at the equator than at the poles.

……

……

……

…… [2]

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**3** **(a)** State 3 assumptions of the kinetic theory of gases. [3]

**1.** ……..……..

……..……..

**2.** ……..……..

……..……..

**3.** ……..……..

……..……..

**(b)** A cylinder fitted with a frictionless piston contains a fixed mass of Argon, assumed to be ideal. Initially, the gas has a volume of $6.0 \times 10^{-4}$ $m^3$, at a temperature of 300 K and a pressure of $1.0 \times 10^5$ Pa.

Calculate the number of Argon molecules in the cylinder.

number of Argon molecules = …….. [3]

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**(c)** The p-V cycle within a heat engine is a cyclic process characterised by rapid compression of the fuel-air mixture to a higher pressure for greater engine efficiencies.

The cycle uses the following processes

**A → B** **Compression stroke**, an adiabatic compression of air in the cylinder with no fuel added.

**B → C** **Ignition,** heat addition at constant pressure through the introduction of fuel into the compressed air when the fuel-air mixture is ignited.

**C → D** **Expansion (Power) stroke**, isothermal expansion of the hot gases in the cylinder.

**D → A** **Exhaust & Induction strokes**, the ejection of spent, hot gases and the intake of the next air change into the cylinder. The net volume change in this process is zero.

On the Pressure-Volume (p-V) axes below, sketch the graph that represents the heat cycle of the heat engine. The graph should include the labels **A**, **B**, **C** and **D**. [4]




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**4** **(a)** The graphs on Fig. 4.1 show how the resistance of a metal resistor **R** and a thermistor **T** varies when the temperature changes.

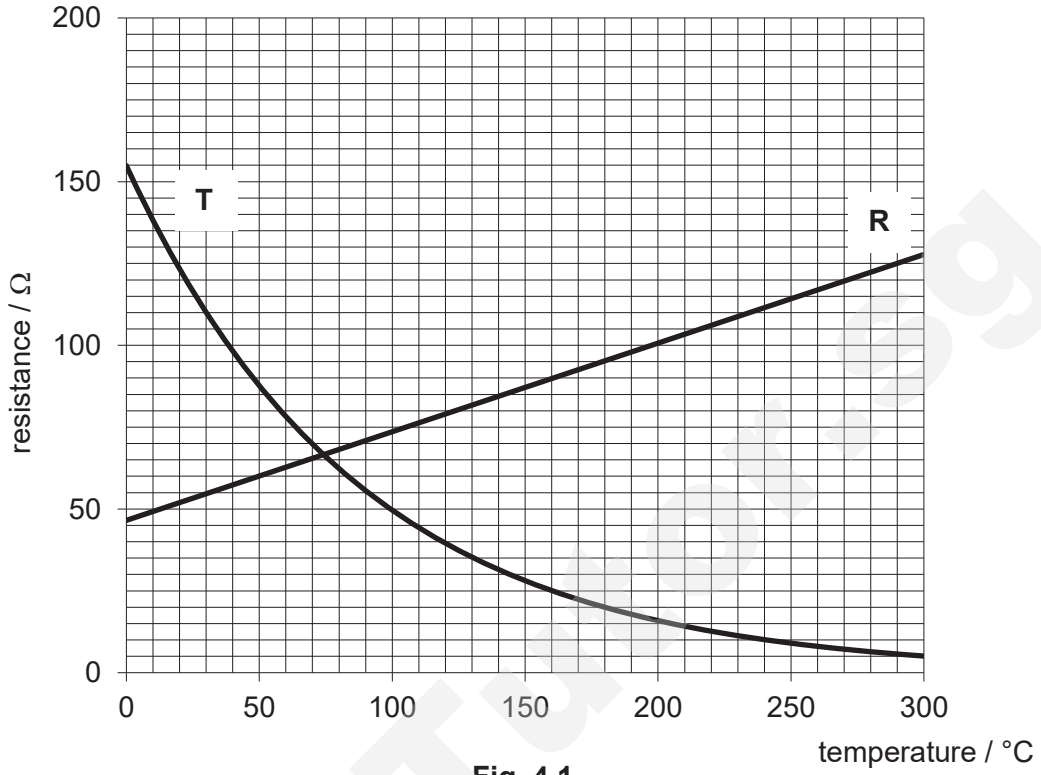


**Fig. 4.1**

The metal resistor **R** and the thermistor **T** are connected in series as shown in Fig. 4.2 together with a battery of negligible internal resistance. **R** and **T** are kept at the same temperature as each other

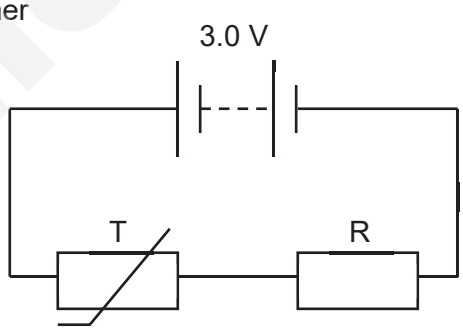


**Fig. 4.2**

**(i)** Determine the current in the circuit shown in Fig 4.2 when the resistance of **R** is twice that of **T**.

current = …….. A [2]

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**(ii)** Describe how the effective resistance of the circuit in Fig 4.2 changes as temperature increases from 0 °C to 75 °C.

……...

…….. [1]

**(iii)** When the temperature is at 30 °C, determine the potential difference across **T**.

potential difference across **T** = …….. V [2]

**(b)** The circuit shown in Fig 4.2 is now connected to a potentiometer as shown in Fig. 4.3.

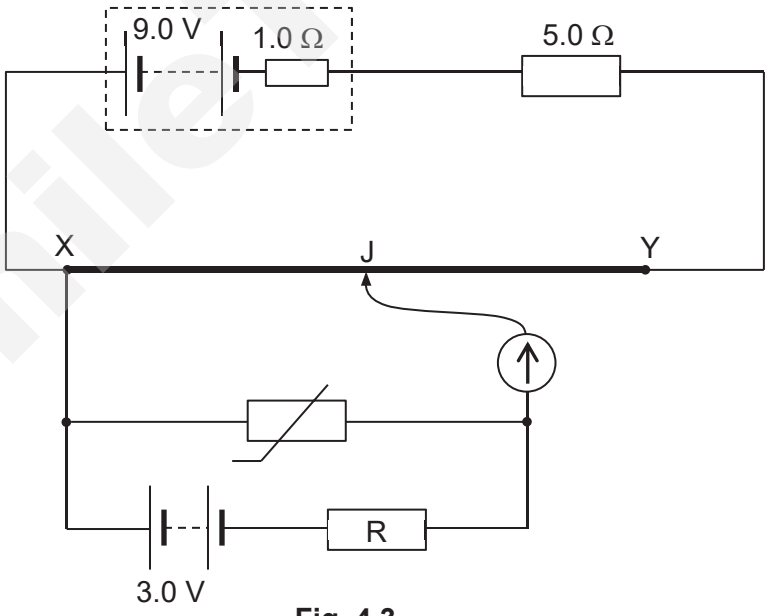


**Fig. 4.3**

The potentiometer has a driver cell of e.m.f. 9.0 V with internal resistance of 1.0 Ω. It is connected in series with a resistor of resistance 5.0 Ω and a uniform resistance wire XY of length 120 cm and radius 0.200 mm. The resistivity of the wire is $1.20 \times 10^{-6}$ Ω m.

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**(i)** Determine the resistance of the wire XY.

resistance of wire XY = …….. Ω [2]

**(ii)** At a temperature of 30 °C, determine the balance length XJ where there is no deflection in the galvanometer.

balance length XJ = …….. m [2]

**(iii)** Explain what will happen to the position of the balance point J if the temperature is at 75 °C.

……...

…….. [1]

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**5** **(a)** Fig. 5.1 below shows an a.c. waveform displayed on a cathode ray oscilloscope screen. The time base of the oscilloscope is set at 1.5 ms per division and the y-gain at 1.5 V per division.

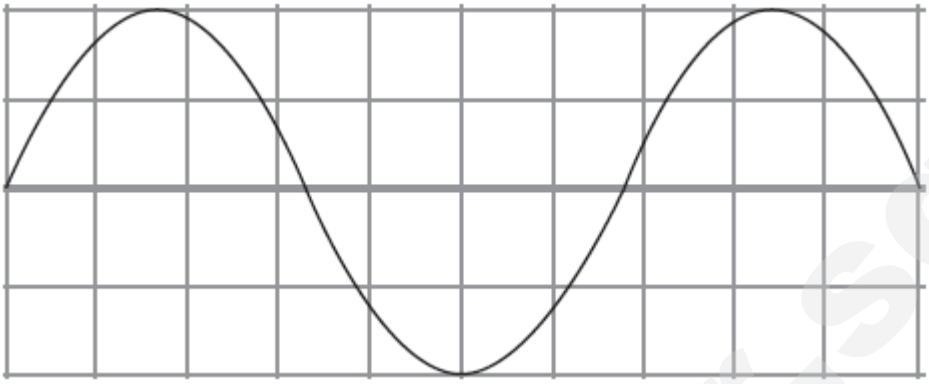

**Fig. 5.1**

**(i)** Determine the frequency and root-mean-square voltage.

frequency = …….. Hz [2]

$V_{rms}$ = …….. V [2]

**(ii)** Draw on Fig. 5.1 a second waveform that is half the frequency and full-wave rectified. [2]

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**(b)** Explain how an induction cooker works and why it works only on metal cookware instead of non-metallic cookware such as wood or ceramic.

……

……

……

……

……

……

…… [4]

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**6** **(a)** A possible fusion process which has been suggested for the generation of energy is represented by the following equation:

$$ {}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n $$

Rest mass of proton = $1.67357 \times 10^{-27}$ kg
Rest mass of neutron = $1.67496 \times 10^{-27}$ kg
Rest mass of ${}^{2}_{1}H$ = $3.34454 \times 10^{-27}$ kg
Rest mass of ${}^{3}_{2}He$ = $5.00835 \times 10^{-27}$ kg

**(i)** Using the data above, calculate the energy released.

energy released = …….. J [2]

**(ii)** The total kinetic energy of the helium nucleus, neutron and the energy of radiation for the reaction is found to be more than the answer in **(i)**.

Suggest a reason for this difference.

……

…….. [1]

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**(b)** In order to achieve nuclear fusion, the particles involved must first overcome the electric repulsion to get close enough for the attractive strong nuclear force to fuse the particles. This requires extremely high temperatures.

Consider a proton "gas" at high temperature and assume a proton is a sphere of radius $r \approx 1 \times 10^{-15}$ m. Two protons are moving towards each other with the same kinetic energy $K$ as shown in Fig. 6.1.



**Fig. 6.1**

**(i)** Calculate the value of $K$ which is just enough to bring the two protons to 'just touch' one another as seen in Fig. 6.2 so that the nuclear force can come into action. Assume that the 2 protons are initially far apart



**Fig. 6.2**

$K$ = …….. J [2]

**(ii)** If the proton "gas" behaves like an ideal gas, determine the temperature of the proton "gas" for the protons to have an average kinetic energy as that calculated in **(b)(i)**.

temperature = …….. K [1]

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**(c)** Beryllium nuclei when bombarded by alpha particles may undergo nuclear reactions. One such reaction is

$$^{9}_{4}\text{Be} + ^{4}_{2}\text{He} \rightarrow ^{12}_{6}\text{C} + \text{X}$$

**(i)** State what is meant by the binding energy of a nucleus.

……

……

…… [1]

**(ii)** Identify particle X and explain why it is not taken into consideration in the calculation of energy released when using the binding energy approach.

……

……

…… [1]

**(iii)** The binding energy per nucleon of Beryllium-9 and Helium-4 are approximately 6.4763 MeV and 7.0819 MeV respectively and that of Carbon-12 is 7.6885 MeV.

Calculate the net energy released during this process.

energy released = …….. J [3]

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**7** To simulate a bungee jump, a solid cuboid of 600 N weight is attached to one end of a long rubber cord on a high platform, with the other end of the cord secured to the platform. The cube is pushed off in the horizontal direction from the platform, dragging the cord from the platform. The variation of the vertical position of the cuboid below the platform with time is shown in Fig. 7.1.

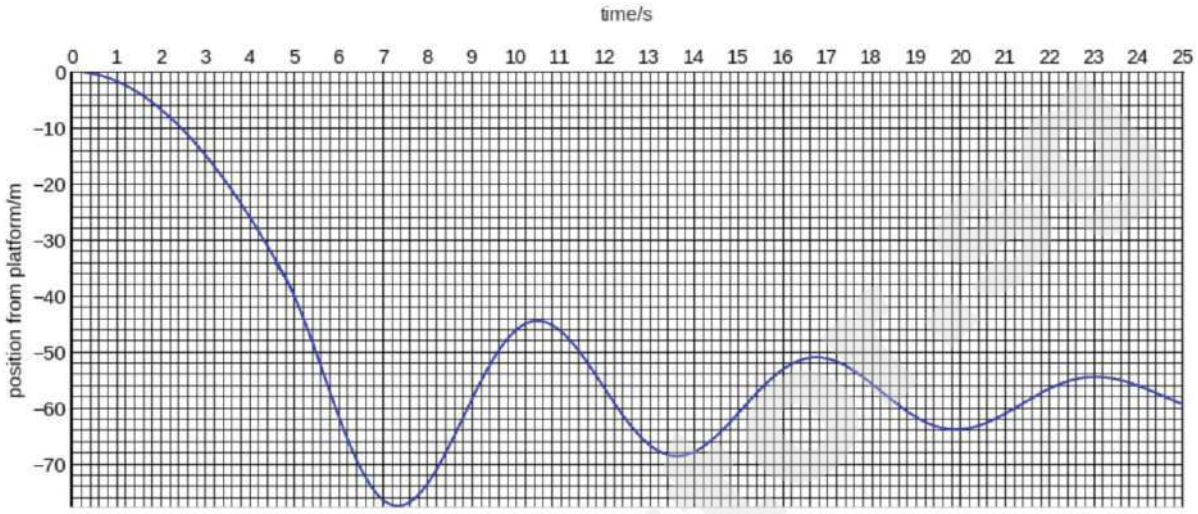


**Fig. 7.1**

**(a)** Determine the maximum speed of the cube at 58.0 m below the platform from the graph.

maximum speed = …….. m $s^{-1}$ [2]

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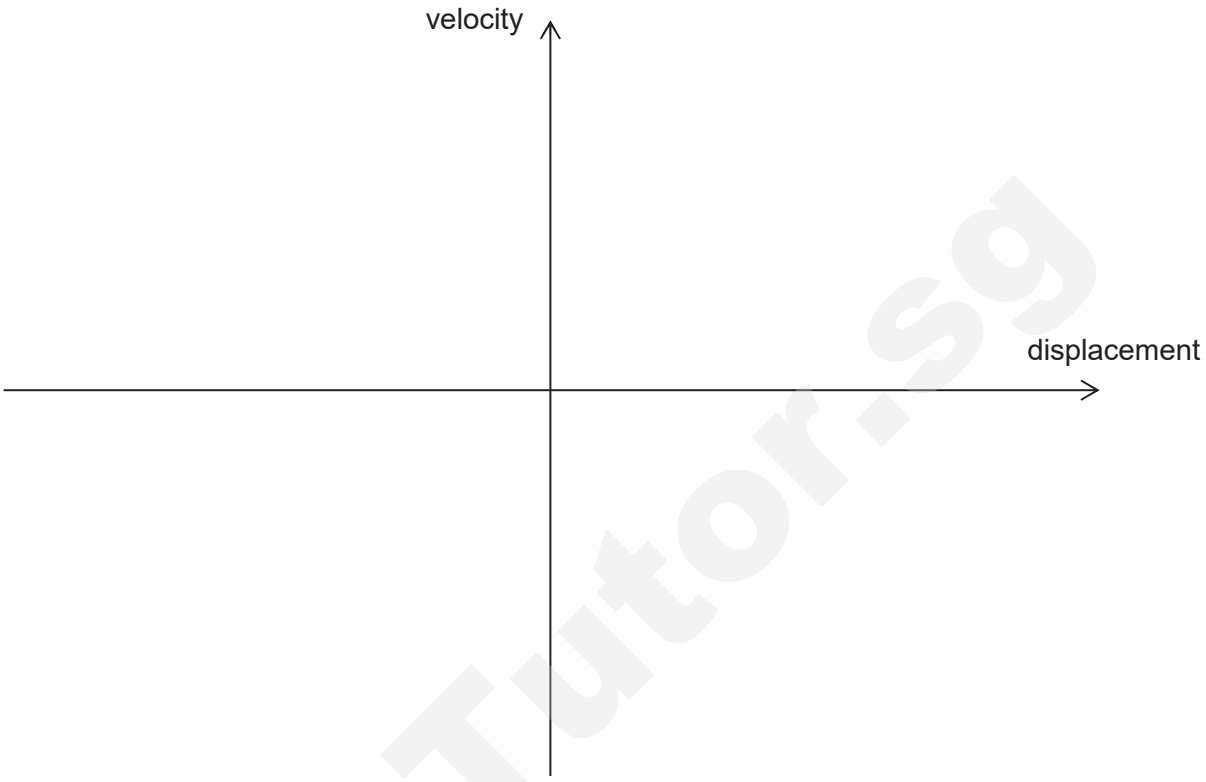
**(b)** Sketch a graph of velocity versus displacement of the mass from the position of the maximum speed mentioned in **(a)** for at least 2 cycles.




[2]

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**(c)** **(i)** The vertical equilibrium position of the cuboid during the oscillation is at 58.0 m below the platform. Explain what is meant by the equilibrium position.

……..

……. [1]

**(ii)** During the oscillations, the maximum magnitude of displacement from the equilibrium position $A$, of the oscillating cuboid varies with time $t$ according to this equation,

$$A = A_o e^{-ct}$$

where $A_o$ and $c$ are constants.

Complete the table below, for the maximum magnitude of displacement at various $t$. Also complete the 4th column of the table in order to plot a suitable graph to determine the values of $A_o$ and $c$.

| $t$ / s | Position / m | Magnitude of displacement, $A$ / m | |
|---|---|---|---|
| 7.4 | - 78 | 20 | |
| 10.5 | - 44 | 14 | |
| 13.6 | - 69 | 11 | |
| 16.8 | - 51 | 7 | |
| 20.0 | - 64 | | |
| 23.0 | - 54 | | |

[2]

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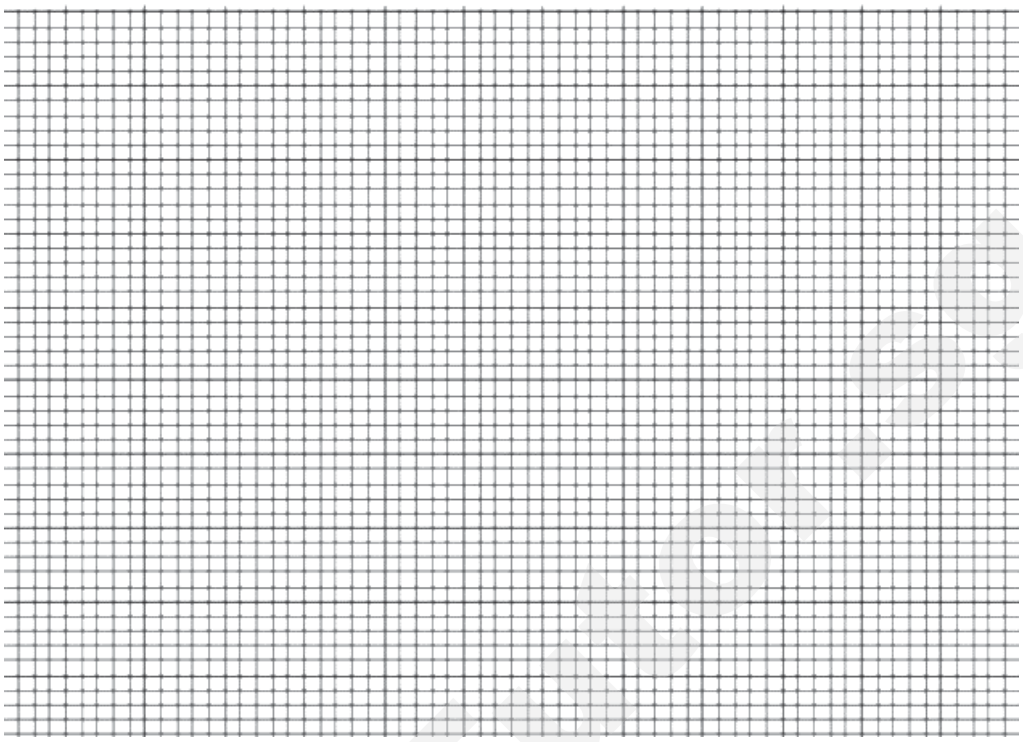
**(d)** Plot a suitable graph and use it to determine the values of $c$ and $A_0$.



$c$ = ..... $s^{-1}$

$A_0$ = ..... m [5]

**(e)** Suggest why the data from the graph *just* after t = 0 is not to be included in the analysis in part **(cii)**.

.....

..... [1]

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**(f)** **(i)** Using Fig. 7.1, determine the period $T$ of the oscillation.

period $T$ = …….. s [1]

**(ii)** Theory suggests that

$$\frac{4\pi^2}{T^2} = \frac{k}{m} - q,$$

where $k$ is the elastic constant of the cord,
$m$ is the mass of the cuboid, and
$q = 1.00 \times 10^{-2}$ s$^{-2}$.

Determine the extension of the cord at equilibrium.

extension = …….. m [2]

**(iii)** Hence, calculate the loss in total energy when the mass first crosses the equilibrium point.

energy loss = …… J [3]

**(g)** Explain why a thicker cord has to be used for a person with larger mass for a bungee jump.

……..

…… [1]

**End of paper**

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| Class | Index Number | Name |
|---|---|---|
| 18S | | |

**ST. ANDREW'S JUNIOR COLLEGE**
**JC 2 2019**
**Preliminary Examination**

**PHYSICS, Higher 2** **9749/03**

Paper 3 Longer Structured Questions **19th September 2019**
**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.
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 **one** question.

You are advised to spend about one hour on each Section.

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

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

| For Examiner's Use | |
|---|---|
| **Section A** | |
| 1 | / 10 |
| 2 | / 10 |
| 3 | / 10 |
| 4 | / 10 |
| 5 | / 10 |
| 6 | / 10 |
| **Section B** | |
| 7 | / 20 |
| 8 | / 20 |
| Total | / 80 |

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## Data

| | |
|---|---|
| speed of light in free space, | $c = 3.00 \times 10^{8}$ m s$^{-1}$ |
| permeability of free space, | $\mu_0 = 4\pi \times 10^{-7}$ 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 |
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| the Avogadro constant, | $N_A = 6.02 \times 10^{23}$ mol$^{-1}$ |
| the Boltzmann constant, | $k = 1.38 \times 10^{-23}$ J K$^{-1}$ |
| gravitational constant, | $G = 6.67 \times 10^{-11}$ N m$^2$ kg$^{-2}$ |
| acceleration of free fall, | $g = 9.81$ m s$^{-2}$ |

## Formulae

| | |
|---|---|
| uniformly accelerated motion, | $s = ut + \frac{1}{2}at^2$ |
| | $v^2 = u^2 + 2as$ |
| work done on/by a gas, | $W = p\Delta V$ |
| hydrostatic pressure, | $p = \rho g h$ |
| gravitational potential, | $\phi = -\frac{Gm}{r}$ |
| temperature, | $T/\text{K} = T/^{\circ}\text{C} + 273.15$ |
| pressure of an ideal gas, | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule, | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m., | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m., | $v = v_0 \cos \omega t$ |
| | $v = \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series, | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel, | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential, | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage, | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire, | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil, | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid, | $B = \mu_0 nI$ |
| radioactive decay, | $x = x_0 \exp(-\lambda t)$ |
| decay constant, | $\lambda = \frac{\ln 2}{t_{1/2}}$ |

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## Section A

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

**1** **(a)** Define displacement.

……

…… [1]

**(b)** A small ball is thrown horizontally with a velocity $v$ at A. It falls through a vertical height of 1.96 m before bouncing off a smooth horizontal table at B as shown in Fig. 1.1. It then bounces to a maximum height at C. Air resistance is negligible.

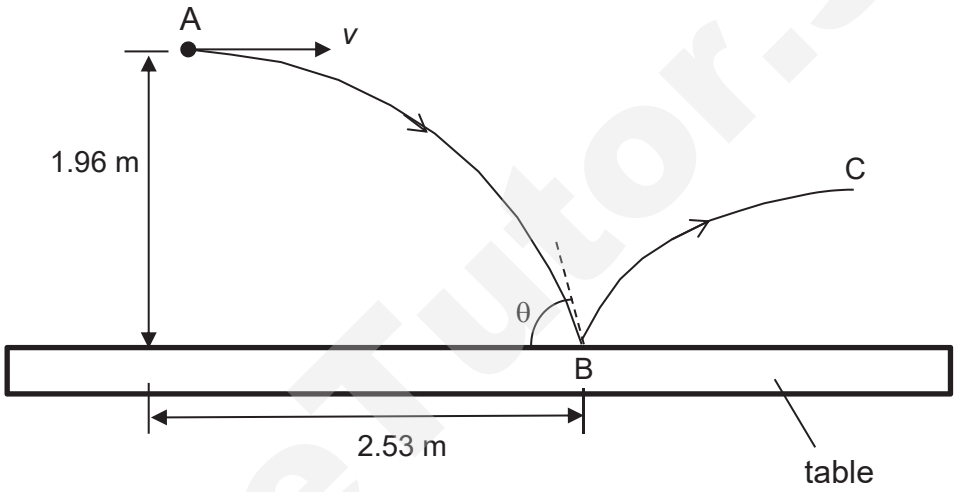


**Fig. 1.1**

Calculate, for the ball,

**(i)** the value of $v$,

$v$ = …….. m $s^{-1}$ [3]

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**(ii)** the vertical component of the velocity $v_y$ just before it hits the table at B,

$v_y$ = ……..…… m $s^{-1}$ [2]

**(iii)** the angle $\theta$ the ball makes with the horizontal at B.

$\theta$ = ……..…… ° [1]

**(iv)** State the magnitude and direction of the acceleration of the ball at C.

magnitude and direction = ……... [1]

**(c)** On the axes of Fig. 1.2, sketch the variation with time of the vertical component of velocity $v_y$ of the ball, from A to C if air resistance is **not** negligible. Taking downward as positive.




**Fig. 1.2**

[2]

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**2** Two blocks, P and Q, of masses 0.50 kg and 1.00 kg respectively, are connected by a string that passes over a pulley as shown in Fig. 2.1. The spring constant is 200 N $m^{-1}$.

The pulley is frictionless and the string is inelastic. The system is released from rest.

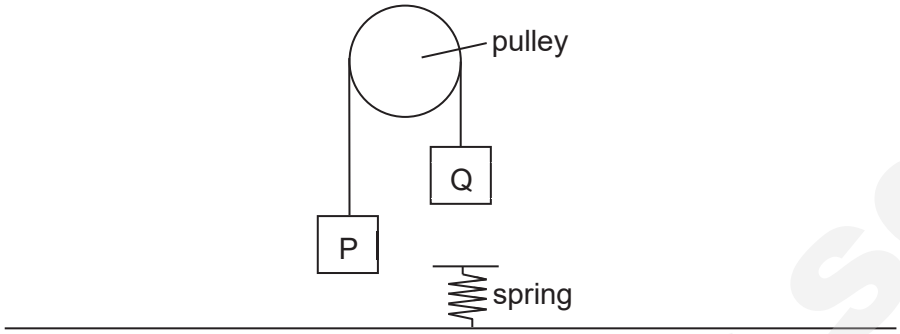


**Fig. 2.1**

**(a) (i)** Block Q falls vertically before it strikes a spring that is firmly attached to the floor.

Determine the magnitude of acceleration of block Q just before it strikes the spring.

acceleration of block Q = …….…… m $s^{-2}$ [2]

**(ii)** Hence, determine the tension in the string just before block Q strikes the spring.

tension in the string = …….…… N [2]

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**(iii)** The acceleration of Block Q decreases after it touches the spring. Block Q comes to a permanent stop after some time and the spring is observed to be compressed.

Calculate the compression of the spring, $x$.

compression of spring, $x$ = …….…… m [2]

**(iv)** In an ideal system where there is no energy loss, explain how is it that collision between Block Q and the spring is elastic even though the kinetic energy of Block Q and the spring was momentarily zero.

……....

……....

…….. [1]

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**(b)** A bullet of mass 5.0 g is fired from a gun into a block of mass 0.500 kg, which is suspended by thin threads from fixed points. The bullet remains in the block, which swings upwards as to a maximum height of h as shown in Fig. 2.2.

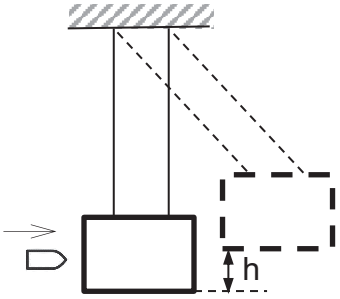


**Fig. 2.2**

**(i)** If the velocity of the bullet just before it strikes the block is 100 m $s^{-1}$, determine the maximum height h.

maximum height = ……..……. m [2]

**(ii)** State the type of collision between the bullet and the block.

…….. [1]

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3 **(a)** Three months ago (20th June 2019), the 'Montezooma's Revenge' at the Knott's Berry Farm theme park in Los Angeles received the 'American Coaster Enthusiasts' Landmark Status as a historic roller-coaster.

Opened in 1978, the ride involves a train being launched by a mechanism that accelerates it to 89 km $h^{-1}$ in 4.5 seconds. As depicted in Fig. 3.1 below, the train will then negotiate a 23.0 m diameter loop before ascending the open-end 45.0 m tall front track. The train then falls backwards under its own weight, going through the loop a second time, ascending the back vertical track and returning to its starting position at the station, brought to a halt through brakes in the station.

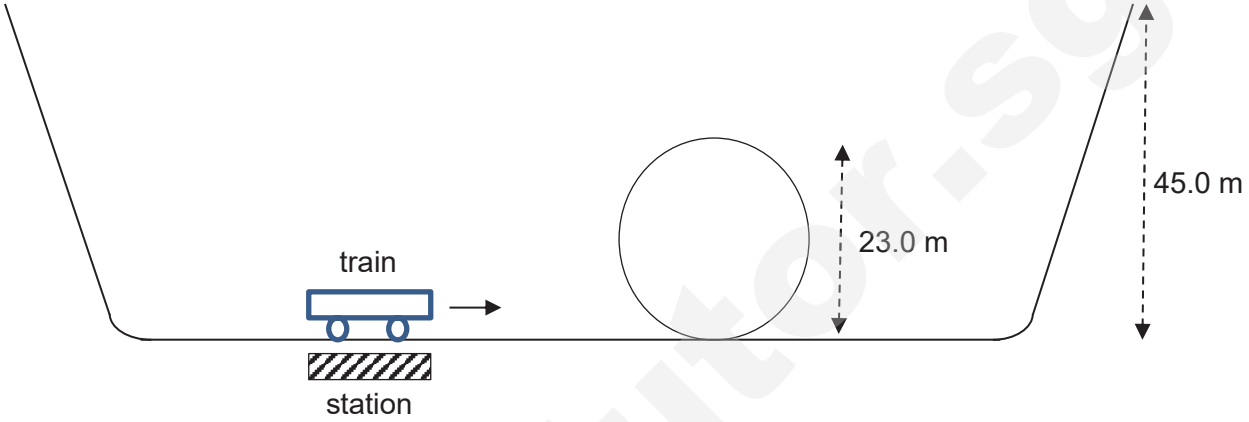


**Fig. 3.1**

In a typical operation, 28 riders in a single train with 7 cars have a combined mass of 6500 kg. Assume that the track is smooth.

**(i)** Determine the average power required by the mechanism to bring the train to 89 km $h^{-1}$ in 4.5 s.

power = ……..…… W [2]

**(ii)** Show that the train will not travel beyond the open-end part of the track after emerging from the loop.

[1]

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**(iii)** Each rider is to be restrained by a lap bar. Should the lap bar's locking mechanism fail and unlock itself as the train negotiates the loop, determine if the rider will fall off the train.

.....

..... [3]

**(b)** A straight length of tape winds on to a roll rotating about a fixed axis with constant angular velocity as shown in Fig. 3.2 below. The radius of the roll is increasing at a steady rate.

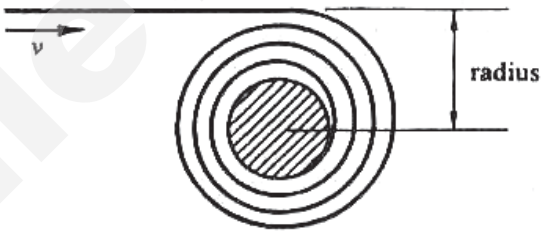


**Fig. 3.2**

Sketch a speed-time graph to show how the speed v, at which the tape moves towards the roll, varies with time. [2]




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**(c)** A coin of mass $m$ is placed on a horizontal turntable at a distance $r$ from the centre. The maximum frictional force between the coin and the turntable is $\frac{1}{2}mg$. The turntable starts to rotate with increasing angular velocity.

Determine the angular velocity at which the coin will begin to slide. Express it in terms of $g$ and $r$ accordingly. [2]

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**4** Two vertical springs, each having spring constant k = 3.0 N $cm^{-1}$, support a mass. The lower spring is attached to an oscillator anchored on a bench, as shown in Fig. 4.1.

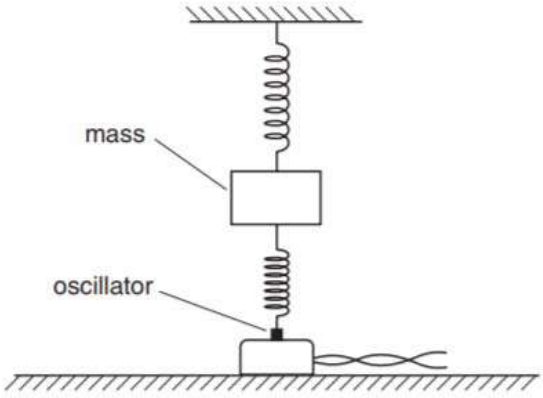


**Fig. 4.1**

The oscillator is switched off. The mass is displaced vertically and then released so that it vibrates. During these vibrations, the springs are always extended. The vertical acceleration *a* of the mass *m* is given by the expression

$$ma = -2kx,$$

where *x* is the vertical displacement of the mass from its equilibrium position.

**(a)** For a mass of 250 g, an amplitude of 1.50 cm,

**(i)** Determine the frequency of vibration of the mass.

frequency = ……..…….. Hz [2]

**(ii)** Determine the maximum speed of vibration of the mass

maximum speed = ……..……. m $s^{-1}$ [2]

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**(b)** The oscillator is switched on and the frequency f of vibration is gradually increased. The amplitude of vibration of the oscillator is constant.

**(i)** Draw a graph in Fig. 4.2 showing the variation of the amplitude of vibration with the frequency of the oscillator for an object of mass *m*.

Label the graph appropriately and name it as (i). [2]

**(ii)** The mass is now replaced with another of the same dimension but of half the density. Draw another graph on Fig. 4.2, showing the variation of the amplitude of vibration with the frequency of the oscillator. Label this (ii). [1]

**(iii)** The mass in part **(ii)** is now replaced with another object of mass *m* but is spherical in shape. Draw another graph on Fig. 4.2, showing the variation of the amplitude of vibration with the frequency of the oscillator. Label this (iii). [1]




**Fig. 4.2**

**(c)** The oscillating mass is now doubled.

Explain how the frequency of oscillation in part (a) can be maintained.

……..

……..

……..

…… [2]

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**5** The diagram below shows an X-ray tube used for the production of X rays. The potential difference between the cathode and anode is 90 kV.

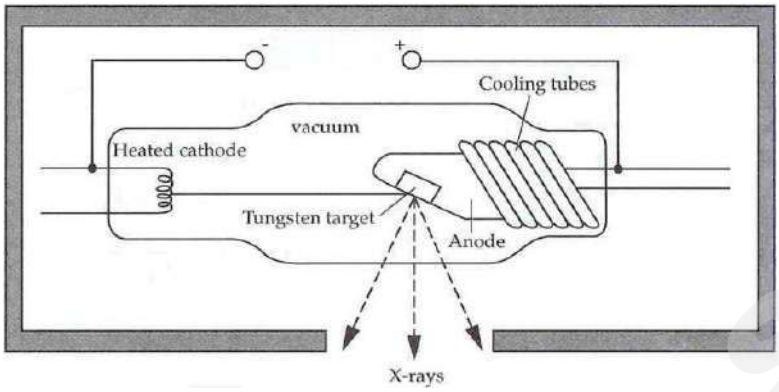


**Fig. 5.1**

The target is made of tungsten. The energy levels of tungsten for the three lowest electron shells are given in Fig 5.2.




**Fig. 5.2**

**(a)** **(i)** X-ray photons of specific wavelengths are emitted from these atoms when they are excited by collisions with electrons.

Explain why the emitted photons have specific wavelengths.

……...

……...

……...

…… [2]

**(ii)** Calculate the shortest characteristic wavelength that will be observed in the X ray spectrum produced by the tungsten target.

wavelength = ……..…… m [2]

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**(b)** When the potential difference between the cathode and anode i.e. tube voltage is set to 80 kV and then 100 kV. The X-ray spectra for the two voltages are shown in Fig. 5.2.

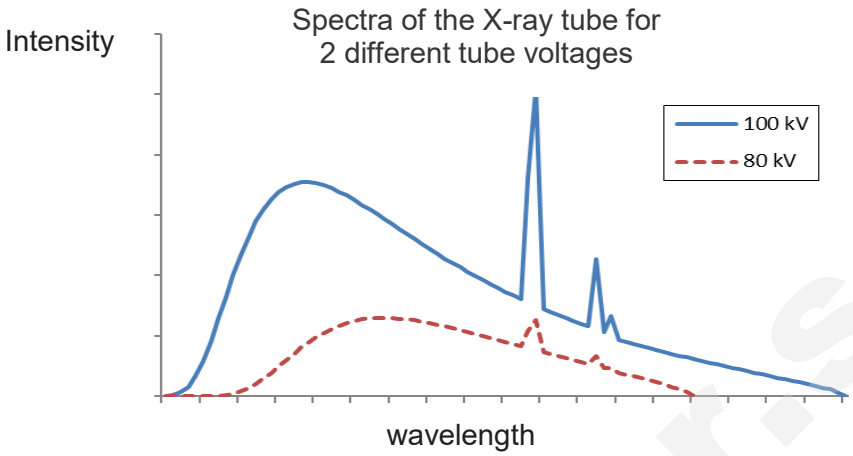


**Fig. 5.3**

Explain the similarities and differences of the X-ray spectra in Fig 5.3.

……

……

……

……

……

……

……

…… [3]

**(c)** State what is meant by the wave–particle duality of electrons. Give one example of each type of behaviour.

……

……

……

……

…… [3]

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6 **(a)** In a particular radioactive decay, Plutonium-241 ($^{241}_{94}Pu$) decays to form the daughter product Americium-241 ($^{241}_{95}Am$). A fresh sample of radioactive material contains only Plutonium-241 nuclei and no Americium-241. Fig. 6.1 shows the variation with time *t* of the activity *A* of Plutonium-241.

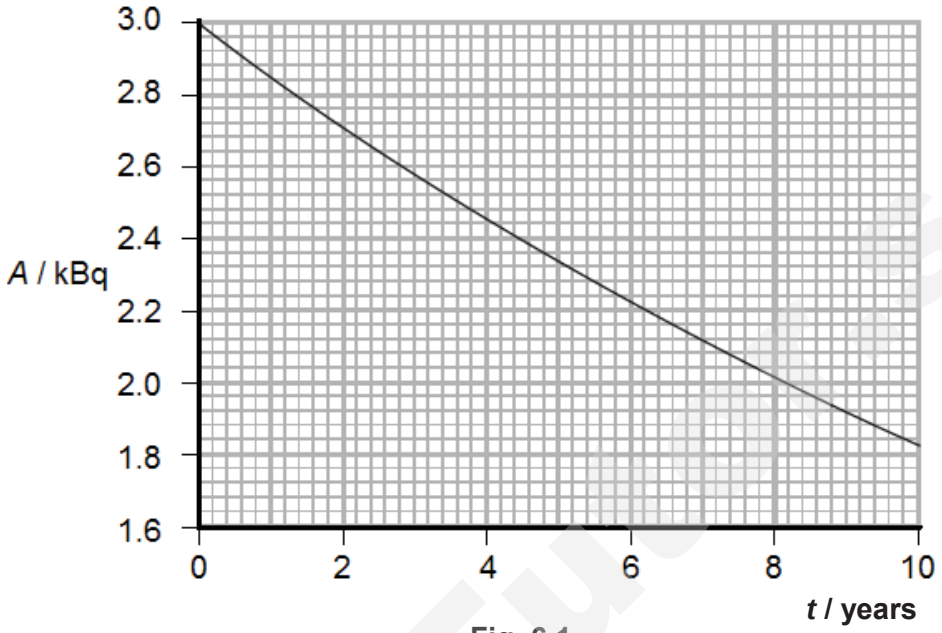


**Fig. 6.1**

Some data derived from Fig. 6.1 is shown in the table below.

| Time *t* / years | Activity *A* / kBq |
|---|---|
| 0.0 | 3.00 |
| 2.0 | 2.70 |
| 4.0 | 2.44 |
| 6.0 | 2.22 |
| 8.0 | 2.02 |
| 10.0 | 1.82 |

**Fig. 6.2**

**(i)** Using Fig. 6.2, show that the half-life of Plutonium-241 is 14 years.

[3]

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**(ii)** Assume the half-life of Plutonium-241 is very much shorter than that of Americium-241 and Americium-241 is very stable once formed.

Deduce the age of the sample of radioactive material when

$$\frac{\text{Number of Americium} - 241 \text{ nuclei in sample}}{\text{Number of Plutonium} - 241 \text{ nuclei in sample}} = \frac{1}{3}.$$

age of the sample = ……..…….. years [2]

**(b)** The radioactive nuclide $^{60}_{27}$Co is used in radiotherapy. It has a half-life of 5.27 years and, at each disintegration, two $\gamma$-rays are emitted, one of energy 1.17 MeV and the other of energy 1.33 MeV.

In a radiotherapy treatment, it is necessary to determine the amount of energy absorbed from the radiation. A fresh 1.0 g sample of $^{60}_{27}$Co, which may be treated as a point source, is placed at a position 1.50 m from a patient.

Calculate the intensity of the radiation received by the patient.

intensity = ……..…….. W m$^{-2}$ [3]

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**(c)** Radioactivity is often said to be a random process.

Explain what is meant by the word *random* in this context.

……...……..

……...……..

……...……..

…… [2]

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## Section B

Answer **one** question from this Section in the spaces provided.

**7** **(a)** **(i)** Explain the *principle of superposition*.

……...……...

……...

……... [2]

**(ii)** Two-source interference fringes using light can only be obtained if light from the two sources is coherent.

Explain

**1.** the meaning of the term coherent,

……

……... [1]

**2.** why in practice, interference fringes can be seen only if light from a single source is split into two.

……

……... [1]

**(iii)** Coherent, monochromatic light from two narrow slits a distance 0.38 mm apart causes an interference pattern on a screen 1.20 m from the slits, as illustrated in Fig. 7.1.

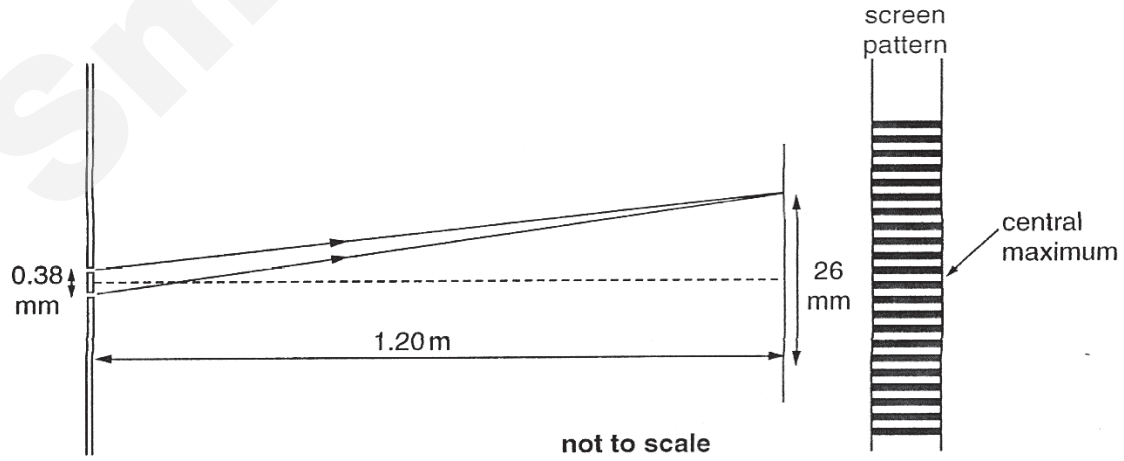


**Fig. 7.1**

The distance from the sixth bright fringe on one side of the pattern to the sixth bright fringe on the other side of the pattern is found to be 26 mm.

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Calculate the wavelength of the monochromatic light.

wavelength = …….. m [3]

**(iv)** Another way of obtaining fringes similar to those described in (iii) is illustrated in Fig. 7.2.

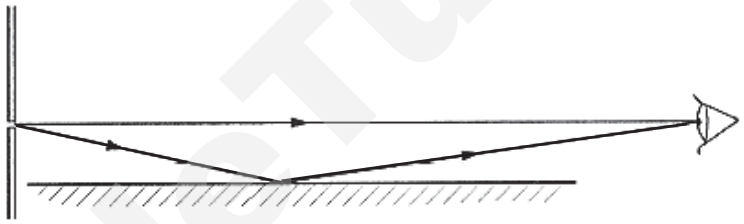

**Fig. 7.2**

A single slit is viewed both directly and by reflection from a mirror surface.

Explain why this system produces a fringe pattern.

……...

……...

……...

……...

…….. [2]

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**(b)** Fig. 7.3 shows a long horizontal tube that is closed at one end, containing a fine powder. A loudspeaker, connected to a signal generator, is positioned at the other end.

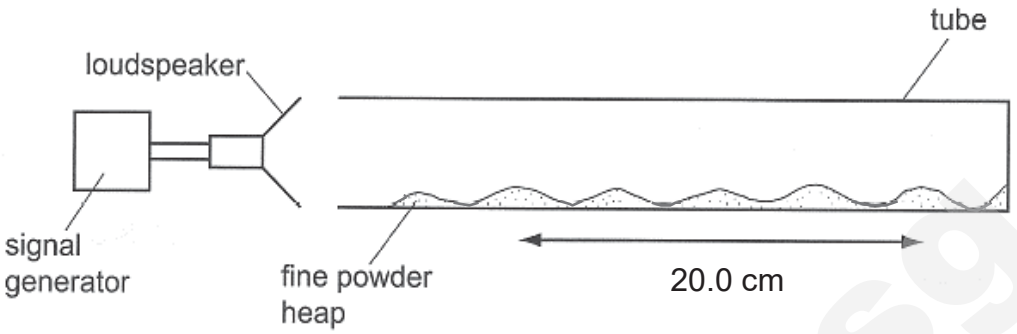


**Fig. 7.3**

At a particular frequency, a stationary wave is set up inside the tube and the powder forms small heaps and depressions in the tube. The speed of sound is 330 m $s^{-1}$.

**(i)** Explain, by reference to the properties of stationary waves, why the heaps and depressions are formed.

……...

……...

……...

…… [2]

**(ii)** The distance between five heaps as shown in Fig. 7.3 is 20.0 cm. Calculate the frequency of sound in the tube.

frequency = …….. Hz [3]

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**(iii)** One of the stationary waves that may be formed in the tube is shown in Fig. 7.4.

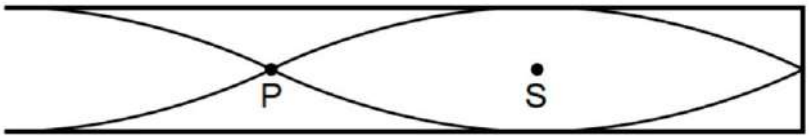


**Fig. 7.4**

Describe the motion of the air particles in the tube at

**1.** point P,

..... [1]

**2.** point S.

..... [1]

**(c)** Fig. 7.5 shows vertically polarised light of intensity 147 W $cm^{-1}$ passing through a polaroid. The polarising axis of the polaroid is tilted at an angle of 23° to the vertical.

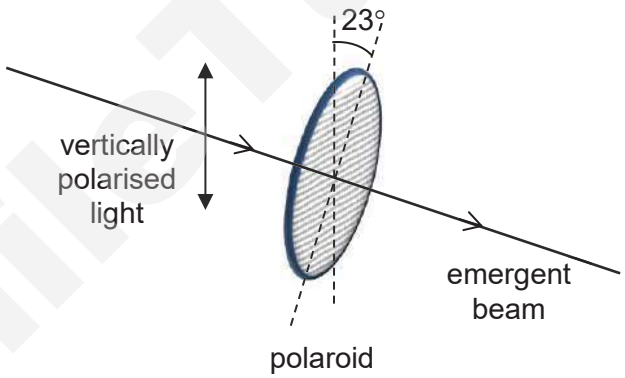


**Fig. 7.5**

**(i)** Determine the intensity of the emergent beam.

intensity = ..... W $cm^{-1}$ [2]

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**(ii)** Determine the fractional reduction in the amplitude of the emergent beam.

fractional reduction = ..... [2]

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8 **(a)** A charged particle may experience a force in an electric field and in a magnetic field. State two differences between the forces experienced in the two types of field.

……

……

……

…… [2]

**(b)** Fig. 7.1 shows a positively charged particle of mass $6.64 \times 10^{-27}$ kg moving with speed $1.37 \times 10^{6}$ m $s^{-1}$ in a vacuum through a uniform electric and magnetic field.

The electric field is due to an applied p.d. of 3600 V across the plates and the plates are separated by a distance of 0.0275 m. The length of the plates is 0.10 m. The charged particle enters midway between the two plates.

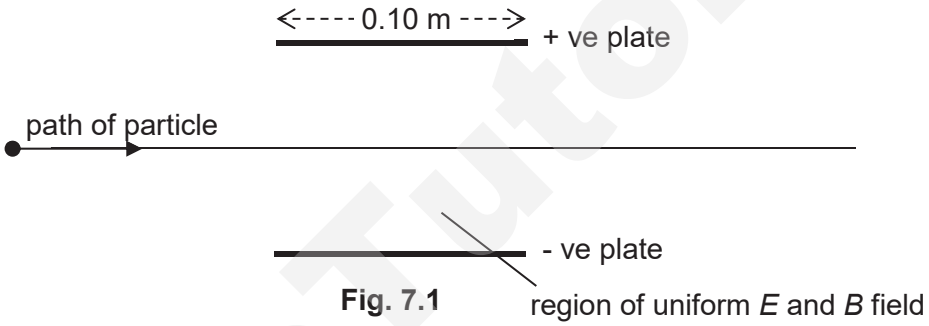


**Fig. 7.1**

The path of the particle is a straight line both within and outside the region of the fields.

**(i)** State the direction of the magnetic field. Explain how you arrive at your answer.

……

……

……

……

…… [3]

**(ii)** Determine the value of the magnetic flux density.

magnetic flux density = …… T [2]

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**(iii)** The electric field is switched off. Explain why the particle moves in a circular path.

……...

……...

……...

…… [2]

**(iv)** The particle moves in a circular path of radius 0.300 m. Show that the charged particle may be an alpha particle.

[2]

**(v)** The electric field is switched back on while the magnetic field is switched off.

Determine whether the charged particle will be able to exit the two plates without colliding with them.

[3]

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**(c)** Two point charges +1.0 μC and –2.0 μC of the same mass are placed 10.0 cm apart, as shown in Fig. 7.2 below.




**Fig. 7.2**

**(i)** Draw the electric field lines for the two charges in the space provided below.




[2]

**(ii)** A third charge is placed such that there is no net electrostatic force acting on it. Determine its position *x* with respect to the positive charge.

*x* = …… m [2]

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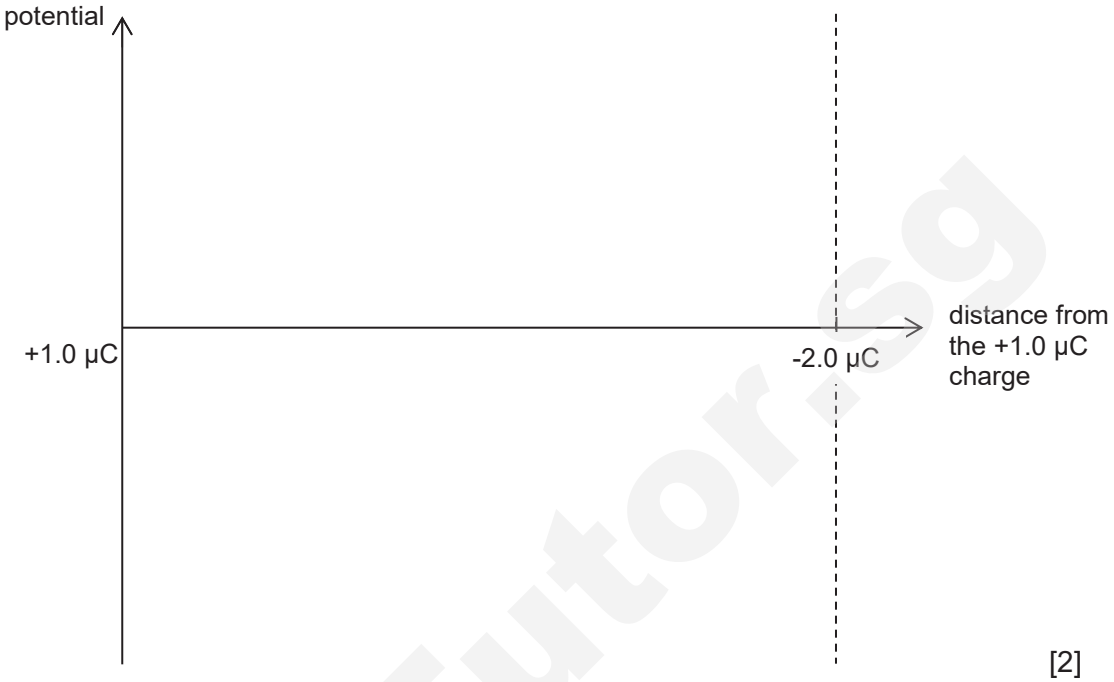
**(iii)** Sketch on the axis below the variation of the potential with the distance from the +1.0 μC to the –2.0 μC.




[2]

**End of paper**

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| Civics Group | Index Number | Name |
|---|---|---|
| 18S | | |

**ST. ANDREW'S JUNIOR COLLEGE**
**JC 2 2019**
**Preliminary Examination**

**PHYSICS** **9749/04**

Paper 4 Practical

**3rd September 2019** **2 hours 30 minutes**

Candidates answer on the Question Paper.

Additional Materials: As listed on the Confidential Instructions.

**READ THESE INSTRUCTIONS FIRST**

Write your name, index number and Civics Group in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.
Give details of the practical shift and laboratory where appropriate in the boxes provided.

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

| Shift |
|---|
| |
| Laboratory |

| For Examiner's Use | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| Total | /55 |

This question paper consists of **22** printed pages including this page.

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**1** In this experiment, you will investigate an electric circuit.

**(a)** **(i)** You have been provided with a length of constantan wire attached to a metre rule, and a resistor Y of unknown resistance.

Connect the circuit as shown in Fig. 1.1.

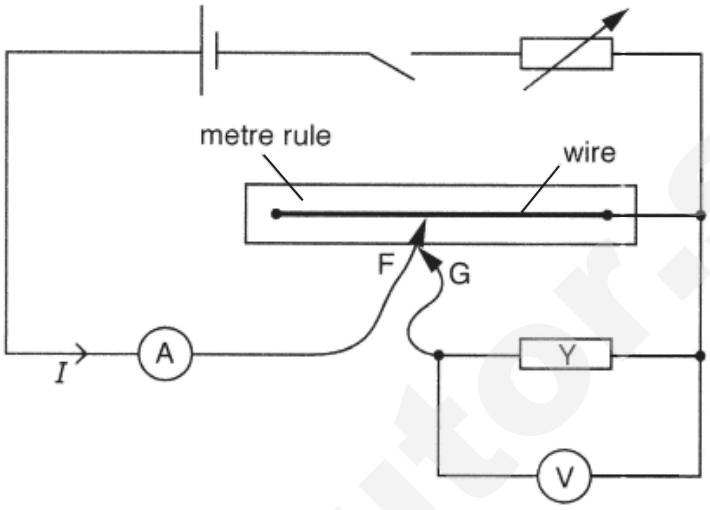


**Fig. 1.1**

F and G are crocodile clips.

**(ii)** Connect F to a point half-way along the wire. Connect G to F.

**(iii)** Place the slider of the rheostat at its mid-point.

**(iv)** Close the switch and record the voltmeter reading $V_0$ to the nearest 0.01 V.

$V_0$ = .....[1]

**(v)** **1** Adjust the slider of the rheostat until the voltmeter reading just changes to ($V_0$ + 0.01) V.

Record the ammeter reading.

ammeter reading = .....

**2** Adjust the slider of the rheostat until the voltmeter reading just changes to ($V_0$ – 0.01) V.

Record the ammeter reading.

ammeter reading = .....
[1]

**(vi)** Open the switch

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**(b)** The distance *x* between the end of the wire and F is shown in Fig. 1.2.

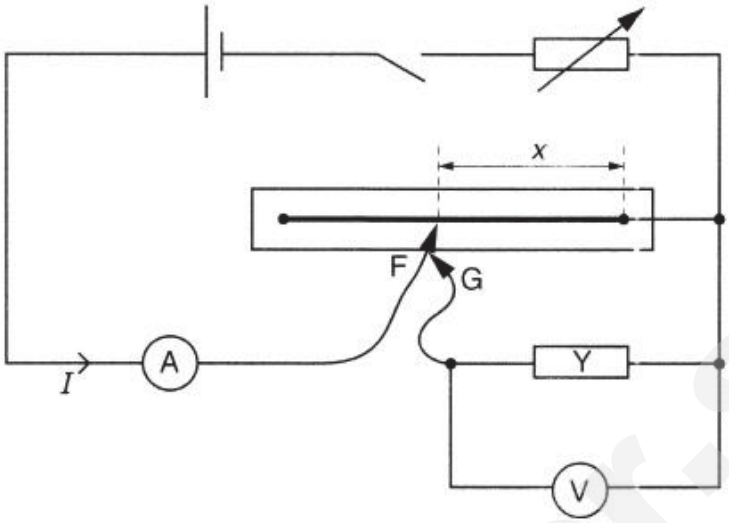


**Fig. 1.2**

**(i)** Move F so that *x* is approximately 30 cm.

**(ii)** Close the switch and adjust the slider of the rheostat until the voltmeter reading is equal to $V_0$.

**(iii)** Record *x* and the ammeter reading $I$.

*x* = .....

$I$ = .....

[1]

**(iv)** Open the switch.

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**(c)** Vary $x$ and repeat **(b)(ii)**, **(b)(iii)** and **(b)(iv)** keeping the voltmeter reading equal to $V_0$ throughout.

[5]

**(d)** $I$ and $x$ are related by the expression

$$I = \frac{P}{x} + Q$$

where $P$ and $Q$ are constants.

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

$P$ = .....

$Q$ = .....

[6]

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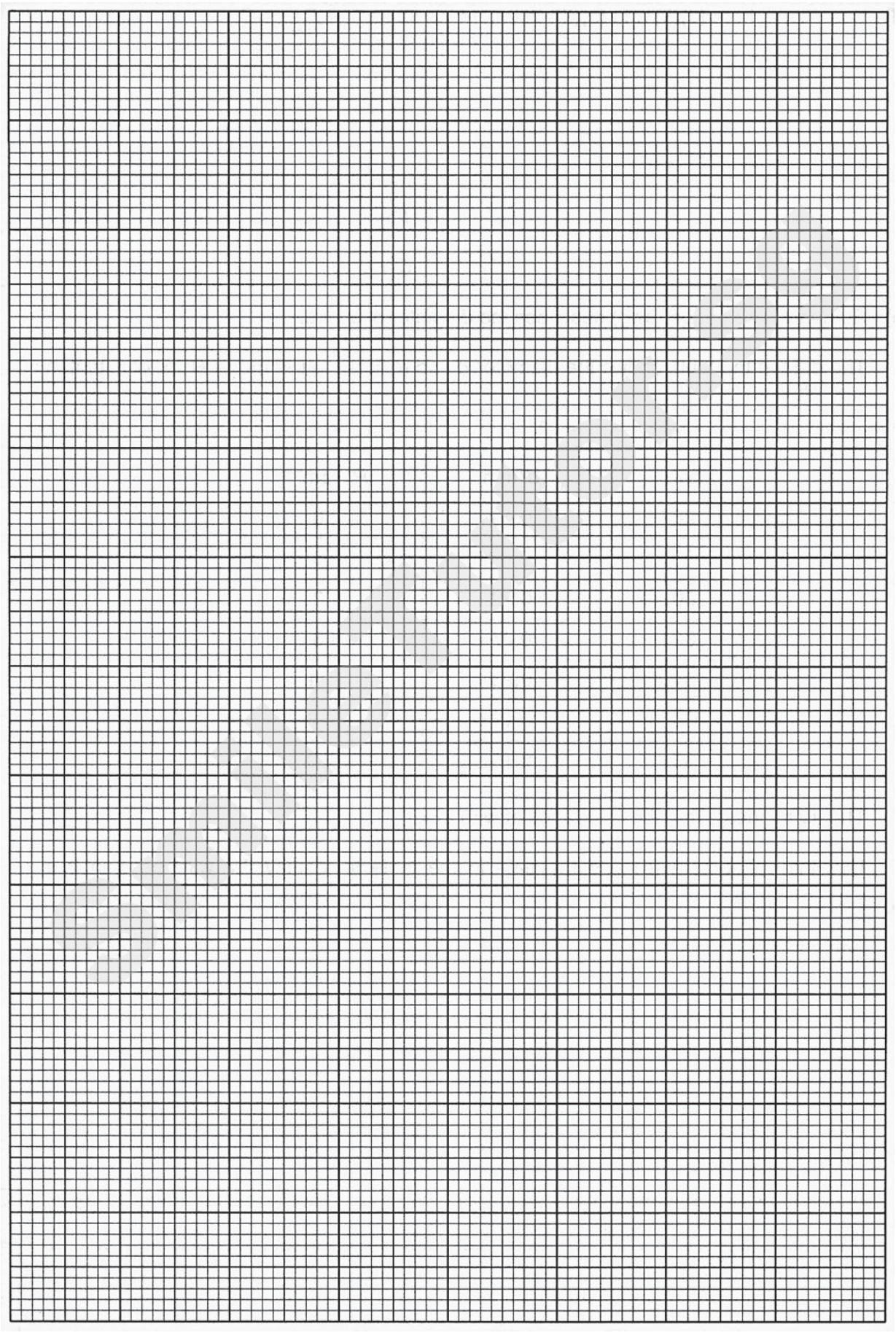

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**(e)** Theory suggests that

$$\frac{P}{Q} = L$$

where $L$ is the length of wire that has the same resistance as resistor Y.

Calculate $L$.

$L$ = ……[1]

**(f)** **(i)** Remove Y from the circuit and replace it with a wire of length L from the wire wound on the card. **Do not cut the wire.**

**(ii)** Connect F to a point half-way along the wire on the metre rule.

Repeat **(b)(ii)**, **(b)(iii)** and **(b)(iv)**.

$x$ = ……

$I$ = ……

**(iii)** Use your values in **(f)(ii)** to plot another point on your graph.

Label this point Z.

**(iv)** State whether this point agrees with the pattern of the other points on your graph.

Use your values in **(a)(v)** to justify your statement.

……...

……...

……...

……...

……...

……..……[2]

[Total: 17]

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**Question 2 begins on the next page.**

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**2** In this experiment, you will determine the spring constant of a spring.

**(a)** You have been provided with three identical springs, attached to a ring.

The length of an unstretched spring is *S*, as shown in Fig. 2.1.

Without disconnecting the springs, measure and record *S* for **one** of the springs.

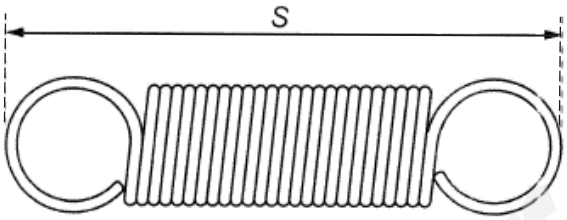


**Fig. 2.1**

*S* = .....

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**(b)** **(i)** Set up the apparatus as shown in Fig. 2.2.

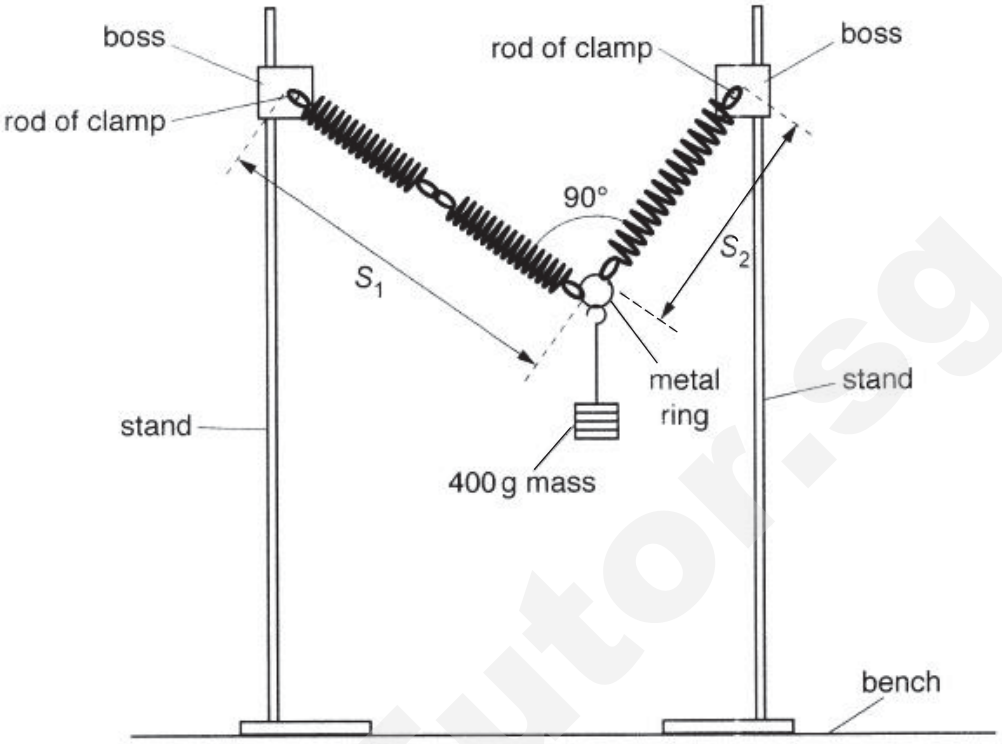


**Fig. 2.2**

Adjust the apparatus so that the angle between the springs is 90°.

The extended length of the double spring is $S_1$ and the extended length of the single spring is $S_2$.

Measure and record $S_1$ and $S_2$.

$S_1$ = .....

$S_2$ = .....

[1]

**(ii)** The extensions are p and q where

$$p = S_1 - 2S \text{ and } q = S_2 - S.$$

Calculate $p$ and $q$.

$p$ = .....

$q$ = .....

[1]

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**(c)** Theory suggests that

$$m^2g^2 = \frac{k^2p^2}{4} + k^2q^2$$

where m = 400 g, $k$ is the spring constant of one of the springs and $g$ = 9.81 m s$^{-2}$.

**(i)** Calculate $k$.

$k$ = …… N m$^{-1}$ [1]

**(ii)** If you were to repeat this experiment with other masses, describe the graph that you would plot to determine $k$.

……...

……...

……...

……..……[2]

[Total: 5]

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**Question 3 begins on the next page.**

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**3** In this experiment, you will investigate the behaviour of an oscillating system.

You have been provided with two lengths of copper wire, two spheres of modelling clay and a rubber band.

**(a)** **(i)** Bend the **longer** copper wire at its mid-point so that the two arms of the wire form an angle $\theta$, as shown in Fig. 3.1. Adjust the arms so that $\theta$ is approximately 40°.

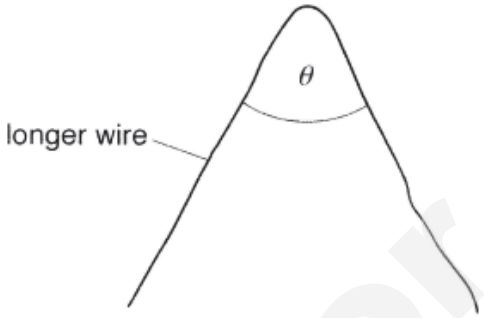


**Fig. 3.1**

**(ii)** Measure and record $\theta$.

$\theta$ = ……° [1]

**(iii)** Estimate the percentage uncertainty in your value of $\theta$.

percentage uncertainty in $\theta$ = …… [1]

**(iv)** Calculate $\sin(\theta/2)$.

$\sin(\theta/2)$ = …… [1]

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**(b)** **(i)** Place the modelling clay spheres on the ends of the wire and set up the apparatus as shown in Fig. 3.2.

The distance *C* is the distance between the top of the wire and the bottom of the sphere on each side of the bent wire.

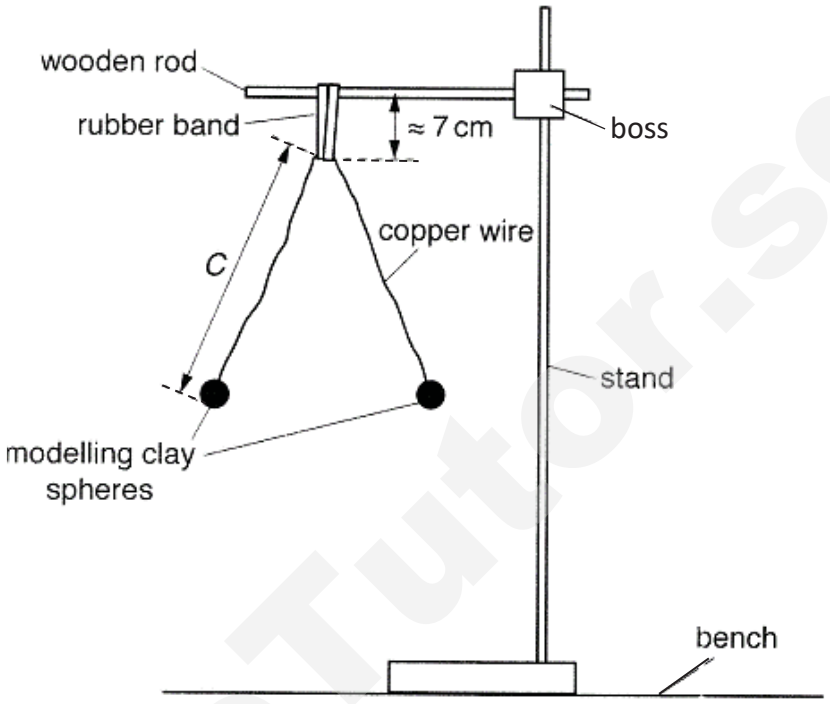


**Fig. 3.2**

Loop the rubber band twice over the wooden rod. The distance between the rod and the bottom of the band should be approximately 7 cm.

**(ii)** Determine *C* and estimate the percentage uncertainty in your value of *C*.

*C* = .....

percentage uncertainty in *C* = .....

[3]

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**(iii)** Move one of the spheres so that the wire turns through approximately 90° about a vertical axis. Release the sphere.

The wire will oscillate about a vertical axis.

Determine the period $T$ of these oscillations.

$T$ = ..... s [1]

**(c)** Increase $\theta$ and repeat **(a)(ii)**, **(a)(iv)** and **(b)(iii)**.

$\theta$ = .....°

sin($\theta$/2) = .....

$T$ = ..... s
[2]

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**(d)** It is suggested that

$$T = k\,C \sin(\theta/2)\,\sqrt{m}$$

where $k$ is a constant and $m$ is the mass of each sphere, with a value of 50.0 g.

**(i)** Use your values from **(a)(iv)**, **(b)(ii)** and **(c)** to determine two values of $k$.

Give your values of $k$ to an appropriate number of significant figures.

first value of $k$ = …….

second value of $k$ = …….
[1]

**(ii)** State whether the results of your experiment support the suggested relationship in **(d)**.

Justify your conclusion by referring to your values in **(a)(iii)** and **(b)(ii)**.

……...

……...

……...

……..……[1]

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**(e) (i)** You will now determine two more values of *k* using:

- the **shorter** wire with the spheres on the ends of the wire, as shown in Fig. 3.3
- the **longer** wire with the spheres placed along the wires, as shown in Fig. 3.4.

The values of *C* and $\theta$ must be the **same** in both cases and $\theta$ must be approximately 40° as in **(a)(i)**.

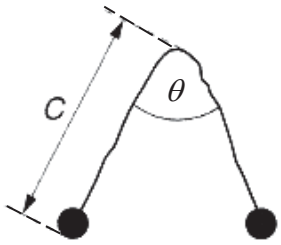


**Fig. 3.3**

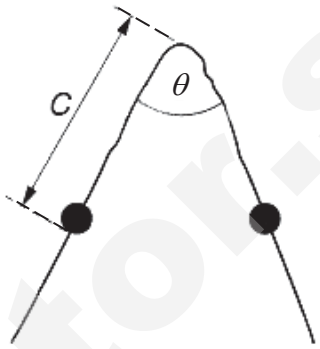


**Fig. 3.4**

Tabulate your results.

[3]

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**(ii)** Comment on your values of $k$ in **(d)(i)** and **(e)(i)**.

……...

……...

……...

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……...

……...

……..……[2]

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**(f)** The behaviour of the oscillating system depends on the properties of the rubber band.

It is suggested that the period $T$ is inversely proportional to the number $n$ of loops in the rubber band.

Explain how you would investigate this relationship using the same apparatus.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show inverse proportionality
- why you might not have enough results to reach a valid conclusion.

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……[5]

[Total: 21]

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**Question 4 begins on the next page.**

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**4** The acoustics in a multipurpose hall is rather poor because of strong reflections of sound. Sound absorption material can be used to improve the acoustics. When sound wave reaches a barrier, the amount of sound energy transmitted through the barrier depends on the thickness and the frequency of the sound.

The intensity, $I$, of the transmitted sound is given by the relationship

$$I = I_o \, d^{\,m} f^{\,n}$$

where $I_o$ is the intensity of the incident sound, $d$ is the thickness of the barrier and $f$ is the frequency of the sound.

You are given pieces of soft-board of equal thickness to use as barriers. Design an experiment to measure the transmission of sound intensity through soft-boards in order to determine the value of $m$ and $n$.

You should draw a diagram, on page 21, showing the arrangement of your equipment. In your account you should pay particular attention to

**(a)** the procedure to be followed,

**(b)** the measurements to be taken,

**(c)** the control of variables,

**(d)** the analysis of the data,

**(e)** the safety precautions to be taken.

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**Diagram**

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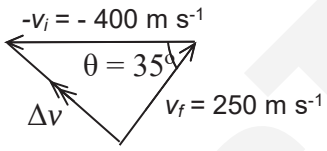
# JC2 Preliminary Exam 2019 (H2 Physics)
# Paper 1 Solutions

| Qn | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ans | C | B | D | C | D | C | C | B | B | B |
| % correct | | | | | | | | | | |

| Qn | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ans | B | D | A | D | C | D | A | C | B | B |
| % correct | | | | | | | | | | |

| Qn | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ans | A | B | B | A | C | C | D | C | D | C |
| % correct | | | | | | | | | | |

| Qn | Ans | Description |
|---|---|---|
| 1 | C | A is precise and accurate (but not the most accurate)<br>B is precise but not accurate<br>D is not precise and not accurate |
| 2 | B | $\Delta v = v_f - v_i = v_f + (-v_i)$<br>  <br><br>$(\Delta v)^2 = 250^2 + 400^2 - 2(250)(400)\cos 35^0$<br>$\Delta v$ = 242 m s$^{-1}$<br><br>**Note:** The negative sign of 400 MUST be removed in the calculation as the 400 represents the length of one side of the triangle which cannot be negative. |
| 3 | D | From t = 0 s to point X, car is accelerating (speeding up). Hence, greatest velocity is at X. From X to Z, car is decelerating (slowing down) but still travelling forward, hence the displacement is still increasing till point Z. |
| 4 | C | $s = ut + \frac{1}{2}at^2$<br>$s_1 = \frac{1}{2}at_1^2, \quad u = 0$<br>$s_2 = \frac{1}{2}at_2^2$<br>$h = s_2 - s_1$<br>$= \frac{a}{2}\left(t_2^2 - t_1^2\right)$<br>$a = \frac{2h}{\left(t_2^2 - t_1^2\right)}$ |

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| | | |
|---|---|---|
| **5** | D | $s = ut + \frac{1}{2}at^2$<br>Since u = 0, $s = \frac{1}{2}at^2$; graph of s vs $t^2$ will be a straight line passing through origin i.e. Graph 1<br>$v^2 = u^2 + 2as$<br>Since u = 0, $v^2 = 2as$; $v = \sqrt{2as}$, hence $mv = m\sqrt{2as}$; graph of mv vs s will be square root graph i.e. Graph 4 |
| **6** | C | Change in momentum = Average force x time<br>$m[v- (-u)] = Ft$<br>$0.060(v + 45) = 95 \times 70 \times 10^{-3}$<br>$V = 66\ ms^{-1}$ |
| **7** | C | Regardless of the nature of the wall, it will exert a normal contact force (horizontally) on to the ladder. To balance it, a horizontal force acting to the left must be provided by the ground. That is only possible if the ground is rough so as to provide a frictional force on the ladder. |
| **8** | B | $U_w + U_m = W$<br>$\rho_w V_w g + \rho_m V_m g = \rho_n V_n g = \rho_n (V_w+V_m) g$<br>$1000\ V_w + 13600\ V_m = 7900\ (V_w+V_m)$<br>$5700\ V_m = 6900\ V_w$<br>$V_w / V_m = 57/69 = 0.826$ |
| **9** | B | The only forces acting on the mass are the tension and the weight, which combines to a resultant centripetal force. |
| **10** | B | Since $W = \frac{GMm}{R_E^2}$ and $-U = -\frac{GMm}{R_E}$, the new weight becomes $\frac{GMm}{(2R_E)^2} = \frac{W}{4}$ and new GPE becomes $-\frac{GMm}{2R_E} = -\frac{U}{2}$, increased by $\frac{U}{2}$. |
| **11** | B | Gravitational force provides the centripetal force.<br>$F = \frac{GMm}{R^2} = m\left(\frac{R}{2}\right)\omega^2$<br>$2GM = R^3(\frac{2\pi}{T})^2$<br>$\frac{2GM}{R^3} = \frac{4\pi^2}{T^2}$<br>$T = \sqrt{\frac{2R^3\pi^2}{GM}}$ |
| **12** | D | Heat gained by A = Heat lost by B<br>$m_A c_A \Delta\theta_{A\to T} = m_B c_B \Delta\theta_{B\to T}$<br>$m_A c_A (75) = m_B c_B (25)$<br>$\frac{c_A}{c_B} = \frac{m_B(25)}{m_A(75)}$<br>$= \frac{4}{3}$ |
| **13** | A | Total number of moles before = Total number of moles after<br>$\frac{P_1V_1}{RT} + \frac{P_2V_2}{RT} = \frac{P(V_1 + V_2)}{RT}$<br>$100 \times 4.0 + 50 \times 6.0 = P \times (4.0 + 6.0)$<br>$P = 70\ Pa$ |

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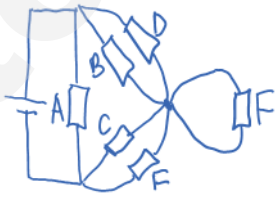
| | | |
|---|---|---|
| **14** | D | The equation of the tide can be modelled as 1.5 = -cos(2πt/12.5) + 2 , where 2 is the equilibrium level, with an amplitude of 1 m and period of 12.5 hours. Solving gives t = 2.08 or 2.1 hours. |
| **15** | C | Max a = $(2\pi x120)^2$ x 40 x $10^{-3}$ = 22716 $ms^{-2}$ and<br>max v = (2πx120) x 40 x $10^{-3}$= 30.1 $ms^{-1}$ |
| **16** | D | Q leads P by $\frac{\pi}{2}$ rad. Equivalently, P leads Q by $\frac{3\pi}{2}$ rad. |
| **17** | A | $\theta_{min} \approx \frac{\lambda}{b} = \frac{550 \times 10^{-9}}{35 \times 10^{-2}} = 1.57 \times 10^{-6}$ rad<br>$\theta_s = \frac{s}{r} \quad \Rightarrow s = r\,\theta_s = r\,\theta_{min} = 200{,}000 \times 1.57 \times 10^{-6} = \underline{0.31\ m}$ |
| **18** | C | Using $d \sin\theta = n\lambda$<br>$(1/ 3.0 \times 10^5) \sin 90^o = n_{max} (600 \times 10^{-9})$<br>$n_{max}$ = 5.56 = 5 (round down)<br>Hence highest order = 5th;<br>∴total number of diffracted images = 5 + 5 = <u>10</u> |
| **19** | B | Effective resistance of B and D<br>= effective resistance of C and E<br>= (10 x 10)/(10 +10) = 5.00 Ω<br><br>Total effective resistance<br>$= (\frac{1}{10} + \frac{1}{10})^{-1}$<br>= 5.00 Ω<br><br>Current through cell = V/I = 9.0 /5.00 = 1.80 A<br>  |
| **20** | B | $P = \frac{E^2R}{(R+2+r)^2} = \frac{6^2R}{(R+7)^2}$<br>$\frac{dP}{dR} = \frac{(R+7)^2 6^2 - 2 \times 6^2 R(R+7)}{(R+7)^4}$<br>$= \frac{6^2(7-R)}{(R+7)^3}$<br>When $\frac{dP}{dR} = 0$, R = 7 Power output is maximum $P_{max}$ = 1.29 W |
| **21** | A | The proton experiences an upward force, $F_E$ = qE = ma.<br>Hence, upward acceleration of proton, $a_{proton}$ = qE / m.<br><br>An alpha particle is a helium nucleus that has approximately 4 times the mass and twice the charge of a single proton.<br>Hence, upward acceleration of helium, $a_{He}$ = 2qE / 4m = 0.5 $a_{proton}$.<br><br>Using $s_y = u_y t + ½ a_y t^2$ and $u_y = 0$,<br>time taken by helium to hit the top plate<br>= $\sqrt{2}$ × time taken by proton to hit the top plate<br><br>However, since horizontal velocity of helium is half of proton, the helium particle will cover a shorter horizontal distance (70.7% of proton's) |

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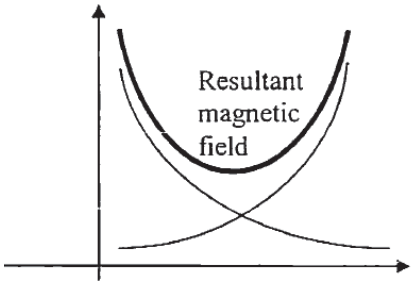
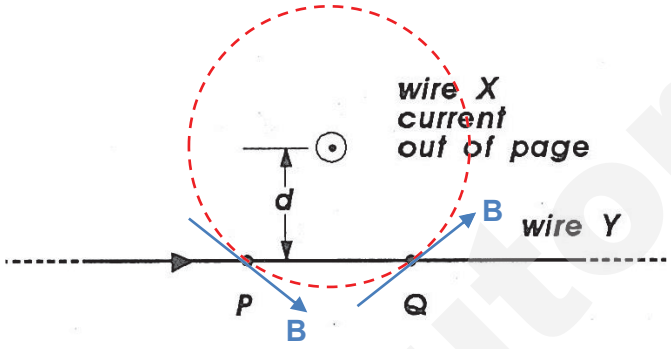
| | | |
|---|---|---|
| **22** | B | Using B = $\frac{\mu_o I}{2\pi r}$<br>  <br> |
| **23** | B |  <br><br>B induced by wire X at P and Q as shown above.<br><br>Resolving the B at P and Q into vertical components and using FLHR, we will get<br>- Force at P into the page<br>- Force at Q out of the page. |
| **24** | A | There is no induced current in the coil as the coil experiences no change in magnetic flux due to the steady flux that the long conductor produces. |
| **25** | C | The induced e.m.f. $\varepsilon$, is proportional to negative of the rate of chance of magnetic flux, hence, the answer is the differential of the original graph. However, this question stated that $\varepsilon$, is the magnitude only so the negative sign can be ignored. |
| **26** | C | Consider each cycle which is represented by 100 ms (in this case, considering each cycle as 50 ms will have the same effect).<br><br>The 100 ms is divided into 4 sectors, and the squared value of each sector is $10^2$, $20^2$, $(-20)^2$ and $(-10)^2$. Their combined sum is 1000.<br><br>The mean of the square value is the combined sum divided by the number of sectors, so it is $\frac{1000}{4}$ = 250.<br>Hence, the root of the mean of the combined sum, ie the root-mean-square,<br>is $\sqrt{(250)}$ = 15.8 V. |

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| | | |
|---|---|---|
| **27** | D | $hf_1 = eV_1 + \phi$.....(1)<br>$hf_2 = eV_2 + \phi$ .....(2)<br><br>(2) – (1)<br>$V_2 – V_1 = 0.35$ V |
| **28** | C | $E = ½ m v^2$ ; $p = mv$<br>$\therefore E = \frac{p^2}{2m}$<br>$p = \sqrt{2mE}$<br><br>$\lambda = h/p = h/\sqrt{2mE}$<br>$\lambda \propto 1/\sqrt{E}$<br>The graph of $\lambda$ vs $1/\sqrt{E}$ is a positive gradient straight line through the origin |
| **29** | D | **Statement 1:** False. The greater the binding energy **per nucleon** of a nucleus, the more stable it is.<br><br>**Statement 2:** False. $\beta$ decay often result in an emission of a daughter nucleus, an electron and a neutrino. It is unlikely that the 3 products will move on in opposite direction.<br><br>**Statement 3:** False. A chemical reaction produces a new radioactive compound but the nuclei are unchanged. Thus, half-life is unchanged. |
| **30** | C | Initial $A_0 = \lambda N_0 = (\ln 2 / 4 \text{ years}) N_0 = 0.1733 N_0$<br><br>After 2 years, $A_1 = \lambda N_1 = 0.1733(N_0 e^{-\lambda(2)}) = 0.1225 N_0$<br><br>For the same treatment, (Duration x Activity) now and 2 years later should be equal.<br><br>Hence, $(10 \text{ mins})(A_0) = (t)(A_1)$<br>$(10)(0.1733 N_0) = (0.1225 N_0)(t)$<br>$t = 14$ min |

**End of solutions**

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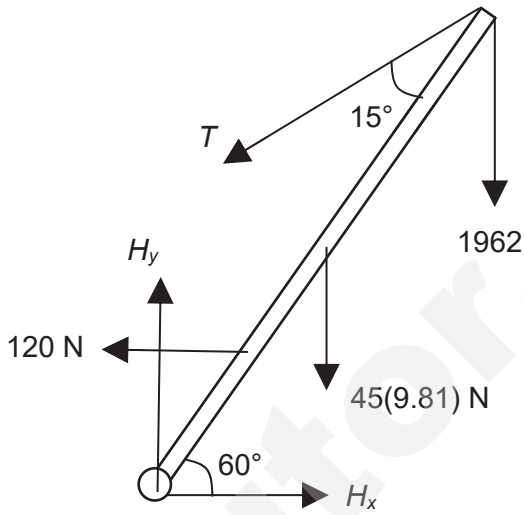
**Solution for 2019 SAJC Prelim Paper 2**

**1** **(a)** Net force is zero (in all direction). [1]
Net moment is zero about any point. [1]
**DO NOT ACCEPT: …a point OR a given point**

**(b)**




Evidence of angle between $T$ and boom (in working) = 15° [1]

Taking moments about the hinge,

(Tsin 15°)(3) + (120sin 60°)(0.75) = (45)(9.81)(1.5cos 60°) + (1962)(3cos 60°)
[1 for correct CW moment]
[1 for correct ACW moment, accept ecf 15°]

T = 4116 = 4.1 kN

**(c)** (Let $H_y$ and $H_x$ be the vertical and horizontal components of the force hinge acts on the boom)

$H_y$ = 1962 + 45(9.81) + Tcos 45° = 5314 N [1]

$H_x$ = 120 + Tsin 45° = 3030 N [1]

Therefore, magnitude of force hinge acts on boom = $\sqrt{5314^2+3030^2}$ = 6120 N
[1, ECF]

Direction of the force = $\tan^{-1}$ (5314 / 3030) = 60.3° above horizontal [1, ECF]

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**2** **(a)** the (mutual) (gravitational) force of attraction between two point masses is proportional to the product of their masses & inversely proportional to the square of their separation. [1]

**(b)** 'Gravity' refers to the gravitational force of attraction acting on an object [1]

while gravitational field strength is gravitational force per unit mass at that point (towards the centre of Earth). [1]

**(c)** $g = \frac{GM_E}{r^2}$, hence $g \propto \frac{1}{r^2}$ [1]

$\frac{g'}{g} = (\frac{6.38 \times 10^6}{6.38 \times 10^6 + 0.12 \times 10^6})^2$ [1]

$g' = 9.45 \text{ N kg}^{-1}$ [1]

**(d)** (The astronaut and spacecraft have the same angular velocity and orbital radius.) (Therefore) they have the same centripetal acceleration / acceleration towards (centre of) Earth / acceleration of free fall (since $a = r\omega^2$). [1]

(Centripetal force is only provided by gravitational force.) Hence contact force is zero and the astronaut feels weightless. [1]

**(e)** Apparent weight, $N = F_G - ma_c$, where $F_G$ is the gravitational force on the person by the Earth and $a_c$ is the centripetal acceleration. [1]

There is no centripetal acceleration at the pole but there is at the equator; hence, the apparent weight is higher at the pole (while that at the equator is smaller by the centripetal force at the equator). [1]

**DO NOT ACCEPT: Earth is bulging at the centre.**

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**3 (a)** *Any three of* [3]

- Intermolecular forces are negligible except during a collision.
- All collisions are perfectly elastic.
- The duration of a collision is negligible compared with time interval between collisions.
- The gas molecules are in rapid, random motion and obey Newton's laws of motion.
- Gas consists of large number of molecules.
- The volume of the all the gas molecules themselves is negligible compared with the volume occupied by the gas. (In other words, the gas consists of mostly empty space)

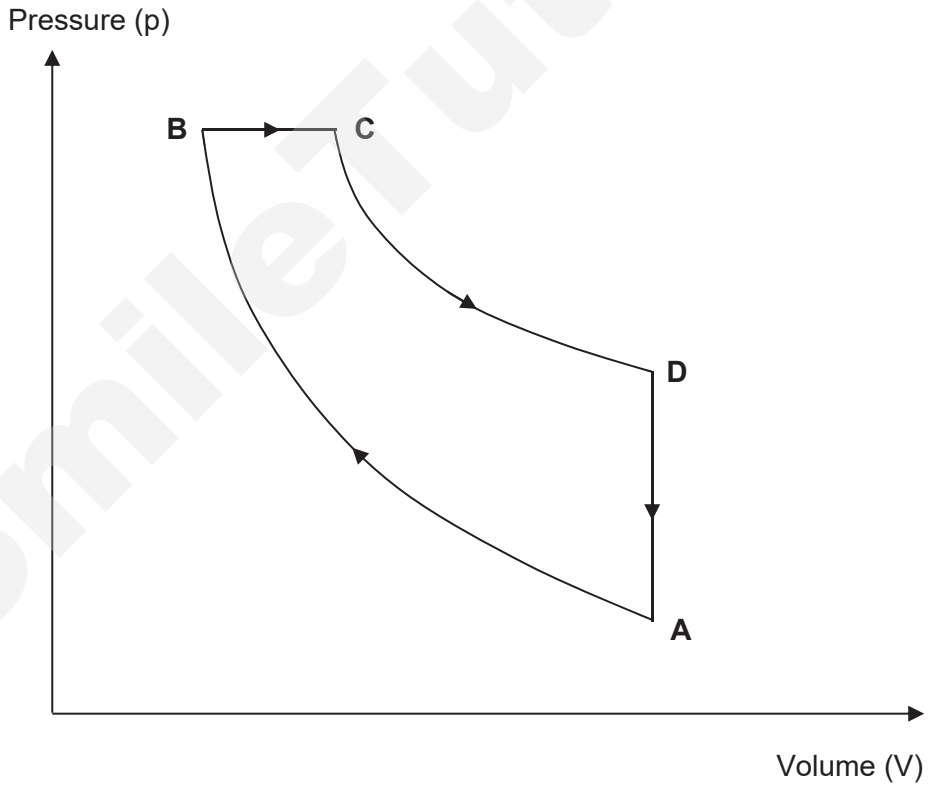
**(b)** $n = \frac{PV}{RT} = \frac{(1.0 \times 10^5)(6.0 \times 10^{-4})}{(8.31)(300)}$ [1]

$= 0.024$ [1]

$N = nN_A = (0.024)(6.02 \times 1023)$

$= 1.45 \times 10^{22}$ [1]

**(c)**




**[First 3 marks given for purely 3 correct lines (no need arrow / and steepness of AB and CD)**
**[Last mark for correct line + arrow + correct steepness of curve]**

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**4** **(a)** **(i)** From the graph, R = 80 Ω, T = 40 Ω, [1]

$E = I R_T$

$3.0 = I (80 + 40)$

$I = 25 \times 10^{-3}$ A [1]

**(ii)** **(**When the temperature increases from 0 ºC to 75 ºC, the resistance of R increases slowly compared to resistance of T, which is decreasing more rapidly, thus,**)** the effective (or total) resistance decreases at a decreasing rate. [1]

{Students who do not describe how the rate of effective resistance changes will only get 0 m}

**(iii)** From the graph at 30 °C,
resistance of R = 55 Ω and resistance of T = 110 Ω
[1 m for both correct. Accept ± 5 Ω]

Using potential divider rule,
p.d. across T = 110/(110 + 55) x 3.0 V = 2.0 V [1]

**(b)** **(i)** Resistance of wire = ρL / A

$= 1.20 \times 10^{-6} \times 1.20 / [\pi \times (0.200 \times 10^{-3})^2]$ [1]

= 11.46 Ω (accept 3 or 4 sf) [1]

**(ii)** p.d. across XY, $V_{XY}$ = [11.46 / (11.46 + 1.0 + 5.0)] x 9.0

= 5.907 V [1]

At balance point, p.d. across XJ = p.d. across thermistor = 2.0 V **(from aiii)**

Therefore, $XJ / XY = V_{XJ} / V_{XY}$

XJ / 1.20 = 2.0 / 5.907

XJ = 0.406 m [1, ECF from part (aiii)]

**(iii)** When the temperature is at 75 °C, the resistances of R and T are equal, the p.d. across thermistor will decrease (to 1.5 V). Hence, the balance length XJ will be shorter. [1]

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**5** **(a)** **(i)** 1.5 T = 15 ms, hence, T = 10 ms [1]

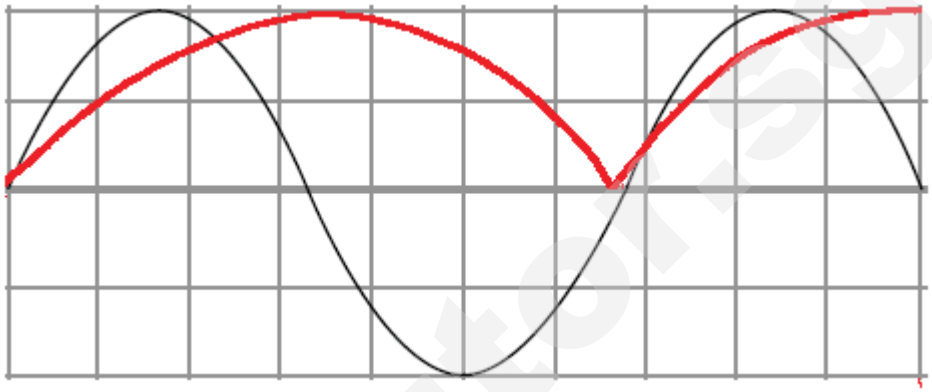
$f = \frac{1}{T} = \frac{1}{0.010} = 100$ Hz [1]

**[Accuracy mark: Penalise 1 m if student get f = 98.8 Hz]**

$V_o = 3.0$ V [1]

$V_{rms} = \frac{V_o}{\sqrt{2}} = 2.12$ V [1]

**(ii)**



**(b)** (High frequency) Alternating current that flows through the induction coil produces changing magnetic field / flux / flux density experienced by the metal cookware. [1]

According to Faraday's law, e.m.f. will be induced in the metal cookware due to the changing magnetic field. [1]

(Eddy) Currents will thus be induced in the metal cookware and heat is dissipated in it, which heats up the food within. [1]

The induction cooker works only on metal cookware because current / emf cannot be induced in non-metallic cookware such as wood or ceramic [1]

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**6 (a) (i)** $\Sigma$ Rest masses before $= 2 \times 3.34454 \times 10^{-27}$ kg $= 6.68908 \times 10^{-27}$ kg
$\Sigma$ Rest masses after $= 5.00835 \times 10^{-27} + 1.67496 \times 10^{-27}$
$= 6.68331 \times 10^{-27}$ kg

Difference in rest masses, $\Delta m = 5.77 \times 10^{-30}$ kg [1]

Using $\Delta E = \Delta mc^2$, Energy released $= 5.77 \times 10^{-30} \times c^2$
$= 5.193 \times 10^{-13}$ J
$= 5.19 \times 10^{-13}$ J [1]

**Note: 1m for answer, 1m for method. Give 1m if student gave a negative (but correct value)**

**(ii)** Since the total energy released is larger than calculated, the reactants must have possessed kinetic energy before the reaction. [1]

**(b) (i)** Loss in KE = Gain in EPE

$$2K - 0 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r} - 0$$ [1]

$$K = \frac{1}{16\pi\varepsilon_0}\frac{e^2}{2r} = \frac{1}{16\pi\varepsilon_0}\frac{(1.6 \times 10^{-19})^2}{(1 \times 10^{-15})} = 5.75 \times 10^{-14} = 5.8 \times 10^{-14} \text{ J}$$ [1]

**Note: Accept if student gives 3 sf (Being lenient)**

**(ii)** $K = \frac{3}{2}$ kT

$T = 2.78 \times 10^9 = 2.8 \times 10^9$ K [1, ECF]

**Note: Accept if student gives 3 sf (Being lenient)**

**(c) (i)** The total energy required to separate a nucleus (completely) into its constituent particles. [1]

**Accept: Total energy release when totally separated nucleons come together to form a nucleus.**

**(ii)** X is the **neutron**. Because it is a **free / individual / single particle** here {or because it is not within a nucleus} it has no binding energy. [1]

**(iii)** Binding Energy of Beryllium = (6.4763)(9) = 58.2867 MeV
Binding Energy of Helium = (7.0819)(4) = 28.3276 MeV
Total Binding Energy of Reactants = 58.2867 + 28.3276 = 86.6143 MeV
Binding Energy of Carbon = (7.6885)(12) = 92.262 MeV
[1 for all 4 values]

Net energy released in the process = B.E(products) - B.E(reactants)
= 92.262 - 86.6143
= 5.65 MeV [1]
$= 5.65 \times 10^6 \times 1.6 \times 10^{-19}$ J
$= 9.04 \times 10^{-13}$J [1]

**Note: Full ecf for 2nd and 3rd mark.**
**Give 1 m for each correct method (i.e. BE(pdt) – BE(rt), convert MeV to J)**

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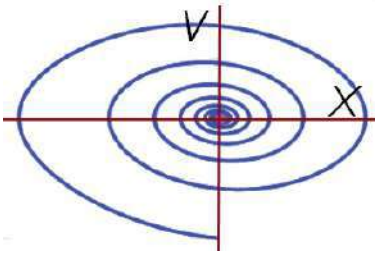
**7** **(a)** Max v at x = -58 m where grad is max [1]
Gradient = -78/(6.8-3.2) = -21.7 m $s^{-1}$ [1]
**(Accept range 18-26 m $s^{-1}$)**

**(b)**




Clockwise spiral, starting from $-V_{max}$ and X = 0 [1]
Decreasing max speed and amplitude [1]
**Note: Give 1 m for anticlockwise spiral**

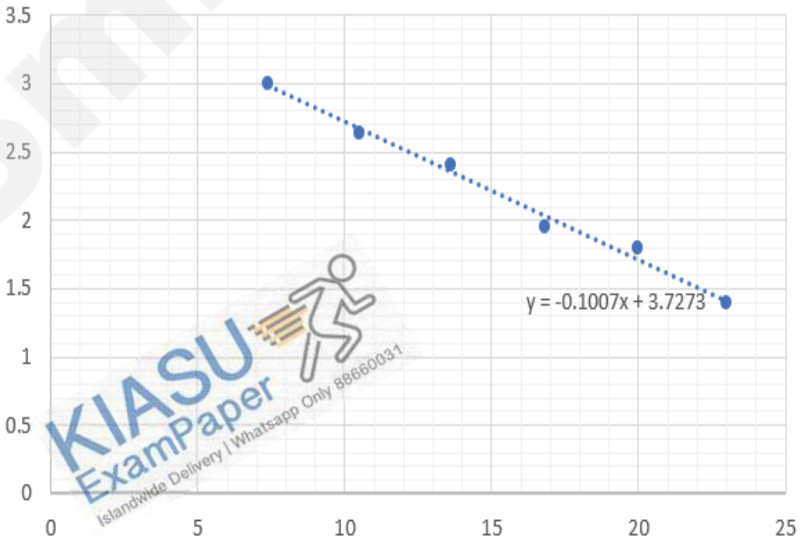
**(c)** **(i)** Position where net force/net acceleration = 0 [1]
**DO NOT ACCEPT: Upward tension by cord = downward weight of cuboid.**

**(ii)**

| Time / s | Position / m | Magnitude of displacement, A / m | ln (A / m) |
|---|---|---|---|
| 7.4 | - 78 | 20 | 3.00 |
| 10.5 | - 44 | 14 | 2.64 |
| 13.6 | - 69 | 11 | 2.40 |
| 16.8 | - 51 | 7 | 1.9 |
| 20.0 | - 64 | 6 | 1.8 |
| 23.0 | - 54 | 4 | 1.4 |

Amplitude column [1]
ln(A/m) column [1]
(**ignore sf totally**)

**(d)**




Plot ln A vs t [1]
-c = gradient = working with coordinates [1] (range 0.09 – 0.11)
c = + 0.1007 $s^{-1}$ [1]
$A_0$ = exp(intercept) or substitution into equation. [1]
$A_0$ = 41.7 m [1] (range 35 – 45)

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**(e)** cuboid is not oscillating / cuboid is free falling [1]

**(f)** **(i)** From the graph, T = 6.2 s (accept 6.0 – 6.4) [1]

**(ii)** Using $\frac{4\pi^2}{T^2} = \frac{k}{m} - (1.00 \times 10^{-2})$, $k = 63.46 \text{ N m}^{-1}$ [1]

Hence, at equilibrium, mg = ke

Solving, we get e = 9.46 m [1]

Note:
T = 6.0, get k = 67.68 and e = ???
T = 6.1, get k = ??? and e = ???
T = 6.3, get k = 61.44765 and e = 9.76
T = 6.4, get k = 59.561 and e = 10.1

**(iii)** Gain in EPE = ½ $ke^2$ = 2838 J
Loss in GPE = mgh = - 34800 J
Gain in KE = ½ (600/9.81)$(21.7)^2$ = 14400 J

**[Give 2 marks for any 2 correct energy changes]**

Change in total energy = -34800 + 14400 + 2838
= - 17562 J
= - 17600 J [1]

**(g)** Thicker cord increases the elastic constant and hence prevents the heavier mass from over-extending the cord, improving safety. (accept cord may snap) [1]

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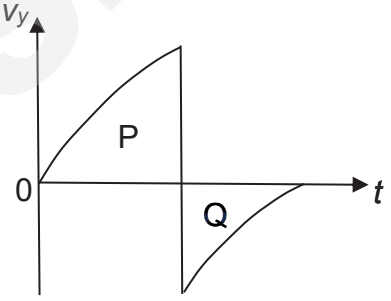
# JC2 Preliminary Exam 2019 (H2 Physics)

## Examiner's Report with answers for Paper 3

| | | |
|---|---|---|
| 1(a) | Displacement is defined as the distance moved in a specific (or certain) direction. | 1 |
| (b)(i) | $s_y = u_y t + \frac{1}{2} a_y t^2$<br>$1.96 = \frac{1}{2}(9.81) t^2$<br>$t = 0.632$ s<br><br>$v t = 2.53$<br>$v = 2.53/0.632 = \underline{4.00 \text{ m s}^{-1}}$ | M1<br><br>M1<br>A1 |
| (ii) | $v_y^2 = u_y^2 + 2a_y s$<br>$= 2(9.81)(1.96)$<br>$v_y = \underline{6.20 \text{ m s}^{-1}}$<br><br>**OR**<br>$v_y = u_y + a_y t$<br>$= (9.81)(0.632)$<br>$= \underline{6.20}\ \underline{\text{m s}^{-1}}$<br><br>**OR**<br>$mgh = \frac{1}{2} m v_y^2$<br>$v_y^2 = 2(9.81)(1.96)$<br>$v_y = \underline{6.20 \text{ m s}^{-1}}$ | M1<br>A1 |
| (iii) | $\tan\theta = \frac{v_y}{v_x} = \frac{6.20}{4.00} = 1.55$<br>$\theta = \underline{57.1°}$ | 1 |
| (iv) | $\underline{9.81 \text{ m s}^{-2}, \text{downwards}}$ | 1 |
| (c) |  <br><br>➢ Correct shape {AB: curve of decreasing gradient, B: vertical or almost vertical line, BC: curve of decreasing gradient}<br><br>➢ Area P greater than area Q **AND** magnitude of $v_y$ just before impact is greater than magnitude of $v_y$ just after impact. | 1<br><br>1 |

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**2 (a) (i)** **Method 1**

Consider P and Q as 1 system.

$W_Q - W_P = (m_Q + m_P)\, a$

$(1.00)(9.81) - (0.50)(9.81) = (1.00 + 0.50)a$ [1]

$a = 3.27\ m\ s^{-2}$ [1]

**Method 2**

Consider each mass separately,

$T - W_P = m_P\, a$ ---(1)

$W_Q - T = m_Q\, a$ ---(2)

Solving the simultaneous equations (1) + (2),

$(1.00)(9.81) - (0.50)(9.81) = (1.00 + 0.50)a$ [1]

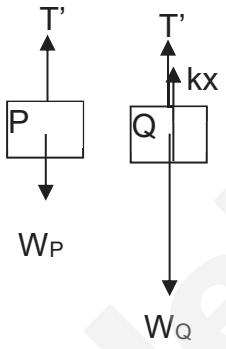
$a = 3.27\ m\ s^{-2}$ [1]

**(ii)** From equation (1) in 1(a)(i),

$T = 0.50(9.81) + 0.50(3.27)$ [1]

$= 6.54$ N (accept 3 or 4 s.f.) [1]

**(iii)**




After Block Q comes to a stop, the forces acting on P and Q are in equilibrium.

$T' = W_P$ ---------- (3)

$T' + kx = W_Q$ ---------- (4)

Substitute (3) into (4)

$0.50(9.81) + 200x = 1.00(9.81)$ [1]

$x = 0.0245$ m (3 s.f.) [1]

**(iv)** (All) initial KE is converted to EPE, which is (all) converted back to KE finally.
Hence, k.e. is conserved and collision is elastic. [1]

**(b) (i)** By conservation of momentum,

Intial momentum of bullet = final momentum of bullet and block

$m_{bullet} \times 100 = (m_{bullet} + m_{block})v$ [M1]

$v = 0.990\ ms^{-1}$

By conservation of energy,

Loss in k.e. of bullet and block = Gain in g.p.e of bullet and block

$\frac{1}{2}(m_{bullet} + m_{block})v^2 = (m_{bullet} + m_{block})gh$

$h = \frac{1}{2}(0.990)^2/(9.81) = 0.050$ m [A1]

**(ii)** The collision is perfectly inelastic. [1]

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**3** **(a)** **(i)** $a = \frac{v - u}{t} = \frac{24.72 - 0}{4.5} = 5.493 \text{ m s}^{-2}$ [1]

$P_{ave} = F(\frac{1}{2}v_{max}) = ma(\frac{1}{2}v_{max}) = (6500)(5.493)(\frac{1}{2})(24.72) = 441 \text{ X } 10^3 \text{ W}$ [1]

**(accept P = change in KE/ time)**

**(ii)** Loss in KE = Gain in GPE

$\frac{1}{2}mv^2 = mgh$

$h = \frac{v^2}{2g} = \frac{24.72^2}{2(9.81)} = 31.2 \text{ m}$ [1]

Hence it will not go beyond the track which is 45.0 m tall.
(accept comparing KE and GPE)

**(iii)** Let the speed of the train at the top of the loop be $v_{top}$,

$\frac{1}{2}mv_{top}^2 = \frac{1}{2}mv^2 - mgh$

$v_{top} = 12.6 \text{ m s}^{-1}$ [1]

To stay on the seat (and not fall off) at the top of the inner loop, N > 0.

$N + mg = \frac{mv_{min}^2}{r}$, $N = \frac{mv_{min}^2}{r} - mg$

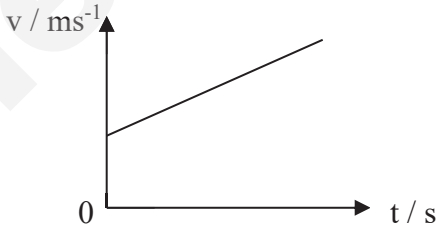
Hence, to not fall off, N > 0 and therefore $v_{min} > \sqrt{(rg)}$.

$\sqrt{(rg)} = \sqrt{(11.5)(9.81)} = 10.6 \text{ m s}^{-1}$ [1]

(accept calculating N instead)

Since $v_{top} > 10.6 \text{ m s}^{-1}$, the rider will not fall off if the lap-bar mechanism fail. [1]

**(b)** $v = r\omega \rightarrow v \propto r \propto t$ (since ω is constant and r is increasing at a steady rate)




Straight line [1]
Non-zero start and increasing [1]

**(c)** $m r \omega_{max}^2 = \frac{1}{2} mg$ [1]

$\rightarrow \quad \omega_{max} = \sqrt{\frac{g}{2r}}$ [1]

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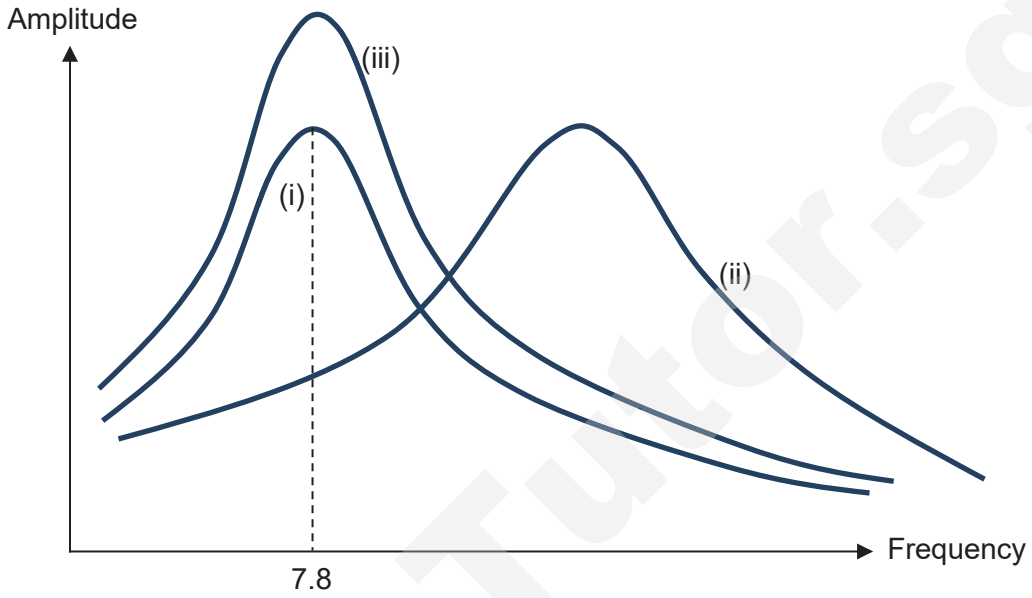
**4** **(a)** **(i)** $k = 3.0 \text{ N cm}^{-1} = 300 \text{ N m}^{-1}$
$\omega^2 = 2k/m = (2\times300) / 0.25$ [1]
$f = \omega/(2\pi) = 7.80 \text{ Hz}$ [1]

**(ii)** Max $v = \omega x_o$ [1]
$= 0.735 \text{ m s}^{-1}$ [1]

**(b)**




**Graph (i):** Shape [1]
Peak at 7.8 Hz (ecf for f from part a) [1]

**Graph (ii):** similar shape at higher f (same amplitude) [1]

**Graph (iii):** similar shape at same f (or slightly to the right) as graph (i) but higher peak [1]

**(c)** To maintain ω when m changes to 2 m, need to increase k to 2k. [1]

Add 2 similar springs, 1 in parallel to each spring. [1]
**OR**
Change to a (stiffer) spring with spring constant 2k. [1]

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**5** **(a)** **(i)** Since electromagnetic radiation is emitted when an electron falls from one discrete (specific) level to another discrete level / discrete energy levels, [1]

the photons emitted have discrete (specific) amount of energy, hence specific wavelengths since E = hf. [1]

**(ii)** $hc/\lambda = -2.5 - (-69.5) = 67.0$ keV [M1]

$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (67.0 \times 10^{3} \times 1.6 \times 10^{-19})$

$= 1.9 \times 10^{-11}$ m [A1]

**(b)** 100kV spectrum shows a lower minimum wavelength (x-intercept value) compared to that of 80 kV. From $eV = hc/\lambda_{min}$ , Since V is larger, $\lambda_{min}$ will be smaller. [1]

100 kV spectrum has higher intensity throughout since at higher voltage, electrons are emitted with higher energy. Hence, it is possible to have more collisions per unit time to produce more photons per unit time will be emitted from the tungsten. Thus increasing the intensity of the X-ray as Intensity $\alpha$ nhf. [1]

Characteristic lines of both spectra occur at the same wavelength since characteristic lines are formed through the release of photons when electrons move from higher energy level to lower ones. As the energy levels of Tungsten are fixed regardless of the voltage, the emitted photons have the same wavelengths. (accept same metal as explanation) [1]

**(c)** Electrons behave as particles and as waves. [1]
Electron diffraction, showing wave behaviour. [1]
Electrons are deflected in electric or magnetic fields showing particle behaviour
Or electron transition between energy levels
Or Photoelectric
Or Production of X-rays
Or Collisions with atoms [1]

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**6 (a) (i)** Using $A = A_0e^{-\lambda t}$, and $A_0 = 3000$

at t = 2.0 years, A = 2700, $\lambda_1 = 0.0527$
at t = 6.0 years, A = 2220, $\lambda_2 = 0.0502$
at t = 8.0 years, A = 2020, $\lambda_3 = 0.0494$ [1, correct calculation of any 1 λ]

Therefore, average λ = 0.0508
[1, using at least 3 points to determine λ]

Hence, half-life = ln 2 / 0.0508 [1]
= 13.7
= 14 years

**(ii)** Number of Plutonium-241 nuclei : Number of Americium-241 nuclei = 3 : 1

This means **¼ of Plutonium-241 nuclei has decayed** and changed to Americium-241 nuclei. **¾ of Plutonium-241 nuclei is remaining**.

$\frac{3}{4} N_0 = N_0 e^{-\lambda t}$ [1]
$t$ = 5.6 years (using λ = 0.051) or 5.8 years (using $t_{1/2}$ = 14 years) [1]

**(b)** Number of nuclide = 0.0010 / 60u = $1.004 \times 10^{22}$

Using A = λN, $A = \left(\frac{\ln 2}{5.27 \times 365 \times 24 \times 3600}\right)(1.004 \times 10^{22})$
$= 4.187 \times 10^{13}$ [1]

Power of radiation = (activity)(energy emitted per activity)
$= (4.187 \times 10^{13})(1.17 + 1.33)(10^6)(1.6 \times 10^{-19})$
= 16.75 W [1]

Intensity = Power / Area = $16.75 / 4\pi(1.5)^2 = 0.592$ W $m^{-2}$ [1]

**(Note: ECF for 2nd and 3rd marks)**

**(c)** 'random' here means:

- it is impossible to know when a nucleus will disintegrate/which nucleus will disintegrate next, [1]
- even though the probability of decay per unit time of a nucleus is constant. [1]

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**Section B**

| | | |
|---|---|---|
| **7(a)(i)** | When two or more waves of the same type meet/superpose {NOT: superimpose} at a point,<br><br>the resultant displacement {NOT: amplitude} of the waves is equal to the vector sum of their individual displacements at that point. | 1<br><br>1 |
| **(ii) 1.** | Two waves are coherent if they have a constant phase difference between them.<br>Do NOT accept: same phase or zero phase difference | 1 |
| **2.** | The two interfering waves coming from a single source are coherent.<br>OR<br>Light from two separate light sources is not coherent. | 1 |
| **(iii)** | Fringe separation, x = 26 mm/12 = 2.17 mm<br><br>$\lambda = ax/D$<br><br>$\lambda = \frac{0.38 \times 10^{-3} \times 2.17 \times 10^{-3}}{1.20}$<br>$= 6.87 \times 10^{-7}$ m | A1<br><br>M1<br><br><br>A1 |
| **(iv)** | Light reaching the eye comes from two beams. The direct beam and reflected beam are coherent as they come from the same slit.<br><br>At locations where the waves are in phase, constructive interference occurs producing maxima intensity. At other locations where the waves are anti-phase, destructive interference occurs producing minima intensity. | 1<br><br>1 |
| **(b)(i)** | Where there are depressions, wave has maximum amplitude / is at an antinode.<br><br>Where there are heaps, wave has zero / minimum amplitude / is at a node. | 1<br><br>1 |
| **(ii)** | $2\lambda = 20.0$ cm<br>$\rightarrow \lambda = \frac{0.20}{2} = 0.10$ m<br><br>$v = f\lambda$<br><br>$f = \frac{330}{0.10} = 3300$ Hz (ecf $\lambda$) | 1<br><br>1<br><br>1 |
| **(iii) 1.** | No motion / vibrate with minimum amplitude | 1 |

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| | | |
|---|---|---|
| **2.** | Vibrate parallel to the length of tube / horizontally with maximum amplitude. | 1 |
| **(c)(i)** | $I_2 = I_1 \cos^2 23^0$<br>$= 147 \cos^2 23^0$<br>$= 125 \text{ W cm}^{-2}$ | 1<br><br>1 |
| **(ii)** | Intensity $\alpha$ Amplitude$^2$,<br><br>$\therefore \quad \frac{125}{147} = \frac{k A_2^2}{k A_1^2} \Rightarrow \frac{A_2}{A_1} = 0.922$<br><br>fractional reduction in amplitude $= \frac{A_1 - A_2}{A_1} = 1 - \frac{A_2}{A_1} = 1 - 0.922 = 0.078$ | <br><br>1<br><br>1 |

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**8 (a)** Electric force is independent of speed of the charged particle, whereas magnetic force is proportional to speed. [1]

Electric force is directed along E-field direction, whereas magnetic force is directed perpendicular to B-field direction. [1]

**(Note: Answers should compare both Electric force and Magnetic force. Elaborating on only 1 force is not sufficient.**

**Penalise if student mentioned Electric force is <u>in the direction</u> of E-Field.)**

**(b) (i)** Since charge is positive, electric force on charge is directed towards –ve plate (downwards). [1]

For the charge to move without deflection, the magnetic force should be directed towards the +ve plate (upwards). [1]

Using <u>Fleming's left hand rule</u>, with magnetic force directed towards +ve plate and conventional current directed towards the right, magnetic field should be directed <u>into the page</u>. (award 1 m for using FLHR correctly) [1]

**(ii)** $Bqv = q(V/d)$
$Bv = V/d$ [1]
$B\ (1.37 \times 10^{6}) = 3600 / 0.0275$
$B = 0.0956\ T$ [1]

**(iii)** Since magnetic force is always directed perpendicular to the velocity of the particle, [1]
the magnetic force provides the centripetal force. [1]
Hence, the particle will move in a circular path.

**(iv)** Mass of the charged particle = $(6.64 \times 10^{-27}) / (1.66 \times 10^{-27}) = 4u$ [1]
$Bqv = mv^2 / r$
$q = mv / Br$
$= (6.64 \times 10^{-27})(1.37 \times 10^{6}) / (0.0956)(0.300)$
$= 3.2 \times 10^{-19}\ C$ [1]

Since the charged particle has mass 4u and charge +2e, it is possibly an alpha particle.

**(Note: Give only 1 m if student uses q/m method)**

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**(v)** $qE = ma_y$

$$a_y = \frac{(3.2 \times 10^{-19})(\frac{3600}{0.0275})}{(6.64 \times 10^{-27})} = 6.309 \times 10^{12}$$ [1]

Using $s_y = u_y t + \frac{1}{2} a_y t^2$, we get $\frac{1}{2}(0.0275) = 0 + \frac{1}{2}(6.309 \times 10^{12})(t^2)$
$t = 6.602 \times 10^{-8}$ s [1]

Therefore, $s_x = u_x t = (1.37 \times 10^{6})(6.602 \times 10^{-8}) = 0.0905$ m [1]

Since $s_x < 0.10$ m, the charged particle will collide with the plate.

**(Note: Penalise 1m if no or wrong conclusion)**

**ALTERNATIVELY,**

$qE = ma_y$

$$a_y = \frac{(3.2 \times 10^{-19})(\frac{3600}{0.0275})}{(6.64 \times 10^{-27})} = 6.309 \times 10^{12}$$ [1]

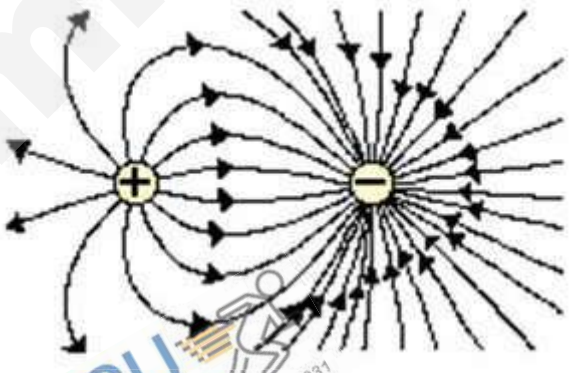
Using $s_y = u_y t + \frac{1}{2} a_y t^2$, we get $\frac{1}{2}(0.0275) = 0 + \frac{1}{2}(6.309 \times 10^{12})(t^2)$
$t = 6.602 \times 10^{-8}$ s [1]

Minimum time required to pass the plate horizontally $= 0.10 / (1.37 \times 10^{6})$
$= 7.3 \times 10^{-8}$ s [1]

Since t < minimum time required, the charge particle will collide with the plate.

**(Note: Penalise 1m if no or wrong conclusion)**

**(c) (i)**



- correct direction of the field lines [1]
- turning point nearer to the (weaker) positive charge and more field lines entering the (stronger) negative charge. [1]

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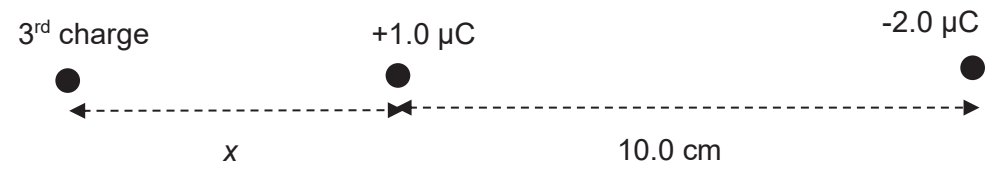
**(ii)**



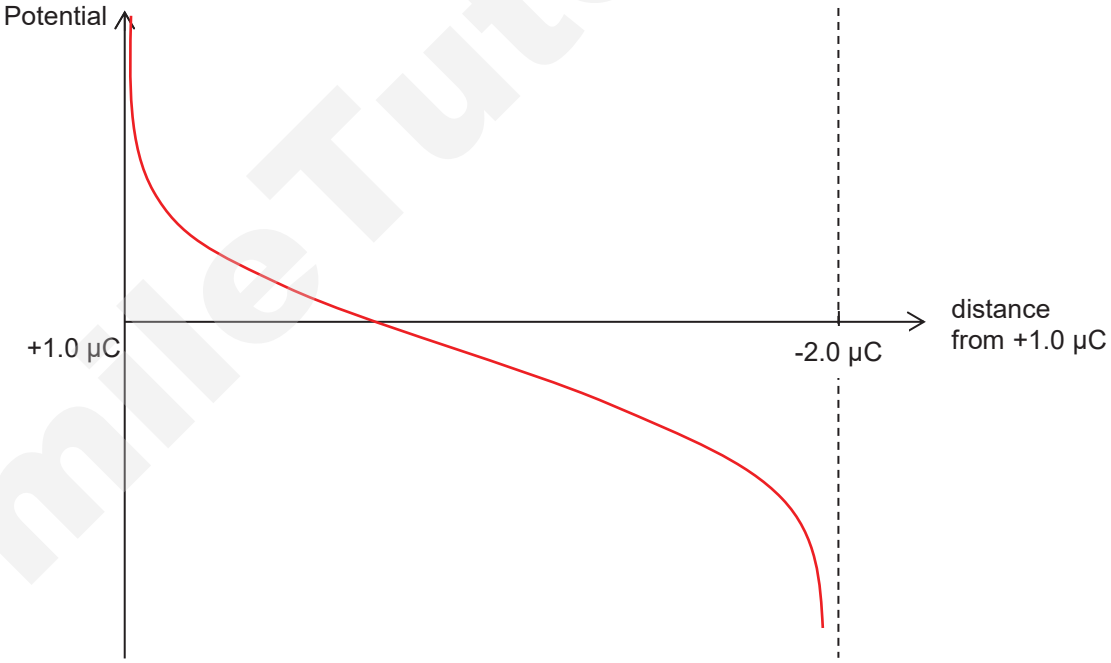

Evidence in student's working showing 3rd charge to be on the LEFT of the +1.0 μC charge (either through diagram or indicate qualitatively in final answer) [1]

$$\frac{(1.0\times10^{-6})q}{4\pi\varepsilon_0 x^2} = \frac{(2.0\times10^{-6})q}{4\pi\varepsilon_0(0.10+x)^2}$$

$$0.10 + x = \sqrt{2}x$$

$x$ = 0.10 / ($\sqrt{2}$ - 1) = 0.24 m [1]

**(iii)**




- correct shape (asymptotic at both end) [1]
- x-intercept nearer to the +1.0 μC charge [1]

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**Mark scheme for Prelim Practical Q1**

| No | Marking Point | Score |
|---|---|---|
| (a)(iv) | Measurement and Observation<br>□ Recorded $V_0$ to the nearest 0.01 V | /1 |
| (v)<br>1 & 2 | □ Recorded both ammeter readings to the nearest 0.1 mA | /1 |
| (b) | □ Recorded $x$ to the nearest mm<br>□ Recorded $I$ to the nearest 0.1 mA | /1 |
| (c) | Tabulation<br>Collected **6 sets** of raw data (i.e $x$ and $I$)<br>{1 mark for 5 sets, zero mark for 4 or less sets. Deduct up to 2 marks if student requires assistance.} | /2 |
| | Range of data/Independent variable<br>Range of $x \geq 50$ cm<br>{In general, the range of independent variable should be at least 75% of the maximum possible range.} | Nil |
| | Column Heading<br>□ Each column heading must contain a **quantity and a unit**: $x$/cm, $I$/mA and $(\frac{1}{x})$ /cm$^{-1}$.<br>□ No split table | /1 |
| | Raw data (i.e $x$ and $I$): Precision of recording<br>□ All values of x to nearest mm &<br>□ All values of $I$ to nearest 0.1 mA | /1 |
| | Calculated quantity: Precision & consistency<br>All values of $(\frac{1}{x})$ recorded consistently to same number of sf as $x$ or, consistently 1 more sf. | /1 |
| | Calculated quantity: Accuracy of calculation<br>All values of $(\frac{1}{x})$ calculated correctly. | Nil |
| (d) | Graph: Scale, Size & Axes<br>□ Sensible scales, no awkward scales (eg 3 units into 10 small squares)<br>□ Plotted pts occupy at least ½ **the graph grid in both x & y directions**<br>□ Axes labelled with the quantity & unit {ECF for wrong units in (c)}<br>□ Successive scale markings: no more than 20 small squares apart. | /1 |

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| | | |
|---|---|---|
| | Plotting of Points<br>□ ALL observations in table must be plotted<br>□ accurate to within half a small square.<br>□ **Thickness of plots** (ie the crosses, 'x') ≤ half a small square | /1 |
| | Best fit line & Anomaly<br>□ **Minimum number of 4** non-anomalous points.<br>□ Line drawn with **approx. equal number** of points on either side of line (anomalous points not considered).<br>□ Line not be kinked/disjointed or thicker than half a small square<br>□ Anomalous plot **clearly indicated** (eg by a circle or labelled.)<br>Allow 1 anomalous plot only.<br>{Rule of thumb: A plot is considered anomalous if it is > 4 mm from line of best fit.} | /1 |
| | Determination of Gradient<br>□ Recorded the **4 coordinates** for gradient calculation **correctly**<br>□ Hypotenuse of triangle **> half length** of line drawn<br>□ **No obscurity** of the 2 points used for gradient calculation. {Hence triangle must not be drawn too near a data plot.} | /1 |
| | Determination of y-intercept<br>Vertical intercept calculated using a point on the line {not from the table} & value of gradient.<br>{Allow reading off the y- intercept if x-axis starts from zero & there is no 'bunching of plots'} | /1 |
| | Linearisation of Eqn<br>□ Stated explicitly: *P* = gradient of graph<br>□ Stated explicitly: *Q* = y-intercept<br>□ Unit for P: **mA m**<br>□ Unit for Q: **mA**<br>□ Values of P and Q written to **3 sf** | /1 |
| (e) | *L* correctly calculated and recorded to the least no. of sf among P and Q {or 1 more} | /1 |
| (f)(iv) | Stated one of the statements below:<br>Statement 1:<br>Since point Z is **close to** the best fit line, it **agrees** with the pattern of the other points.<br>OR<br>Statement 2:<br>Since point Z is **far from** the best fit line, it **does not agree** with the pattern of the other points. | /1 |

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| | | |
|---|---|---|
| | Obtained the value of current from the graph when $x$ = 40.0 cm. Calculated the difference in current, $\Delta I_1$ between the current obtained from the graph and the current obtained in (f)(ii).<br><br>Calculate half the range (accept full range) of current, $\Delta I_2$ between the values obtained in (a)(v).<br><br>Justify Statement 1 by showing that: $\Delta I_1 \leq \Delta I_2$.<br><br>Justify Statement 2 by showing that: $\Delta I_1 > \Delta I_2$. | /1 |
| | Total: | 17 |

**Mark scheme for Prelim Practical Q2**

| No | Marking Point | Score |
|---|---|---|
| (b)(i) | Measurement and Observation<br>Recorded **two values** of $S_1$ and **two values** of $S_2$, and their **averages** to **nearest 0.001 m (i.e. 0.1 cm).** | /1 |
| (ii) | $p$ and $q$ calculated correctly, and recorded to **nearest 0.001 m (i.e. 0.1 cm).** | /1 |
| (c)(i) | $k$ calculated correctly (i.e. ***m* in kg**, ***p* and *q* in m**) and recorded to the **least no. of sf among *p, q, m* and *g*** {or 1 more} | /1 |
| (ii) | Linearised correctly the equation.<br><br>eg. Plot mg against $\sqrt{\frac{p^2}{4} + q^2}$ | /1 |
| | $k$ determined correctly based on candidate's choice of graph.<br><br>eg. $k$ = gradient of the graph<br><br>k has to be expressed as the subject of the equation. | /1 |
| | Total | /5 |

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**Mark scheme for Prelim Practical Q3**

| No | Marking Point | Score |
|---|---|---|
| (a)(ii) | Measurement and Observation<br>Recorded **two values** of $\theta$ and **average** to the **nearest degree**. | /1 |
| (iii) | ☐ Estimate $\Delta\theta$ = **2° to 4°**<br>☐ Calculated percentage uncertainty, $\frac{\Delta\theta}{\theta}$ x 100% = …….. and recorded to **1 or 2 sf. {No mark for 3 sf.}** | /1 |
| (iv) | Correctly calculated sin($\theta$/2) and recorded to the same sf as $\theta$ {or 1 more} | /1 |
| (b)(ii) | Measurement and Observation<br>Recorded **two values** of C and **average** to **nearest 0.001 m (i.e. 0.1 cm).** | /1 |
| | ☐ Estimate $\Delta C$ = **2 mm to 4 mm**<br>☐ Calculated percentage uncertainty, $\frac{\Delta C}{C}$ x 100% = …….. and recorded to **1 or 2 sf. {No mark for 3 sf.} (ECF for $\Delta C$)** | /1<br>/1 |
| (b)(iii) | Measurement and Observation<br>☐ Recorded **two values** of oscillation time $t$ to the **nearest 0.1 s** and $T$ correctly calculated to the same sf as $t$ {or 1 more}<br>☐ Penalise if T < 3 s for wrong mode of oscillation.<br>☐ Total time t must be >= 20.0 s | /1 |
| (c) | ☐ Recorded $\theta$ to the **nearest degree**.<br>☐ Correctly calculated sin($\theta$/2) and recorded to the same sf as $\theta$ {or 1 more} | /1 |
| | ☐ Recorded **two values** of oscillation time $t$ to the **nearest 0.1 s** and $T$ correctly calculated to the same sf as $t$ {or 1 more}<br>☐ Value of $T$ should be greater than that in (b)(iii). | /1 |
| (d)(i) | Calculated correctly **two values** of k **with unit** and recorded to the **least no. of sf among *T, C, $\theta$* and *m*** {or 1 more}. Unit: s $m^{-1}$ $kg^{-0.5}$ | /1 |
| (ii) | Justification of Relationship<br>☐ Calculated correctly $\frac{\lvert k_1 - k_2 \rvert}{k_{ave}}$ x 100<br>☐ Chose a criterion from the **sum of** the values in (a)(iii) and (b)(ii)<br>☐ Concluded that **results do not support the suggestion** if $\frac{\lvert k_1 - k_2 \rvert}{k_{ave}}$ x 100 > the criterion chosen.<br>OR<br>Concluded **results support the suggestion** if $\frac{\lvert k_1 - k_2 \rvert}{k_{ave}}$ x 100 ≤ the criterion chosen. | /1 |

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<table>
<tr><td>(e)(i)</td><td>Tabulate two sets of results (for short & long wires) with column headings and units.<br><br>eg<br><table><tr><th>Wire</th><th>C/cm</th><th>No. of oscillations</th><th>$t_1$/s</th><th>$t_2$/s</th><th>T/s</th></tr><tr><td>shorter</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>longer</td><td></td><td></td><td></td><td></td><td></td></tr></table><br>{Award 1 mark only if two sets of results are shown without grid lines or tabulation.}</td><td>/2</td></tr>
<tr><td></td><td>Calculated and recorded two values of k with unit {s $m^{-1}$ $kg^{-0.5}$, allow ECF}.</td><td>/1</td></tr>
<tr><td>(ii)</td><td>Calculate percentage difference in $k_{ave}$ in (d)(i) vs (e)(i).<br><br>If the percentage difference > 10%, stated that the values of k in (e)(i) and in (d)(i) is different.<br><br>If the percentage difference < 10%, stated that the values of k in (e)(i) and in (d)(i) is approximately the same.</td><td>/1</td></tr>
<tr><td></td><td>Calculate the percentage difference in k for (e)(i).<br><br>Stated that the percentage difference in k for (e)(i) is greater {or smaller} than that in (d)(i).</td><td>/1</td></tr>
<tr><td>(f)</td><td><u>Control of Variable:</u><br>Keeping <u>C, $\theta$ (and m) constant</u> throughout the experiment.<br><br><u>Procedure:</u><br>Take the time for N oscillations and calculate period T.<br>Repeat the experiment for different values of n<br><br><u>Analysis:</u><br>Linearisation: Plot a graph of <u>T against (1/n)</u>.<br>If a <u>linear graph</u> passing <u>through the origin</u> is obtained, then T is inversely proportional to n.<br><br><u>Validity of conclusion:</u><br>(As the value of n is limited by the circumference of the rubber band), it is <u>not possible to obtain many sets</u> of readings to improve the validity of the conclusion.</td><td>/1<br><br>/1<br><br>/1<br>/1<br><br>/1</td></tr>
<tr><td></td><td>Total</td><td>21</td></tr>
</table>

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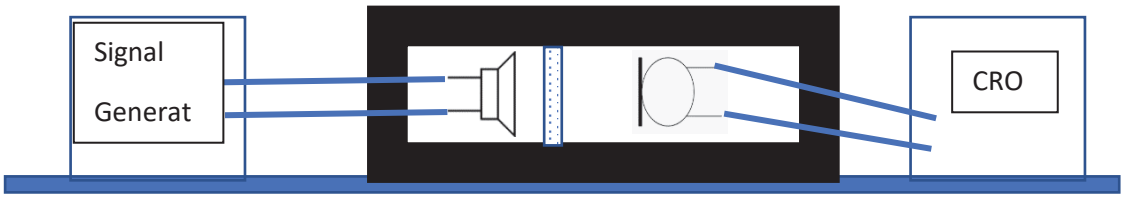
**Markscheme for Planning**

| Item | Mark |
|---|---|
| Defining the problem<br>• **Dependent:** Intensity / output voltage of microphone<br>**Independent:** d<br>**Constant:** f and sound intensity / distance between source-sensor.<br>• **Dependent:** Intensity / output voltage of the microphone<br>**Independent:** f<br>**Constant:** d and the sound intensity / distance between source-sensor. | /1<br>/1 |
| Mtd of collecting data<br>• A labelled and workable diagram, showing the sound from a loudspeaker connected to a source (connected to a signal generator) on one side of barrier and<br>• microphone / sensor connected to datalogger / CRO / sound intensity meter on the other side of a barrier.<br><br>For Intensity against d<br>• Measure thickness of material using ruler/venier calipers. Measure intensity using sound intensity meter / datalogger / peak voltage of microphone signal on CRO. (Set constant sound voltage/amplitude and frequency on loudspeaker.)<br>• Change thickness of d by adding extra layers and repeat measurement of d and peak voltage for 10 sets of data.<br><br>For Intensity against f<br>• Measure frequency using datalogger / CRO (**NOT** sound intensity meter) and intensity using sound intensity meter / datalogger / peak voltage of microphone signal on CRO. (Set constant sound voltage/amplitude and thickness of barrier.)<br>• Change frequency by adjusting signal generator / laptop software and repeat measurement of peak voltage and f for 10 sets of data. | /1<br>/1<br><br>/1<br>/1<br><br>/1<br><br>/1 |
| Mtd of analysis<br>• Plot a graph of log(V) against log(d) (when f is constant), gradient gives m/2<br>• Plot a graph of log(V) against log(f) (when d is constant), gradient gives n/2<br>OR<br>• Plot a graph of log(I) against log(d) (when f is constant), gradient gives m<br>• Plot a graph of log(I) against log(f) (when d is constant), gradient gives n | /1<br>/1<br><br>/1<br>/1 |
| Additional details/safety Max 2<br>• Use ear plug/muff for open setup, to protect ears against high I. (noise cancelling headphone not accepted since not common lab apparatus)<br>• Perform expt in quiet/sound proof room/enclosed container<br>**OR** Some form of sound insulation between loudspeaker/microphone.<br>• Explain how frequency is obtained from CRO reading.<br>• Explain how I is related to peak voltage of CRO.<br>• Mtd of ensuring that output from speaker is constant.<br>• Mtd to ensure that loudspeaker/microphone and board are aligned. | /2 |

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# TAMPINES MERIDIAN JUNIOR COLLEGE

## JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME: _____

CIVICS GROUP: _____ (  )

## H2 Physics 9749/01

Paper 1 Multiple Choice **27 September 2019**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, Civics Group and index number on the Answer Sheet in the spaces provided.

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

**Read the instructions on the Answer Sheet very carefully.**

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

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


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**Data**

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

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**Formulae**

| | | | |
|---|---|---|---|
| uniformly accelerated motion | $s$ | = | $ut + \frac{1}{2}at^2$ |
| | $v^2$ | = | $u^2 + 2as$ |
| work done on/by a gas | $W$ | = | $p\Delta V$ |
| hydrostatic pressure | $p$ | = | $\rho gh$ |
| gravitational potential | $\phi$ | = | $-Gm/r$ |
| temperature | $T$ /K | = | $T$ /°C + 273.15 |
| pressure of an ideal gas | $p$ | = | $\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E$ | = | $\frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x$ | = | $x_o \sin \omega t$ |
| velocity of particle in s.h.m. | $v$ | = | $v_o \cos \omega t$ |
| | | = | $\pm \omega\sqrt{x_o^2 - x^2}$ |
| electric current | $I$ | = | $Anvq$ |
| resistors in series | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R$ | = | $1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V$ | = | $\frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | □ | = | $x_o \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B$ | = | $\frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B$ | = | $\frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B$ | = | $\mu_0 nI$ |
| radioactive decay | $x$ | = | $x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda$ | = | $\frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** Jupiter is at a distance of 0.59 Tm away from the Earth. If a spacecraft is able to travel at an average speed of 5.6 km $s^{-1}$, how much time will it take to reach Jupiter from Earth?

**A** $1.1 \times 10^2$ s **B** $1.1 \times 10^5$ s **C** $1.1 \times 10^8$ s **D** $1.1 \times 10^{11}$ s

**2** In the Stefan-Boltzmann law, the net radiated power $P$ emitted from an object of surface area $A$ and at temperature $T$, placed in an environment of temperature $T_0$ can be obtained from the equation

$$P = \varepsilon\sigma A\left(T^4 - T_0^4\right)$$

where emissivity $\varepsilon$ is a dimensionless property of the object, $\sigma$ is the Stefan constant, and the value of each quantity used is expressed in SI unit.

What unit, if any, should be used for the constant $\sigma$?

**A** J $m^{-2}$ $s^{-1}$ $K^{-4}$ **B** W $m^{-2}$ °$C^{-4}$ **C** W $m^{-2}$ **D** no unit

**3** A steel ball is released from rest at the surface of a deep tank of viscous oil. A multiple exposure photograph is taken of the ball as it falls.
The time interval between exposures is always the same.

Which of the following could represent this photograph?

**A**



**B**



**C**



**D**



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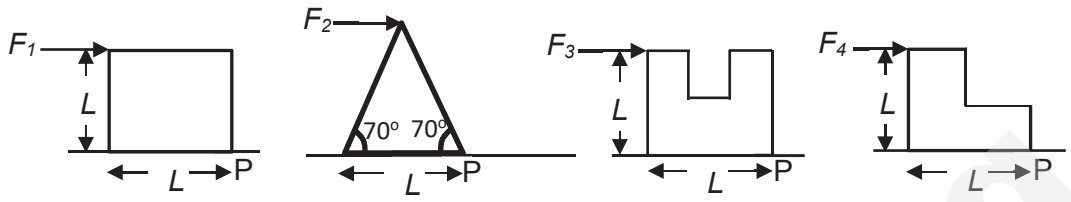
**4** The figure below shows four objects with the same mass. Each object has uniform density and thickness. The dimensions are as shown for each object. A horizontal force *F* is applied at the top of each object. In each case, the object does not slide and is just about to rotate about point P.




Which applied force is the largest?

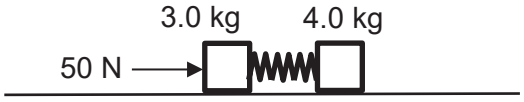
**A** $F_1$ **B** $F_2$ **C** $F_3$ **D** $F_4$

**5** A ball of mass 1.2 kg is dropped from rest from a height of 2.8 m. It hits the ground and rebounds to a height of 2.0 m. The duration of impact with the ground is 0.25 s. Assume air resistance is negligible.

What is the average net force on the ball during impact?

**A** 71 N **B** 66 N **C** 60 N **D** 55 N

**6** A 3.0 kg mass is connected to a 4.0 kg mass by a light spring with a spring constant of 250 N $m^{-1}$. The masses rest on a smooth floor. The two masses are moving with the same acceleration due to a constant horizontal force of 50 N applied on the 3.0 kg mass.




What is the compression of the spring?

**A** 0.11 m **B** 0.14 m **C** 0.20 m **D** 0.22 m

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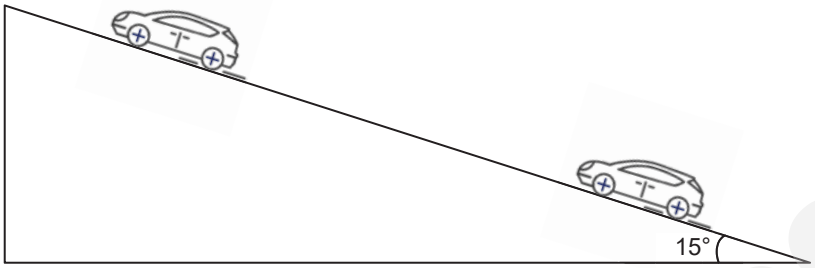
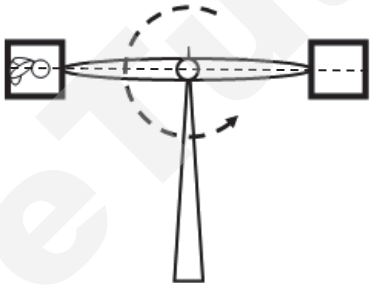
**7** A car of mass 990 kg is driven up a slope angled at 15° to the horizontal, at a steady speed of 12 m $s^{-1}$.



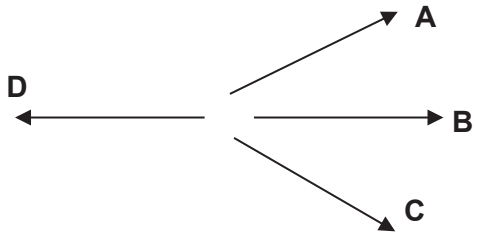

What is the work done by gravity on the car for 8.3 seconds of travel on the slope?

**A** 250 kJ **B** -250 kJ **C** 970 kJ **D** -970 kJ

**8** In a ride at an entertainment park, a person sits in a cage which moves in a vertical circle at a constant speed.



At the instant as shown in the above diagram, which of the following options gives the correct direction of the contact force exerted by the cage on the person?

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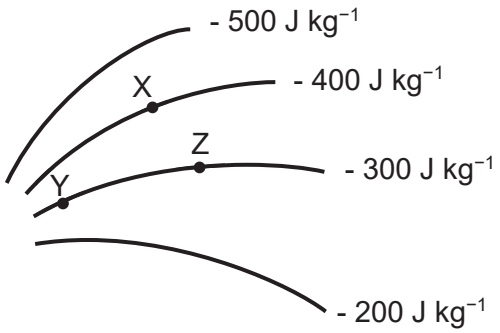
**9** The diagram shows four equipotential lines in a gravitational field.




Which line of the table relates the direction of gravitational field at X and the relative gravitational field strength at Y?

| | direction of gravitational field at X | gravitational field strength at Y |
|---|---|---|
| **A** | perpendicular to the line at X pointing towards higher potential | larger than Z |
| **B** | perpendicular to the line at X pointing towards lower potential | larger than Z |
| **C** | perpendicular to the line at X pointing towards higher potential | equal to Z |
| **D** | perpendicular to the line at X pointing towards lower potential | equal to Z |

**10** A mass of 0.20 kg undergoing simple harmonic motion has a total energy of $4.0 \times 10^{-3}$ J and amplitude of 0.050 m.

What is the period of the motion of the mass?

**A** 0.39 s **B** 1.6 s **C** 4.0 s **D** 7.9 s

**11** A sound wave of amplitude 0.30 mm has an intensity of 4.0 W m$^{-2}$.

What will be the amplitude of a sound wave of the same frequency which has an intensity of 8.0 W m$^{-2}$?

**A** 0.15 mm **B** 0.28 mm **C** 0.42 mm **D** 0.60 mm

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**12** A sound wave of frequency 400 Hz is travelling at a speed of 320 m $s^{-1}$.

What is the phase difference between two points 0.60 m apart in the direction of travel?

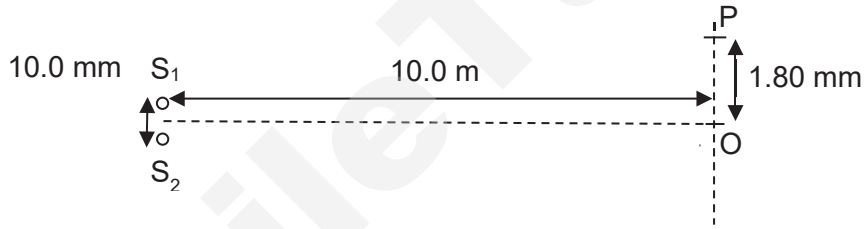
**A** $\frac{\pi}{4}$ rad **B** $\frac{\pi}{2}$ rad **C** $\frac{3\pi}{4}$ rad **D** $\frac{3\pi}{2}$ rad

**13** A monochromatic light of wavelength $5.2 \times 10^{-7}$ m is incident normally on a diffraction grating, the third order lines are formed at an angle of 51.3° to the normal of the grating.

What is the number of lines per millimetre of the grating?

**A** $2.0 \times 10^{-6}$ **B** $5.0 \times 10^{2}$ **C** $5.0 \times 10^{5}$ **D** $2.0 \times 10^{6}$

**14** The figure below (not to scale) shows two coherent electromagnetic wave sources, $S_1$ and $S_2$ which are $\pi$ rad out of phase, placed 10.0 mm apart. The two sources are at an equidistant of 10.0 m from a detector at O. The wavelength of the electromagnetic wave is 532 nm.




How many minima would the detector detect as it moves a distance 1.80 mm from point O to point P?

**A** 2 **B** 3 **C** 4 **D** 5

**15** What is the approximate number of atoms per unit volume of an ideal monatomic gas at a temperature of 30°C and a pressure of $1.2 \times 10^{5}$ Pa?

**A** $1.0 \times 10^{22}$ **B** $6.0 \times 10^{23}$ **C** $2.9 \times 10^{25}$ **D** $2.9 \times 10^{26}$

**16** An ideal gas has an initial volume of $2.0 \times 10^{-3}$ $m^{-3}$ and at a pressure of $1.0 \times 10^{5}$ Pa. When 125 J of energy is supplied to the gas, its volume increases to $2.5 \times 10^{-3}$ $m^{-3}$ while its pressure remains constant.

What is the change in internal energy?

**A** 50 J **B** -50 J **C** 75 J **D** 170 J

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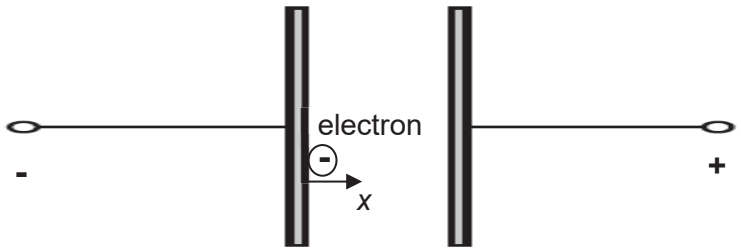
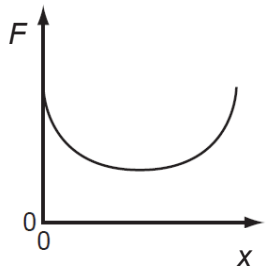
**17** Two long and oppositely-charged parallel plates are arranged as shown.



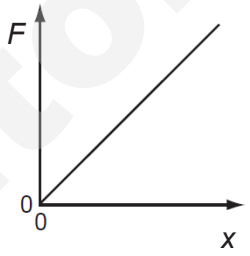

An electron is released from rest from the surface of the negatively-charged plate. The electron travels from the negatively-charged plate towards the positively-charged plate.

Which graph shows how the force $F$ on the electron varies with $x$ its distance from the negative plate?

**A**



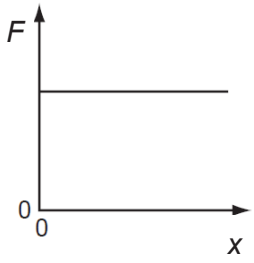

**B**




**C**




**D**




**18** A point electric charge $-q$ is brought from a point $P_1$ in space to another point $P_2$ by an external agent. The electric potentials at points $P_1$ and $P_2$ are $V_1$ and $V_2$ respectively.

What is the work done on the charge?

**A** $q(V_2 + V_1)$ **B** $q(-V_2 - V_1)$ **C** $q(V_2 - V_1)$ **D** $q(V_1 - V_2)$

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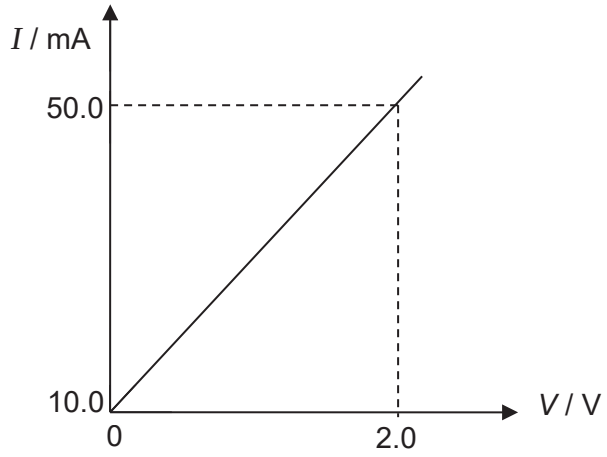
**19** The following graph shows the $I$-$V$ characteristic of a certain conductor.




Which of the following statements about the conductor is correct?

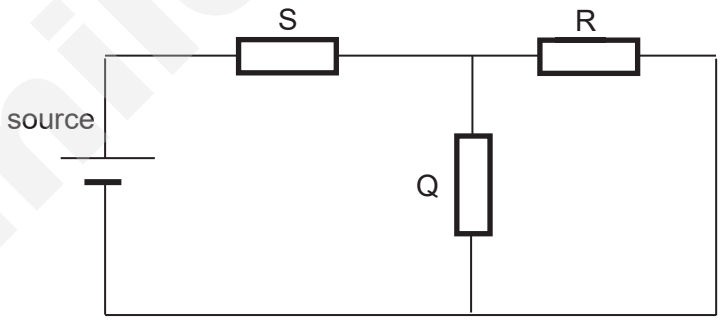
**A** It obeys Ohm's law and when $V$ = 2.0 V, resistance = 40.0 Ω.

**B** It obeys Ohm's law and when $V$ = 2.0 V, resistance = 50.0 Ω.

**C** It does not obey Ohm's law and when $V$ = 2.0 V, resistance = 40.0 Ω.

**D** It does not obey Ohm's law and when $V$ = 2.0 V, resistance = 50.0 Ω.

**20** An e.m.f. source of negligible internal resistance is connected across three identical resistors Q, R and S, of resistance 50 Ω.




If the source is supplying a total power of 12 W, what is the power dissipated as heat in resistor R?

**A** 2.0 W **B** 3.0 W **C** 4.0 W **D** 8.0 W

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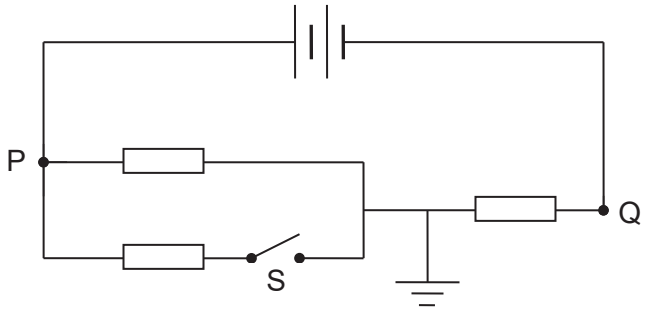
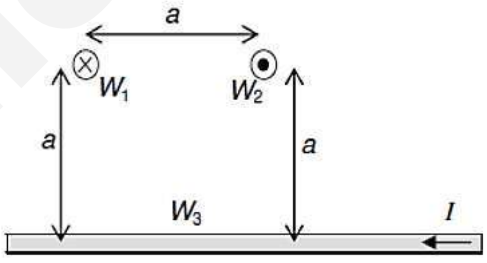
**21** A group of resistors are connected as shown to a battery of constant e.m.f. with negligible internal resistance. All resistors have the same resistances.




What will happen to the potentials at P and at Q when the switch S is closed?

| | potential at P | potential at Q |
|---|---|---|
| **A** | unchanged | unchanged |
| **B** | increased | increased |
| **C** | decreased | increased |
| **D** | decreased | decreased |

**22** Three long wires $W_1$ , $W_2$, $W_3$, carrying the same current $I$ are arranged in the configuration as shown below. Current is flowing into paper for wire $W_1$. Current is flowing out of paper for wire $W_2$. The direction of current for $W_3$ is leftwards as shown.




What is the direction of the resultant force acting on $W_1$?

**A** downwards

**B** upwards

**C** to the right

**D** to the left

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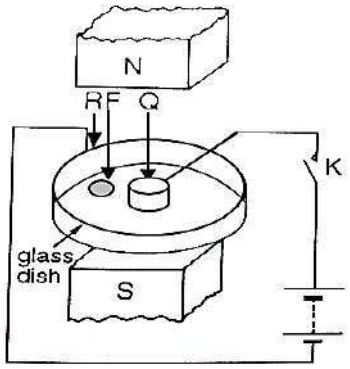
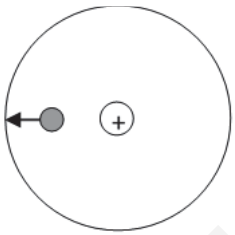
**23** In the diagram below, the inner wall of a glass dish is lined with a copper ring R and a copper rod Q is placed exactly in the middle of the dish. Rod Q is connected, via a switch K, to the positive plate, and ring R is connected to the negative plate of a battery. The arrangement is placed between the poles of a strong magnet. The dish is then filled with an electrically conducting solution and a small float F added to indicate any motion of the liquid.

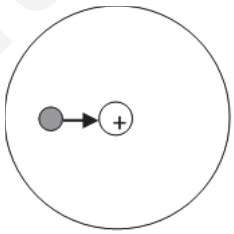



When switch K is closed, current flows from Q and radially towards ring R. Which sketch indicates correctly the possible motion of the float as seen from above when switch K is closed?

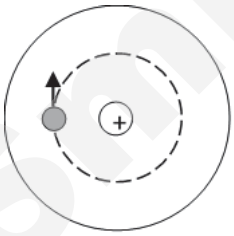
**A**



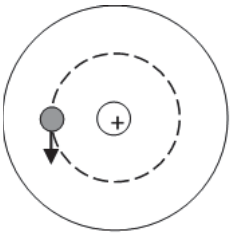
**B**



**C**



**D**



**24** A metal bar is placed in a horizontal position within a region of vertically directed uniform magnetic field. The bar is made to rotate with constant angular velocity about a vertical axis through its center.

Which of the following points should a voltmeter be connected across to detect the maximum potential difference?

**A** any two points on the bar will give the same reading

**B** between the center and one end of the bar

**C** between the two ends of the bar

**D** between start of the bar and across ¾ length of the bar

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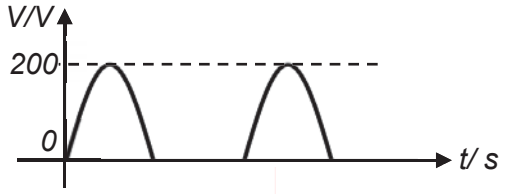
**25** An a.c. supply with peak voltage $V_o$ and frequency of $f$ delivers a mean power $P$ when connected across a load resistor.

With the peak voltage now ½ $V_o$ and frequency 2 $f$, which expression gives the new mean power in the resistor?

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

**26** The graph shows the waveform resulting from half-wave rectification of an alternating sinusoidal voltage of peak voltage of 200 V.




What is the mean value of the rectified voltage?

**A** less than 100 V
**B** 100 V
**C** 141 V
**D** 200 V

**27** Light of constant intensity is incident on a clean metal surface. Electrons are emitted from the metal surface.

The frequency of the light is now increased, but the intensity remains the same.

Which of the following is a consequence of this change?

**A** Maximum kinetic energy of the emitted electrons remains unchanged.
**B** Rate of emission of the electrons is decreased.
**C** Work function energy of the metal is increased.
**D** Threshold wavelength of the metal is decreased.

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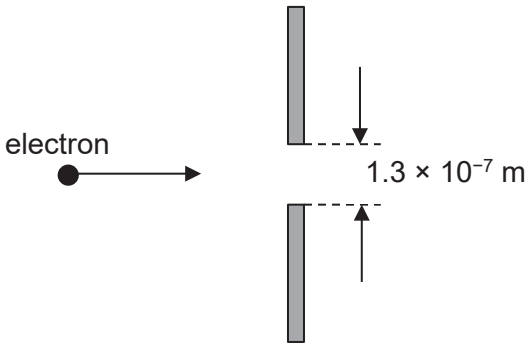
**28** An electron, with an initial energy of 1.28 eV, passes through a small slit of slit width $1.3 \times 10^{-7}$ m.




What is the direction and minimum uncertainty of the momentum of the electron as it passes through the slit?

| | minimum uncertainty | direction |
|---|---|---|
| **A** | $5.1 \times 10^{-27}$ N s | vertical |
| **B** | $5.1 \times 10^{-27}$ N s | horizontal |
| **C** | $6.1 \times 10^{-25}$ N s | vertical |
| **D** | $6.1 \times 10^{-25}$ N s | horizontal |

**29** Which of the following is not a conclusion drawn from the Rutherford alpha-scattering experiment?

**A** Most of the atom is empty space.

**B** The nucleus of the atom is very small and charged.

**C** Negatively charged electrons revolve around the positively charged nucleus.

**D** The majority of the mass of the atom is concentrated at the centre of the atom.

**30** A radioactive source is placed near a detector and the reading is 324 counts per minute. After two half-lives, the reading drops to 108 counts per minute.

What is the background radiation in counts per minute?

**A** 27 **B** 36 **C** 54 **D** 72

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# TAMPINES MERIDIAN JUNIOR COLLEGE

## JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME: _____

CIVICS GROUP: _____ (  )

## H2 Physics 9749/02

Paper 2 Structured Questions **20 September 2019**

**2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

Write your name, Civics Group 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 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.

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

| For Examiner's Use | |
|---|---|
| 1 | / 10 |
| 2 | / 10 |
| 3 | / 10 |
| 4 | / 10 |
| 5 | / 10 |
| 6 | / 10 |
| 7 | / 20 |
| Deductions | |
| Total | / 80 |


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**Data**

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

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**Formulae**

| | | | |
|---|---|---|---|
| uniformly accelerated motion | $s$ | = | $ut + \frac{1}{2}at^2$ |
| | $v^2$ | = | $u^2 + 2as$ |
| work done on/by a gas | $W$ | = | $p\Delta V$ |
| hydrostatic pressure | $p$ | = | $\rho gh$ |
| gravitational potential | $\phi$ | = | $-Gm / r$ |
| temperature | $T$ /K | = | $T$ /°C + 273.15 |
| pressure of an ideal gas | $p$ | = | $\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E$ | = | $\frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x$ | = | $x_o \sin \omega t$ |
| velocity of particle in s.h.m. | $v$ | = | $v_o \cos \omega t$ |
| | | = | $\pm \omega\sqrt{x_o^2 - x^2}$ |
| electric current | $I$ | = | $Anvq$ |
| resistors in series | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R$ | = | $1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V$ | = | $\frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | □ | = | $x_o \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B$ | = | $\frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B$ | = | $\frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B$ | = | $\mu_0 nI$ |
| radioactive decay | $x$ | = | $x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda$ | = | $\frac{\ln 2}{t_{\frac{1}{2}}}$ |

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

**1** **(a)** Explain why it is technically incorrect to define speed as distance travelled per second. Include in your answer the correct statement defining speed of an object.

.....

.....

..... [2]

**(b)** An object is projected at an angle $\theta$ to the horizontal from a cliff. It takes the path as shown in Fig. 1.1.

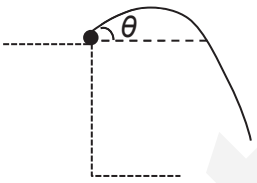


**Fig. 1.1 (not drawn to scale)**

Fig. 1.2 and Fig. 1.3 shows the variation with time $t$ of the vertical component of its velocity $v_y$ and the horizontal component of its velocity $v_x$ respectively.

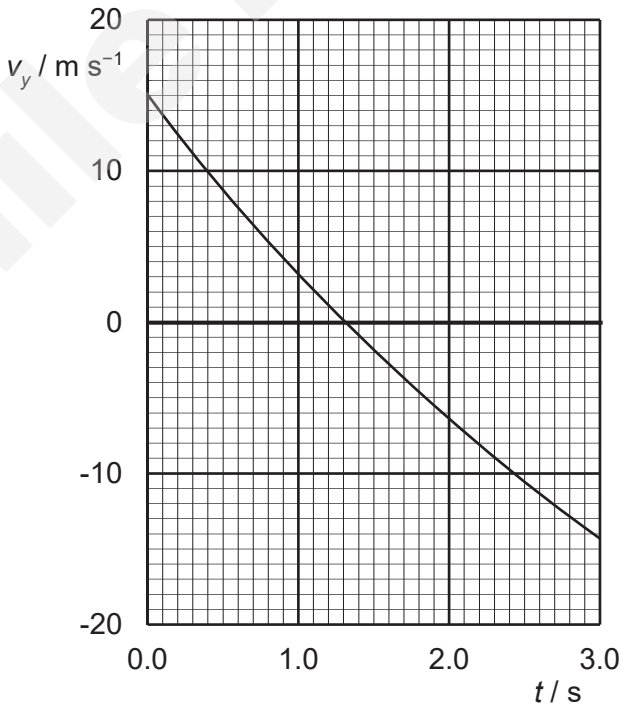


**Fig. 1.2**

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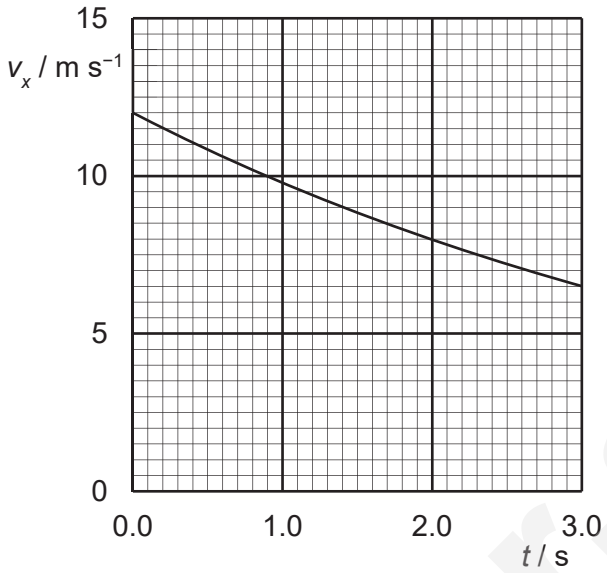


**Fig. 1.3**

**(i)** With reference to either Fig. 1.2 or Fig. 1.3, state and explain if the air resistance acting on the object is significant.

……

……

…… [2]

**(ii)** Calculate the angle $\theta$.

$\theta$ = …….. ° [2]

**(iii)** Use Fig. 1.2 to estimate the maximum height reached above the point of projection.

height = …….. m [2]

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**(c)** The net acceleration $a_{net}$ of a falling object of mass $m$ experiencing a drag force $D$ is given by the equation $a_{net} = g - D/m$, where $g$ is the acceleration of freefall.

When dropped together, it is observed that a table tennis ball would reach a slower terminal speed as compared to a stone of the same shape and size. By considering the above equation, or otherwise, explain for this observation.

……

……

……

…… [2]

**2** A proton is projected with a velocity of $2.4 \times 10^5$ m s$^{-1}$ directly towards a distant stationary helium nucleus as shown in Fig. 2.1. The mass of helium nucleus is four times that of proton. The interaction can be taken to be an elastic head-on collision.




**Fig. 2.1**

**(a)** Explain what is meant by an *elastic collision*.

……

…… [1]

**(b)** Calculate the velocity of each particle after collision.

velocity of proton = …….. m s$^{-1}$

velocity of helium = …….. m s$^{-1}$ [4]


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At one instant during the collision, the two particles have a common velocity $v_o$.

**(c)** Show that the value of $v_o$ is $4.8 \times 10^4$ m $s^{-1}$.

[1]

**(d)** State the energy change that has occurred up to this instant.

……

…….. [1]

**(e)** Using energy considerations, calculate the separation between the two particles at this instant.

separation = …….. m [3]

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**3** A satellite moves about Earth in a circular orbit, as illustrated in Fig. 3.1.

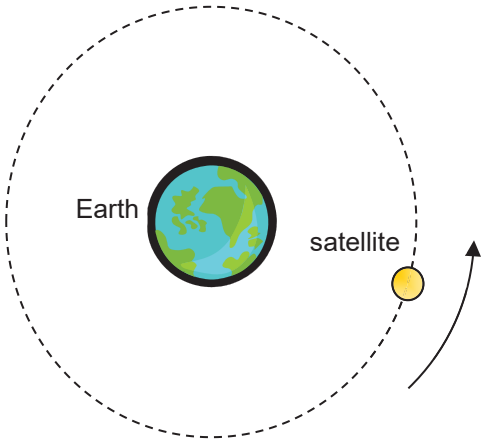


**Fig. 3.1**

The Earth and the satellite may be considered to be point masses with their masses concentrated at their centres.

**(a)** In a certain time interval, the satellite moved from position A to position B, as shown in Fig. 3.2, such that the straight line distance between A and B is equal to the radius of orbit.

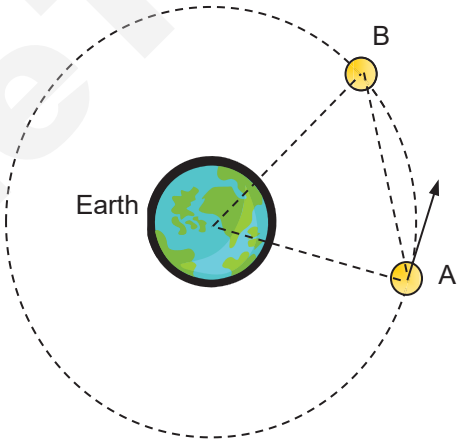


**Fig. 3.2**

Calculate the angular displacement of the satellite during this time interval.

angular displacement = …… rad [1]

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**(b)** The Moon can also be considered to be a point mass with its mass concentrated at its centre. It makes a circular orbit about the Earth, taking 27.3 days to make one complete orbit.

**(i)** Calculate the angular velocity of the Moon

angular velocity = ..... rad $s^{-1}$ [1]

**(ii)** At time $t = 0$, the centres of mass of the Earth, the Moon and the satellite align, as shown in Fig. 3.3.

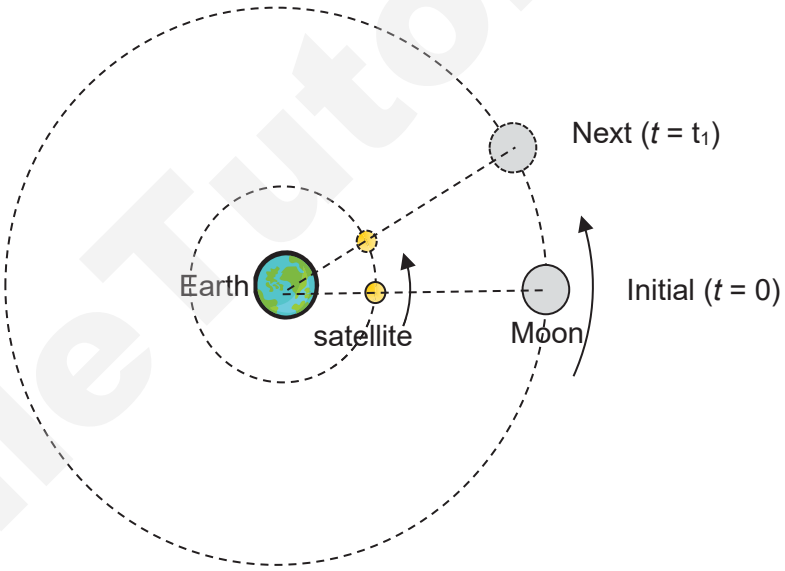


**Fig. 3.3**

At at later time $t = t_1$, the centre of mass of the three bodies align again, as illustrated in Fig. 3.3. The satellite takes 23.9 hours to make one complete orbit.

Calculate the time $t_1$.

$t_1$ = ..... hours [2]

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**(c)** **(i)** The period of the satellite and the radius of its orbit are related by the expression:

$$T = k\sqrt{d^3}$$

where $T$ is the period of orbit, $d$ is the radius of orbit, and $k$ is a constant.

Determine the expression for the constant $k$ in terms of gravitational constant, $G$, and the mass of the Earth, $M$.

[3]

**(ii)** An aged satellite orbiting the Earth, due to resistive forces, will gradually spiral down and towards the Earth.

State and explain what happens to the angular velocity of the satellite as it spirals down.

……

……

……

…… [3]

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**4 (a)** The variation with potential difference (p.d.) $V$ of current $I$ of a semi-conductor diode is shown in Fig. 4.1.

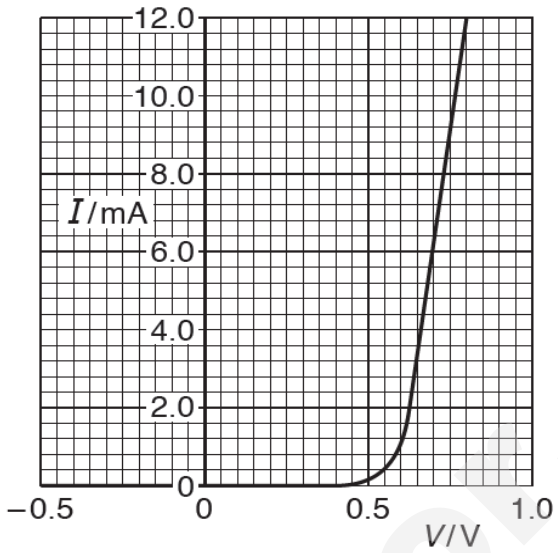


**Fig. 4.1**

**(i)** Use Fig. 4.1 to describe the variation of the resistance of the diode between $V$ = - 0.5 V and $V$ = 0.8 V.

.....

.....

.....

..... [2]

**(ii)** Determine the resistance of the diode at the instant when $I$ = 0.4 mA.

resistance = ..... Ω [2]

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**(b)** On Fig. 4.2, sketch the variation with p.d. $V$ of current $I$ for a filament lamp. Numerical values are not required.

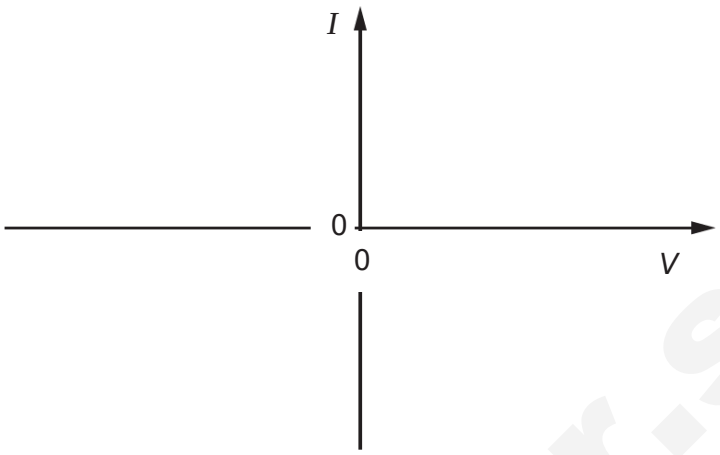


**Fig. 4.2**

[1]

**(c)** Fig. 4.3 shows a power supply of electromotive force (e.m.f.) of 12 V and internal resistance 0.50 Ω connected to a filament lamp, a variable resistor and a switch.

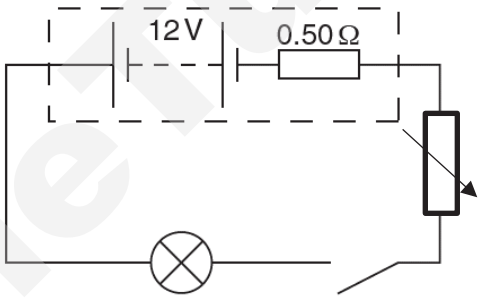


**Fig. 4.3**

**(i)** The switch is closed. The filament lamp has a power of 20 W when the p.d. across it is 10 V. Calculate the resistance of the lamp.

resistance = …….. Ω [2]

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**(ii)** The variable resistor is adjusted to 2.0 Ω and the p.d. across the lamp is now measured to be 2.0 V. Calculate the resistance of the lamp.

resistance = …… Ω [2]

**(d)** Explain how the two values of resistance calculated in **(c)** provide evidence for the shape of the sketch you have drawn in **(b)**.

……

…… [1]

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**5** **(a)** Define magnetic flux density

……

……

……[2]

**(b)** A $\beta$-particle is travelling with momentum $p$ in a vacuum. It enters a region of uniform magnetic field of flux density $B$ as shown in Fig. 5.1. It moves along the arc of a circle $r$.

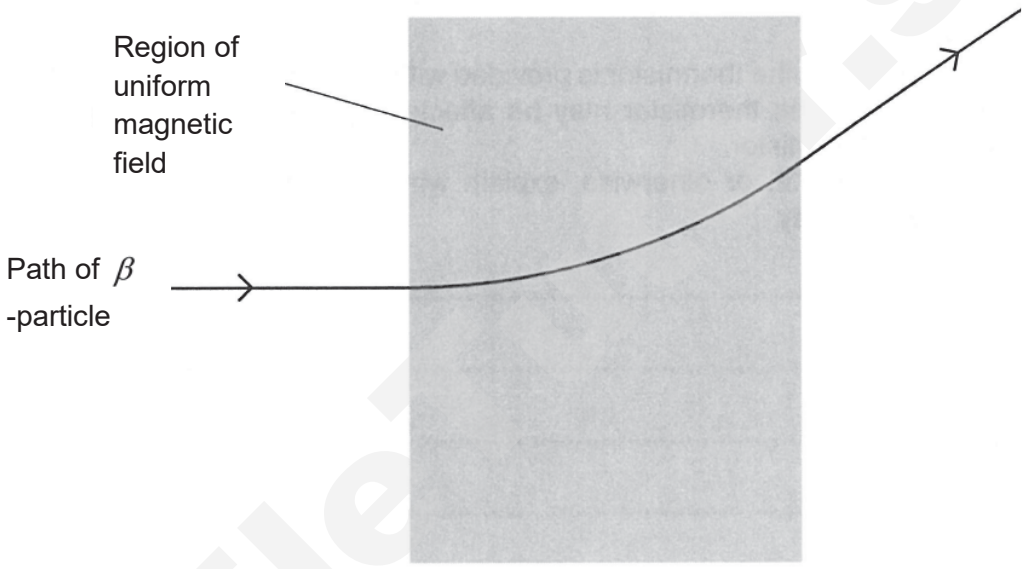


**Fig. 5.1**

**(i)** State the direction of the magnetic field

…… [1]

**(ii)** **1.** Show that the momentum $p$ of the $\beta$-particle is given by

$$p = Ber,$$

where $e$ is the elementary charge.

[2]

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**2.** Hence calculate the momentum $p$ of the $\beta$-particle if the magnetic flux density $B$ is 0.24 T and the radius of the circular path is 6.2 cm.

$p$ = ..... N s [2]

**(c)** A uniform electric field strength, $E$ is then applied across the parallel plate so that the $\beta$ -particle can pass through the region undeflected.

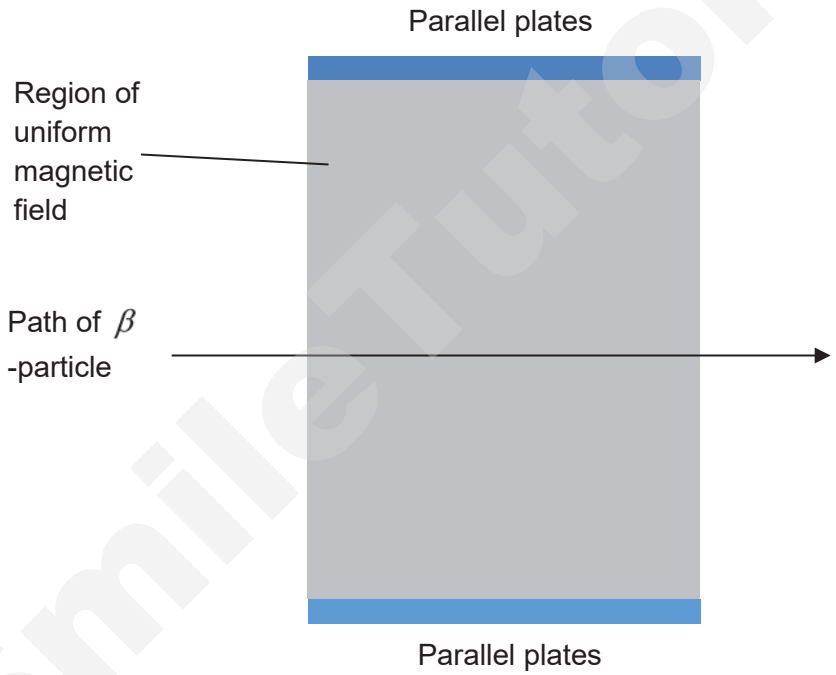


**Fig. 5.2**

**1.** Indicate on Fig. 5.2, the polarity of the respective plates with a "+" or "-". [1]

**2.** State and explain the change, if any, to the path of the $\beta$ -particle if there is an increase in its momentum.

.....

.....

.....

.....[2]

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**6** **(a)** State what is meant by *binding energy* of a nucleus.

……

…… [1]

**(b)** The data for iron-56 $\left({}^{56}_{26}\mathrm{Fe}\right)$ nucleus is given below.

Mass of proton = 1.00728 *u*

Mass of neutron = 1.00866 *u*

Mass of iron-56 nucleus = 55.92132 *u*

**(i)** Show that the binding energy per nucleon of iron-56 nucleus is 8.8 MeV.

[2]

**(ii)** On Fig. 6.1, sketch the variation of binding energy per nucleon with nucleon number.

On your sketch, mark the position of iron-56 and label it with appropriate values.

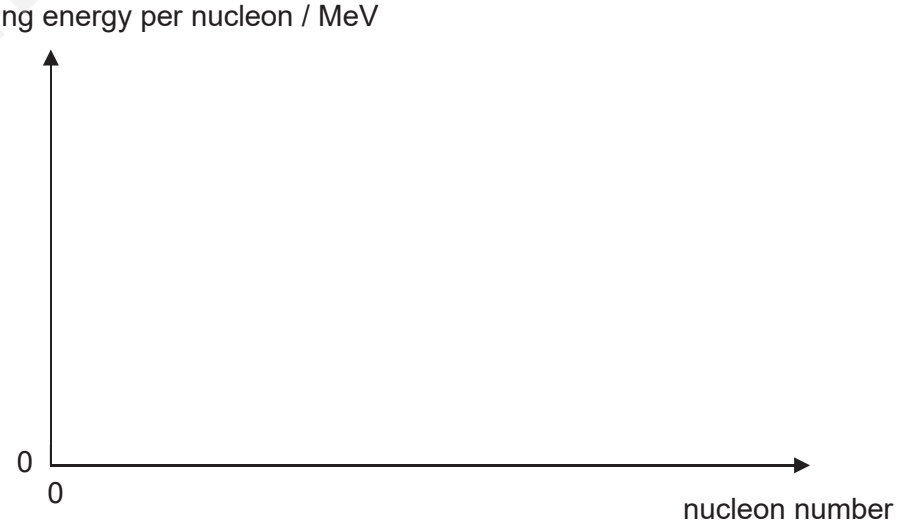


**Fig. 6.1**

[2]

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**(c)** A nuclear fission reaction may be represented by the equation

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n}$$

**(i)** On Fig. 6.1, mark approximate positions for the nuclei of

**1.** uranium–235 (label the position U)

**2.** barium–141 (label the position Ba)

**3.** krypton–92 (label the position Kr)

[1]

**(ii)** Explain, by reference to Fig. 6.1, why energy is released in this fission reaction.

.....

.....

.....

..... [2]

**(iii)** The binding energy per nucleon of the respective nuclei are as follows:

| Nucleus | Binding energy per nucleon / MeV |
|---|---|
| Uranium–235 | 7.6 |
| Barium–141 | 8.3 |
| Krypton–92 | 8.5 |

Calculate the energy released in this nuclear fission.

energy released = ..... MeV [2]

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**7** Read the following article and answer the questions that follow.



**Fig. 7.1**

Pictured in Fig. 7.1 is the C-130 Hercules, manufactured by Lockheed Martin, and employed by Singapore Air Force. It has served numerous missions, such as operation Flying Eagle, which rendered assistance to Indonesia in the aftermath of the 2004 Tsunami.

The C-130 has the following data sheet.

| | |
|---|---|
| Wing Surface Area | 162 $m^2$ |
| Operating mass | 34 000 kg |
| Fuel energy density | 45 MJ $kg^{-1}$ |

Fig. 7.2 shows the height and speed data, plotted with respect to time, during the flight of a C-130.

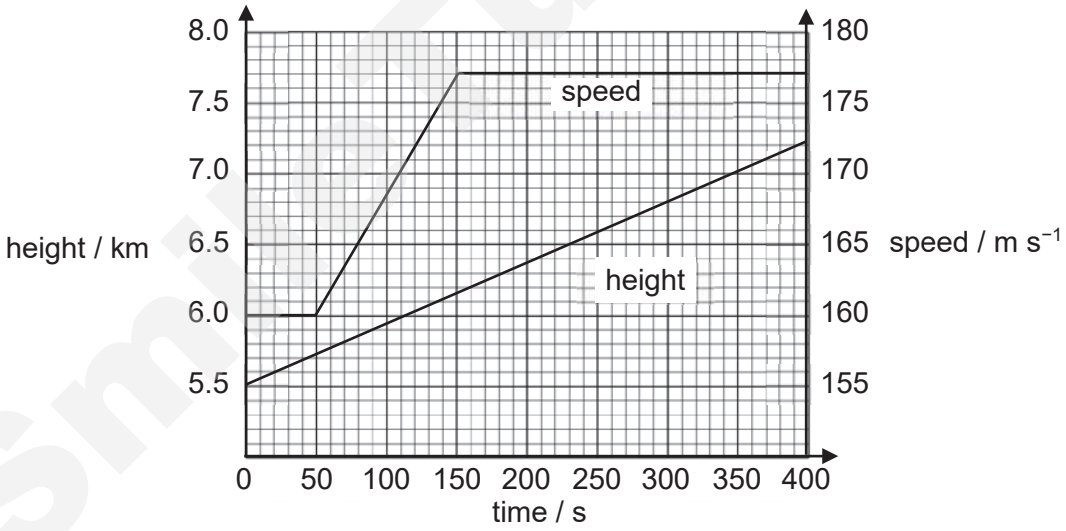


**Fig. 7.2**

**(a) (i)** With reference to Fig. 7.2, show that the vertical component of velocity of the aircraft is 4.3 m $s^{-1}$.

[1]


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**(ii)** Hence, calculate the horizontal velocity of the aircraft at time $t$ = 200 s, correct to 5 significant figures.

horizontal component of velocity = ……m $s^{-1}$ [2]

**(b)** During the flight time of 400 s in Fig. 7.2,

**(i)** calculate the change in kinetic energy of the aircraft.

change in kinetic energy = ……J [2]

**(ii)** the aircraft's gravitational potential energy increases by 5.67 × $10^8$ J.

Determine the highest value of useful power $P_{useful}$, given that $P_{useful}$ is the sum of the power used for climbing and the power used to speed up.

highest value of $P_{useful}$ = ……W [2]

**(c)** **(i)** Use the unit MJ $kg^{-1}$ to deduce what is meant by fuel energy density.

……

…… [1]

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**(ii)** The efficiency of the aircraft is 24%. Calculate the mass of fuel required during the flight time of 400 s as shown in Fig. 7.2.

mass of fuel = ……kg [4]

**(iii)** State why the loss in fuel mass in **c(ii)** can be neglected in the calculation of the value in **b(i)**.

……

…….. [1]

**(d)** The following proposed relationship calculates the drag force, $D$, based on the values of the air density, $\rho$, aircraft speed, $u$, height, $h$, the wing surface area, $S$, and the coefficient of drag, $C_D$. $S$ and $C_D$ are constants.

$$D = \frac{1}{2} C_D S u^2 \rho$$

A table of data is provided in Fig. 7.3.

| $u$ / m s$^{-1}$ | $h$ / m | $\rho$ / kg m$^{-3}$ | $u^2\rho$ / kg m$^{-1}$ s$^{-2}$ | $D$ / $10^6$ N |
|---|---|---|---|---|
| 160 | 5500 | 0.698 | 17900 | 1.160 |
| 167 | 5720 | 0.681 | 19000 | 1.231 |
| 177 | 5930 | 0.665 | 20800 | 1.348 |
| 177 | 6350 | 0.635 | 19900 | 1.290 |
| 177 | 6570 | 0.620 | | 1.257 |
| 177 | 6800 | 0.603 | 18900 | 1.225 |

**Fig. 7.3**

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**(i)** Complete the table for the value of $u^2 \rho$ when $\rho$ is 0.620 kg m$^{-3}$. [1]

**(ii)** Fig. 7.4 is a graph of some of the data of Fig. 7.3.

Plot the point for when $\rho$ is 0.620 kg m$^{-3}$ on Fig. 7.4, and draw the line of best fit. [2]

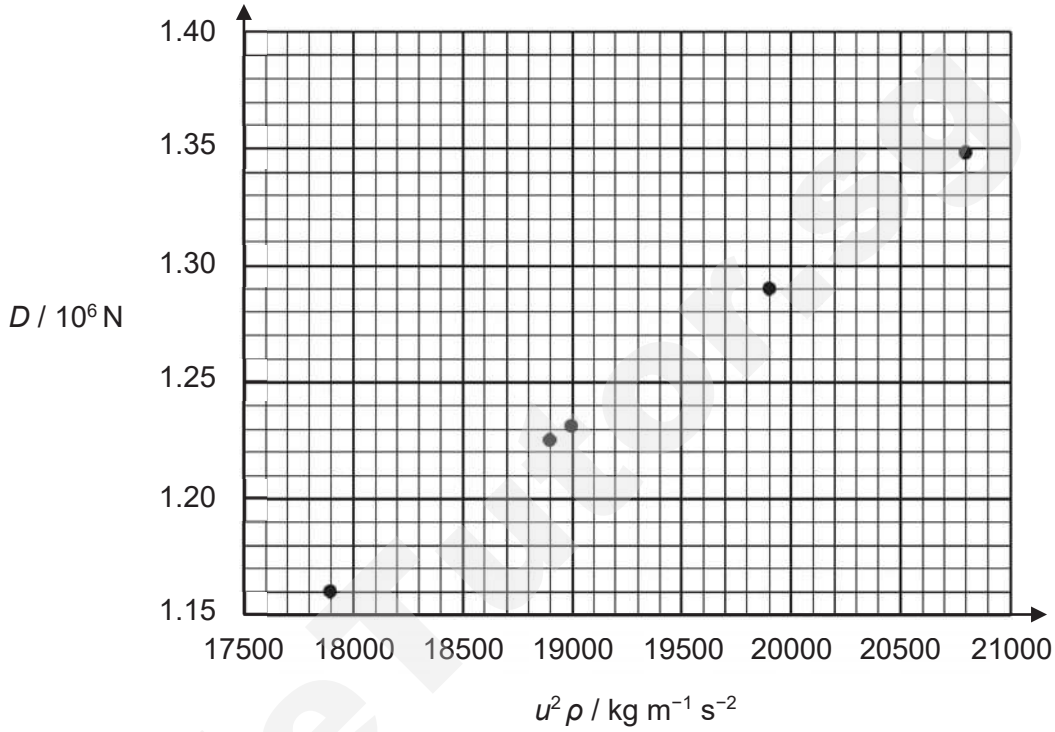


**Fig. 7.4**

**(iii)** Use Fig. 7.4 to determine the drag coefficient, $C_D$.

$C_D$ = ..... [2]

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**(iv)** Using the graph, or otherwise, show quantitatively that the graph of Fig. 7.4 supports the expression given in **(d)**.

.....

.....

..... [2]

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# TAMPINES MERIDIAN JUNIOR COLLEGE

## JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME: _____

CIVICS GROUP: _____ (  )

## H2 Physics 9749/03

Paper 3 Longer Structured Questions **24 September 2019**

**2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

Write your name, Civics Group and index number in the spaces at the top of this page.
Write in dark blue or black pen 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 **one** question only.

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

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

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

| For Examiner's Use | | Percentage |
|---|---|---|
| Subtotal P1 | | /15 |
| Subtotal P2 | /80 | /30 |
| Paper 3 | | |
| 1 | /8 | |
| 2 | /8 | |
| 3 | /9 | |
| 4 | /10 | |
| 5 | /10 | |
| 6 | /15 | |
| 7 | /20 | |
| 8 | /20 | |
| Deductions | | |
| Subtotal P3 | /80 | /35 |
| Subtotal P4 | /55 | /20 |
| Grand total | | /100 |


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**Data**

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

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**Formulae**

| | | | |
|---|---|---|---|
| uniformly accelerated motion | $s$ | = | $ut + \frac{1}{2}at^2$ |
| | $v^2$ | = | $u^2 + 2as$ |
| work done on/by a gas | $W$ | = | $p\Delta V$ |
| hydrostatic pressure | $p$ | = | $\rho gh$ |
| gravitational potential | $\phi$ | = | $-Gm/r$ |
| temperature | $T$/K | = | $T$/°C + 273.15 |
| pressure of an ideal gas | $p$ | = | $\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E$ | = | $\frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x$ | = | $x_o \sin \omega t$ |
| velocity of particle in s.h.m. | $v$ | = | $v_o \cos \omega t$ |
| | | = | $\pm \omega\sqrt{x_o^2 - x^2}$ |
| electric current | $I$ | = | $Anvq$ |
| resistors in series | $R$ | = | $R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R$ | = | $1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V$ | = | $\frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage | □ | = | $x_o \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B$ | = | $\frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B$ | = | $\frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B$ | = | $\mu_0 nI$ |
| radioactive decay | $x$ | = | $x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda$ | = | $\frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

**1** **(a)** Explain the origin of upthrust acting on a body in a fluid.

……

……

……

……[2]

**(b)** An object has a mass of 300 kg and a volume of 0.15 $m^3$. The object rests at the bottom of a lake 20 m deep.

To lift the object to the surface, a lifting balloon is tied to it and pumped with air. The lifting balloon has a mass of 5.2 kg. In order to lift the object up with an initial acceleration of 2.0 m $s^{-2}$, the lifting balloon is pumped up to a volume $V_o$. Density of lake water is 1000 kg $m^{-3}$.

**(i)** Calculate the volume $V_o$ required.

$V_o$ = …….. $m^3$ [2]

**(ii)** As the object accelerates upwards, state and explain:

**1**. one factor which can cause its acceleration to decrease continuously,

……

……

……[2]

**2**. one factor which can cause its acceleration to increase continuously.

……

……

……[2]

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**2** **(a)** Explain what is meant by *work done by a force*.

……

…… [1]

**(b)** Derive, from the definition of work done by a force, the equation $E_p = mgh$ for gravitational potential energy changes near the Earth's surface.

[3]

**(c)** A metal block of mass 650 kg is released from a height of 1.2 m above the top of a 140 kg metal pole, as shown in Fig. 2.1.

The block then collides with the pole and drives it vertically into the soil for a distance *d* as shown in Fig. 2.2, and stops.

For the entire process, the rope remains slack and viscous forces can be taken to be negligible.

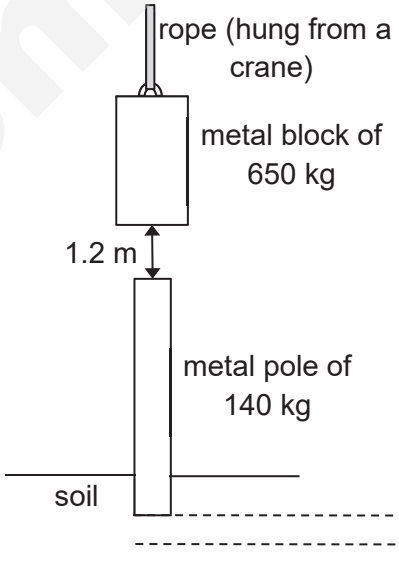


**Fig. 2.1**

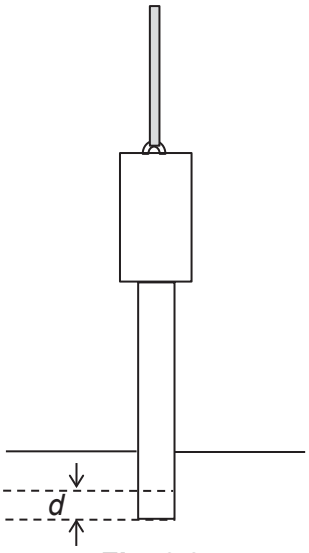


**Fig. 2.2**

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**(i)** The average resistance from the ground against the vertical penetration by the pole is 50 kN.

Assuming all energy is transferred from the block to the pole, calculate *d*.

*d* = ……m [3]

**(ii)** In real-life scenarios, the distance *d* will be smaller than what is calculated in **(c)(i)**. Suggest a reason why.

……

…… [1]

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**3** **(a)** Explain what is meant by *damped* oscillation.

……

…… [1]

**(b)** **(i)** Fig. 3.1 shows a spring-mass system hanging vertically from a fixed support. The mass is displaced vertically upwards by 3.0 cm and released to vibrate in simple harmonic motion with a period of 2.0 s. The effects of air resistance is neglected.

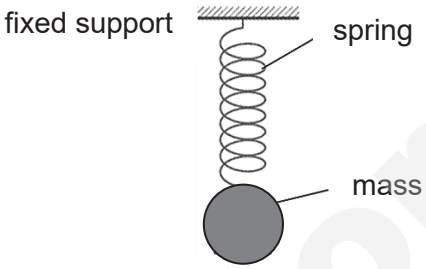


**Fig. 3.1**

Calculate the magnitude of the maximum acceleration of the mass.

maximum acceleration = ……m $s^{-2}$ [2]

**(ii)** The same spring-mass system in **(b)(i)** is now displaced vertically upwards by 3.0 cm and released to oscillate within a low viscosity oil in a container as shown in Fig. 3.2.

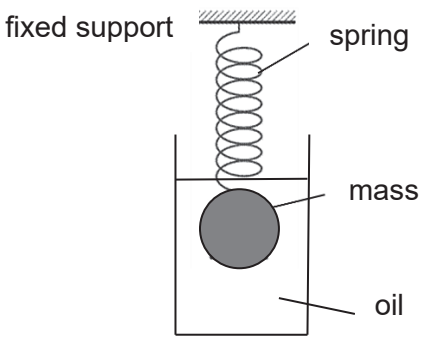


**Fig. 3.2**


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Sketch on the axes of Fig. 3.3, the variation of displacement with time for the mass oscillating in the oil.

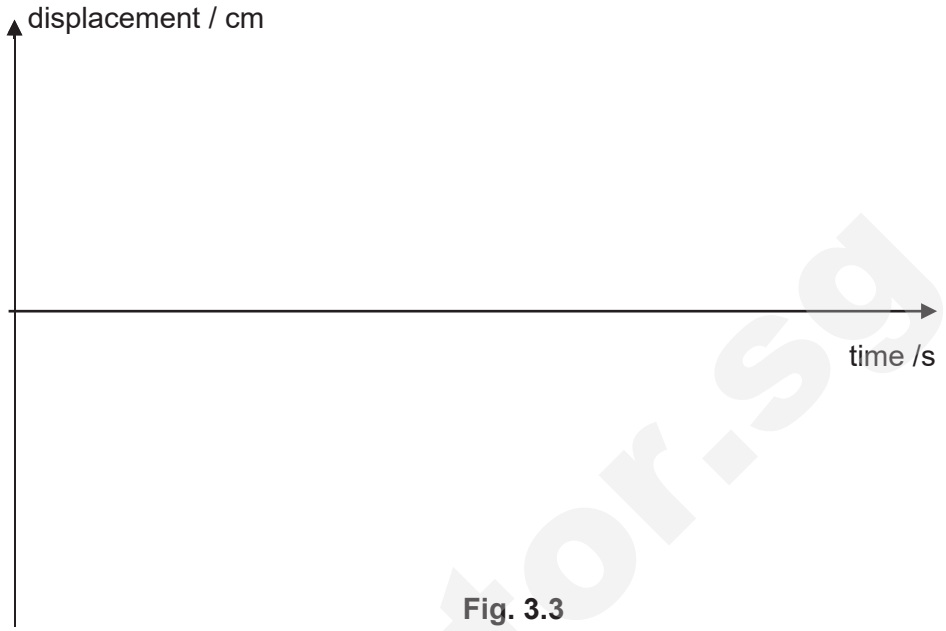


**Fig. 3.3**

[2]

**(c)** The same spring-mass system in **(b)(i)** is now supported by a movable support as shown in Fig. 3.4. The effects of air resistance is neglected.

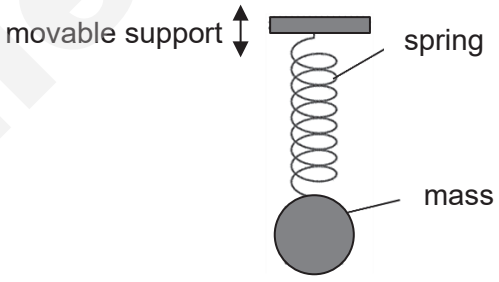


**Fig. 3.4**

A periodic force is now applied to the support such that the mass undergoes forced oscillations with very large amplitude.

State the physical phenomenon associated with this and the condition necessary for this to take place.

physical phenomenon:……

condition:…… [2]

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**(d)** A car's suspension system helps to damp its vertical oscillations as it is driven along a rough road.

State the type of damping and describe the importance of such damping for a working car's suspension system.

……

……

…… [2]

**4** **(a)** A telescope consisting of a satellite dish of diameter 250 m is used to scan the sky for sources that emit electromagnetic waves.

Two distant sources that are $1.8 \times 10^{12}$ m apart are emitting radio waves of wavelength 1.2 m. If the telescope is just able to resolve the two sources, calculate the distance of the sources from the telescope.

distance = …… m [3]

**(b)** In order to measure the depth of a well, an engineer uses a sonar with variable frequency at the opening of the well. Successive maximum signals are detected at 30.0 Hz and 42.0 Hz.

**(i)** The depth of the well, $d$, can be expressed as $d = \frac{n\lambda}{4}$, where $\lambda$ is the wavelength of the soundwave formed in the well when a maximum signal is heard and $n$ is an integer.

State and explain the values that $n$ can take.

……

……

…… [2]

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**(ii)** The speed of sonar sound is 330 m $s^{-1}$.

Calculate the depth of the well.

depth of well = ..... m [3]

**(iii)** Sketch the wave formed in the well at 30.0 Hz.

[2]

**5** **(a)** State two basic assumptions of the kinetic theory of gases.

.....

.....

.....

.....

..... [2]

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**(b)** By considering the random motion of the gas molecules in a cubic container of length *L*, show that the pressure *p* exerted by an ideal gas is given by the equation

$$p = \frac{1}{3}\rho\langle c^2 \rangle$$

where $\rho$ is the density of the ideal gas and $\langle c^2 \rangle$ is the mean-square speed of the gas atoms or molecules.

[4]

**(c)** **(i)** Explain what is meant by *specific latent heat of fusion*.

……

……... [1]

**(ii)** A thermally insulated vessel containing liquid water and water vapour is connected to a vacuum pump that removes water vapour continuously. When the temperature reaches freezing point of water, the vessel contains 120 g of liquid water. The specific latent heat of fusion of water is $3.40 \times 10^5$ J kg$^{-1}$ and the specific latent heat of vaporisation of water is $2.52 \times 10^6$ J kg$^{-1}$.

Calculate the mass of ice formed when no liquid remains.

mass of ice = …… g [3]

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**6** **(a)** An X-ray spectrum from an X-ray machine is shown in Fig. 6.1

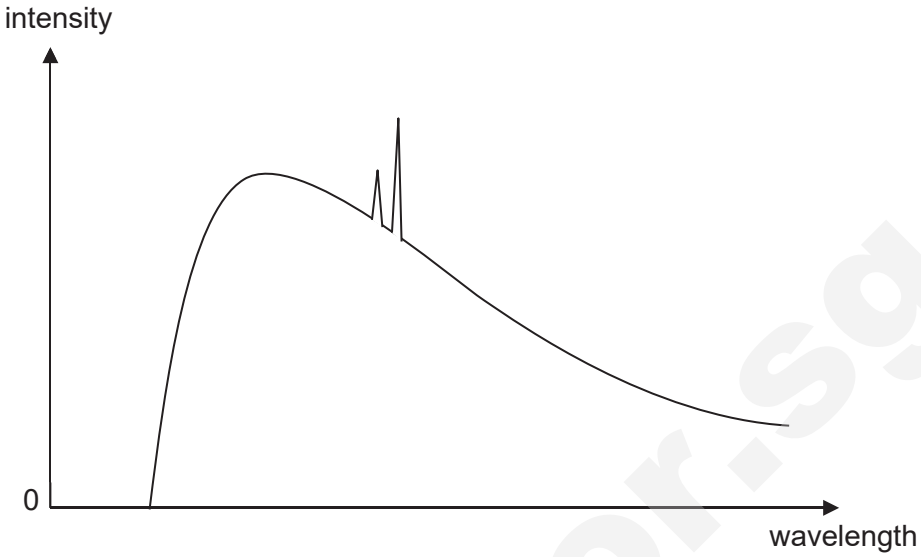


**Fig. 6.1**

**(i)** Explain why there is a minimum wavelength for the emitted X-rays.

……

……

……

……

…….. [3]

**(ii)** The minimum wavelength of the spectrum in Fig. 6.1 is 0.068 nm. Calculate the accelerating voltage used in this X-ray machine to accelerate the electrons.

accelerating voltage = …….…… V [2]

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**(b)** Fig. 6.2 shows some of the inner energy levels of the atom which is used in the metal target of the X-ray machine in part **(a)**.

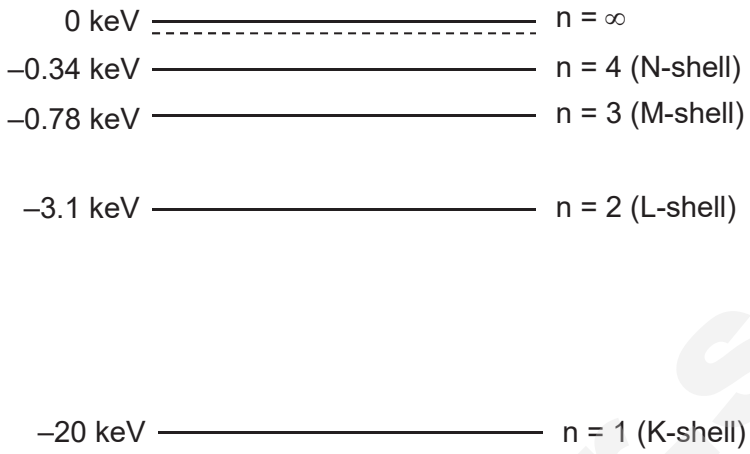


**Fig. 6.2**

**(i)** On Fig. 6.2, indicate with an arrow, the transition that gives rise to the $K_\alpha$ characteristic X-ray. [1]

**(ii)** Calculate the wavelength of the $K_\alpha$ characteristic X-ray for this metal target.

wavelength = ……..…… m [2]

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**(iii)** Explain whether the $K_\alpha$ characteristic X-ray is produced in this X-ray machine.

……

……

……

……

……

…… [3]

**(c)** X-ray diffraction can be used to analyse the structure of long chains of molecules such as DNA molecules. Crystals consisting of these long chains of molecules act as diffraction grating for the X-ray. When X-ray is passed through the crystal, a diffraction pattern can be observed.

In one such analysis, X-rays of 0.11 nm passed through a crystal of DNA to produce a diffraction pattern.

**(i)** Estimate the order of magnitude of the spacing between the DNA molecules. Explain your answer.

……

……

…… [2]

**(ii)** Instead of X-ray, electron diffraction can sometimes be used instead to produce a diffraction pattern.

Calculate the momentum of the electrons which will produce the same diffraction pattern as the X-ray when passed through the same crystal of DNA.

momentum = …… N s [2]

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## Section B

Answer **one** question from this Section in the spaces provided.

**7** **(a)** Explain what is meant by a *gravitational field*.

……

…… [2]

**(b)** Define *gravitational potential* at a point.

……

…… [1]

**(c)** A rocket is launched from the surface of the Earth and moves along a radial path, as shown in Fig. 7.1.

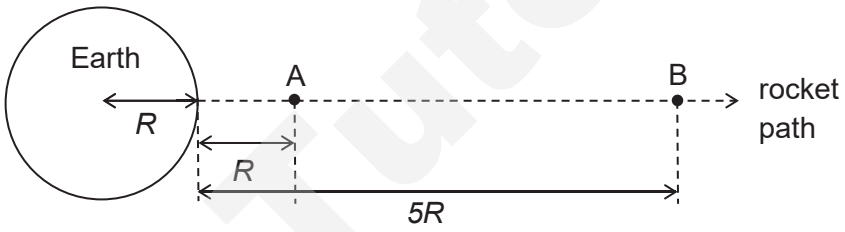


**Fig. 7.1**

The Earth may be considered as an isolated sphere of radius $R$ and mass $M$ concentrated at its centre. Point A is a distance $R$ from the surface of the Earth. Point B is a distance $5R$ from the surface.

**(i)** Show that the difference in gravitational potential between points A and B is given by the expression

$$\Delta\phi = \frac{GM}{3R}$$

where $G$ is the gravitational constant.

[1]

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**(ii)** The rocket motor is switched off at point A. During the journey from A to B, the rocket has a constant mass of $4.7 \times 10^4$ kg and its kinetic energy changes from 1.7 TJ to 0.72 TJ.

For the Earth, the product $GM$ is $4.0 \times 10^{14}$ N m$^2$ kg$^{-1}$.

Use the expression in **c(i)** to determine the distance from A to B. State an assumption that you have made.

distance = …… m

assumption: ……..…….. [4]

**(iii)** Upon reaching point B, the rocket is set to orbit in a circular path around the Earth.

Calculate the speed of the orbiting rocket.

speed = …… m s$^{-1}$ [2]

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**(d)** Define *electric field strength* at a point.

……..

…… [1]

**(e)** State one similarity and one difference between the electric field lines and the gravitational field lines around an isolated positively charged metal sphere.

similarity ……

……..

difference……...

……..[2]

**(f)** A positive point charge +*Q* is positioned at a fixed point X and an identical positive point charge is positioned at a fixed point Y, as shown in Fig. 7.2.

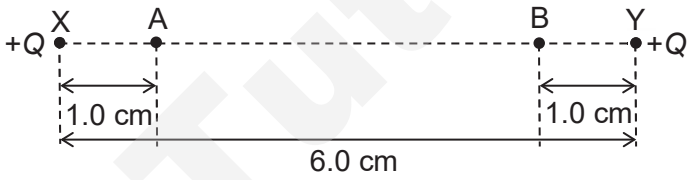


**Fig. 7.2**

The charges are separated in a vacuum by a distance of 6.0 cm.

Points A and B are on the line XY. Point A is at a distance of 1.0 cm from X and point B is a distance of 1.0 cm from Y. The electric field strength at point A is $4.1 \times 10^{-5}$ V m$^{-1}$.

**(i)** Calculate charge of +*Q*.

charge of +*Q* = …… C [3]

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**(ii)** On Fig. 7.3, sketch the variation of the electric field strength $E$ with distance $d$ from A to B, along the line AB.

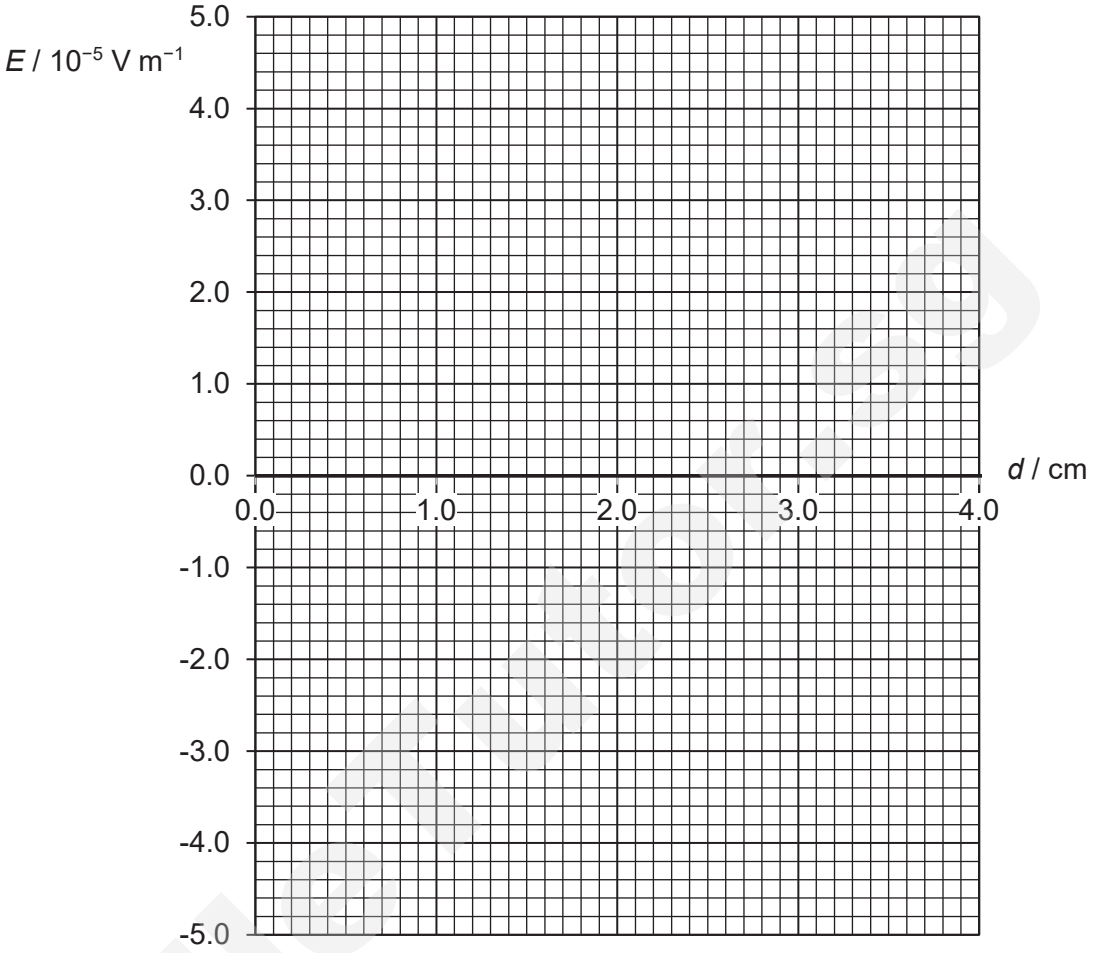


**Fig. 7.3**

[2]

**(iii)** A small positive charge is placed at A. The electric field causes this charge to move from rest along the line AB.

Describe the acceleration of the charge as it moves from A to B.

.....

.....

.....

..... [2]

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8 **(a)** In Singapore, power is supplied to our homes in the form of alternating current at a root-mean-square (r.m.s.) value of 230 V.

Fig. 8.1 shows typically how this voltage varies with time.

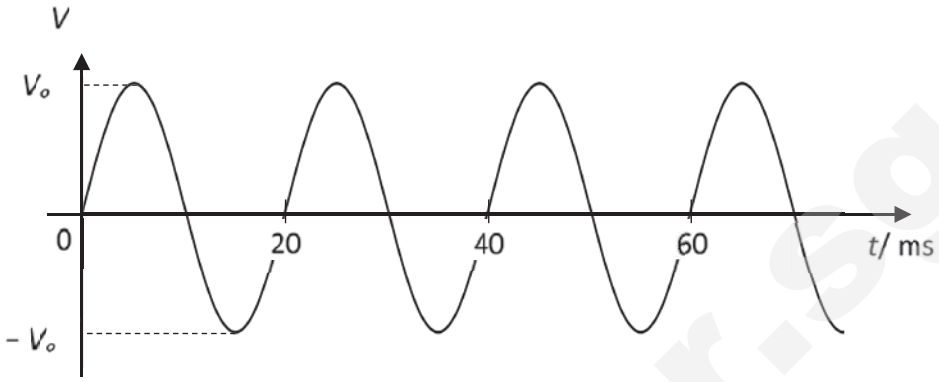


**Fig. 8.1**

**(i)** By reference to the heating effect, state what is meant by the r.m.s. value of an alternating current.

……

……

……

…… [2]

**(ii)** Use Fig. 8.1 and relevant information to determine

**1.** $V_o$

$V_o$ = …… V [1]

**2.** the angular frequency

angular frequency = …… rad $s^{-1}$ [2]

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**3.** the equation relating $V$ and $t$

[1]

**(iii)** Show that, for a sinuisodal alternating voltage, the mean power, $P_{mean}$, in a resistive load $R$ is half the maximum power, $P_o$.

[1]

**(iv)** With the use of a circuit diagram, describe how the A.C. power supplied can be converted for our household appliances that requires direct current operating on a much lower potential difference.

.....

.....

..... [3]

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**(b)** A long bar magnet is suspended in equilibrium from a helical spring such that one pole of the magnet lies within a short cylindrical coil as shown in Fig. 8.2.

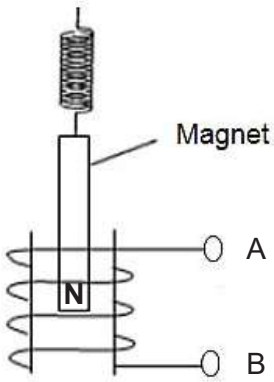


**Fig. 8.2**

The magnet is made to oscillate vertically with a frequency of 2.0 Hz such that one pole of the magnet oscillates in and out of the coil. The experiment is conducted in a draught free environment.

**(i)** Indicate on Fig. 8.2, the polarity of point A and B due to the induced e.m.f. with a "+" and "-", when the magnet is just entering the coil. [1]

**(ii)** Sketch on the axes of Fig. 8.3, with appropriate values, how the induced e.m.f. across terminal AB might vary with time, *t* for a duration of 1.0 s.




**Fig. 8.3**

[2]

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**(iii)** Use Faraday's Law of electromagnetic induction to explain the variation of the e.m.f. with respect to your graph drawn in Fig. 8.3.

……

……

……

…… [2]

**(c)** A resistor is now connected across the terminal AB as shown in Fig. 8.4.

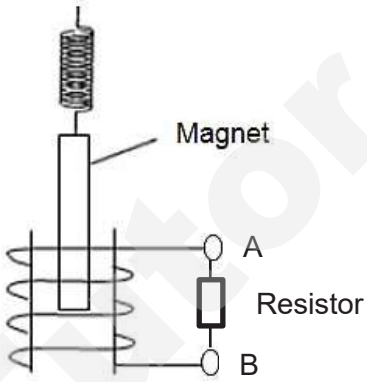


**Fig. 8.4**

**(i)** State and explain the change in the amplitude of the oscillation.

……

……

……

……

…… [3]

**(ii)** Sketch another graph on Fig. 8.3 to show how the power dissipated in the resistor varies with time for the same time interval of 1.0 s as in **b(ii)**. Label the graph **P**. [2]

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# TAMPINES MERIDIAN JUNIOR COLLEGE

## JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME: _____

CIVICS GROUP: _____ (  )

## H2 Physics 9749/04

Paper 4 Practical

**17 September 2019**

**2 hours 30 minutes**

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

**READ THESE INSTRUCTIONS FIRST**

Write your name and Civics Group in the spaces at the top of this page, page **9** and **15**.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **ALL** the questions.

You are allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| 1 | /15 |
| 2 | / 7 |
| 3 | /21 |
| 4 | /12 |
| Total | /55 |

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**1** In this experiment, you will investigate an electrical circuit.

**(a)** **(i)** You have been provided with a length of resistance wire attached to a metre rule, a light bulb and two identical resistors labelled Y.

Connect the circuit as shown in Fig. 1.1.

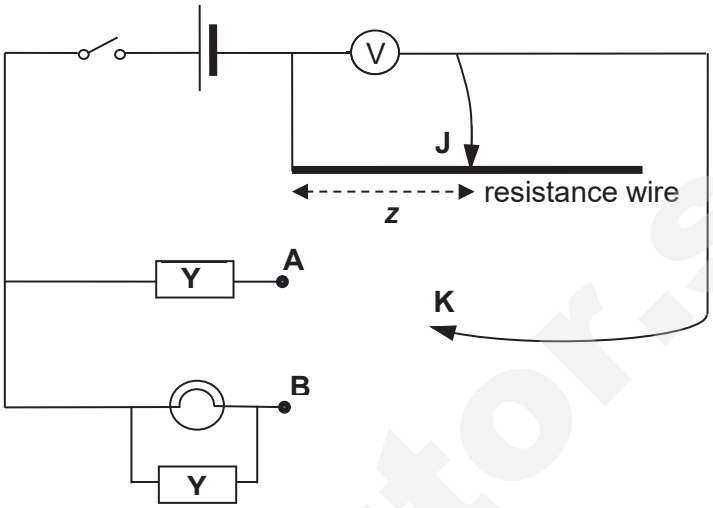


**Fig. 1.1**

J and K are crocodile clips.

**(ii)** Connect J to a point half-way along the wire. Measure and record □.

□ = ..... [1]

**(iii)** Estimate the percentage uncertainty in your value of □.

percentage uncertainty = ..... [1]

**(iv)** **1** Connect K to A. Close the switch and record the voltmeter reading $V_A$.

$V_A$ = .....

**2** Open the switch. Connect K to B. Close the switch and record the voltmeter reading $V_B$.

$V_B$ = .....

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3 Determine the value of $\frac{1}{V_B} - \frac{1}{V_A}$

$\frac{1}{V_B} - \frac{1}{V_A}$ = ..... [1]

**(b)** Vary □and repeat **(a)(iv).**

[5]

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**(c)** $V_A$, $V_B$ and □ are related by the expression

$$\frac{1}{V_B} - \frac{1}{V_A} = \frac{P}{\square} + Q$$

where $P$ and $Q$ are constants.

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

$P$ = .....

$Q$ = .....

[6]

**(d)** Sketch a second graph to represent the results if $Q$ increases. Label this graph **W**.

[1]

**[Total: 15 marks]**

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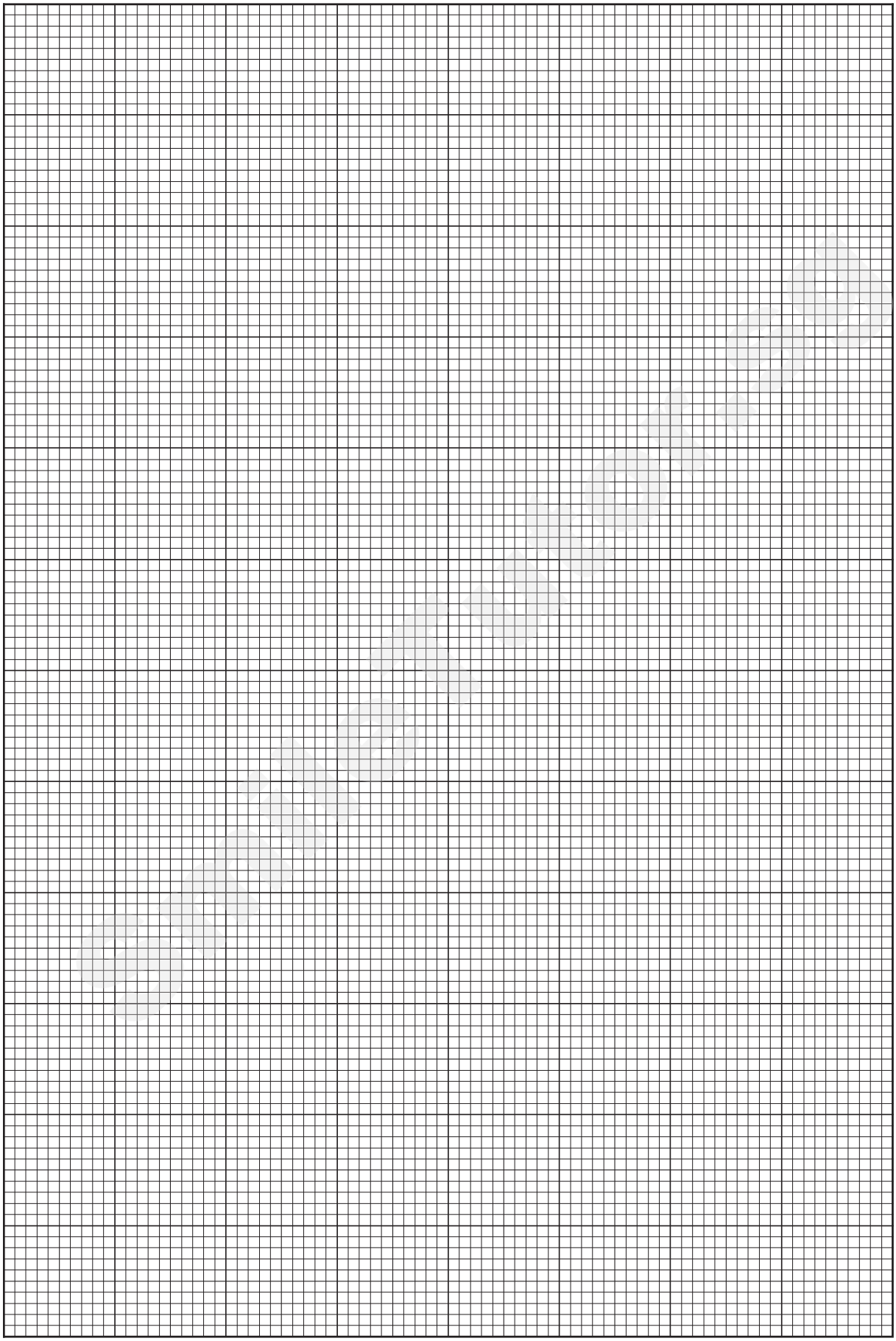

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**2** In this experiment, you will investigate the stability of a container of water as the height of water in the container is changed.

**(a) (i)** You are provided with two plastic bottles, of which one is empty, and the other is partially filled with water.

Each bottle has a 30 cm rule fixed to one side. You should **not** remove the rule from the bottles during the experiment.

Place the empty bottle so that the bottom of the rule is just touching the card that has been taped to the bench. The arrangement is shown in Fig. 2.1.

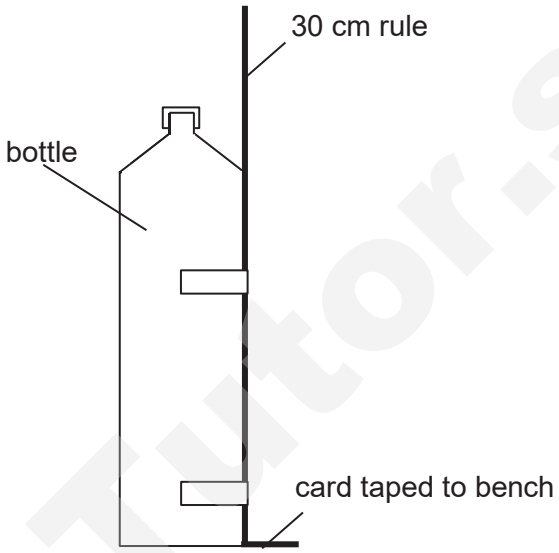


**Fig. 2.1**

**(ii)** Place the standing protractor scale behind the bottle so that the left-hand edge of the scale is aligned with the rule. The arrangement should now be as shown in Fig. 2.2.

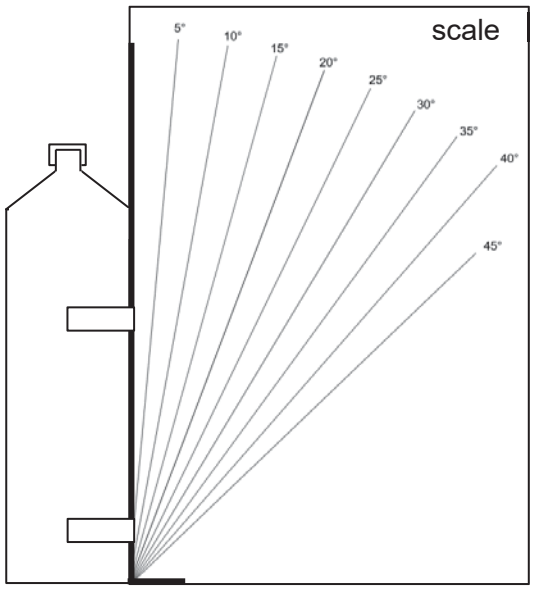


**Fig. 2.2**

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**(b)** **(i)** Gently push the top of the bottle in the direction shown in Fig. 2.3 so that the bottle begins to tilt.

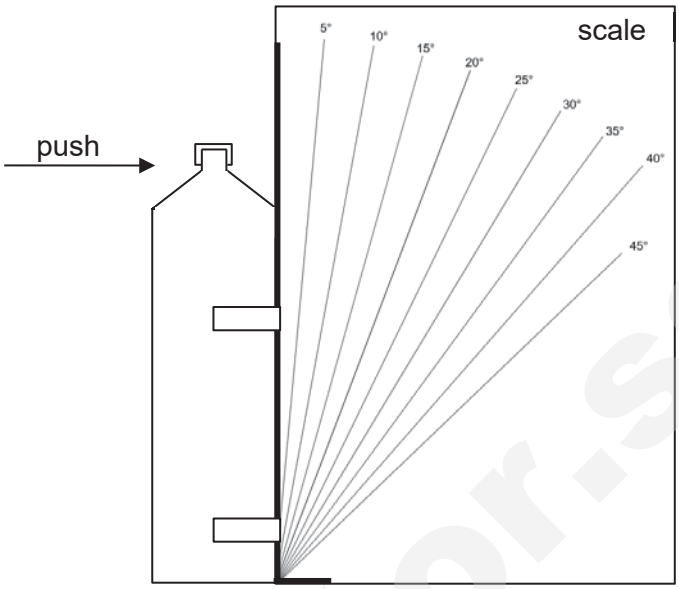


**Fig. 2.3**

Continue pushing until the bottle falls over. Measure and record the angle $\theta$ at which the bottle just falls over.

$\theta$ = ..... [1]

**(ii)** Using the other bottle with water of depth $d$ inside, repeat **(b)(i)**. Measure and record your values of $d$ and $\theta$ below.

$d$ = .....

$\theta$ = ..... [1]

**(iii)** State one significant source of error in the measurement of $d$.

.....

..... [1]

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**(c)** The experiment is repeated with different depth of water $d$ in the bottle.

The variation with $d$ of $\theta$ is shown in Fig. 2.4.

**(i)** Plot the data obtained in **(b)(i)** and **(b)(ii)** in Fig. 2.4.

**(ii)** Complete Fig. 2.4 by drawing the line of best fit. [3]

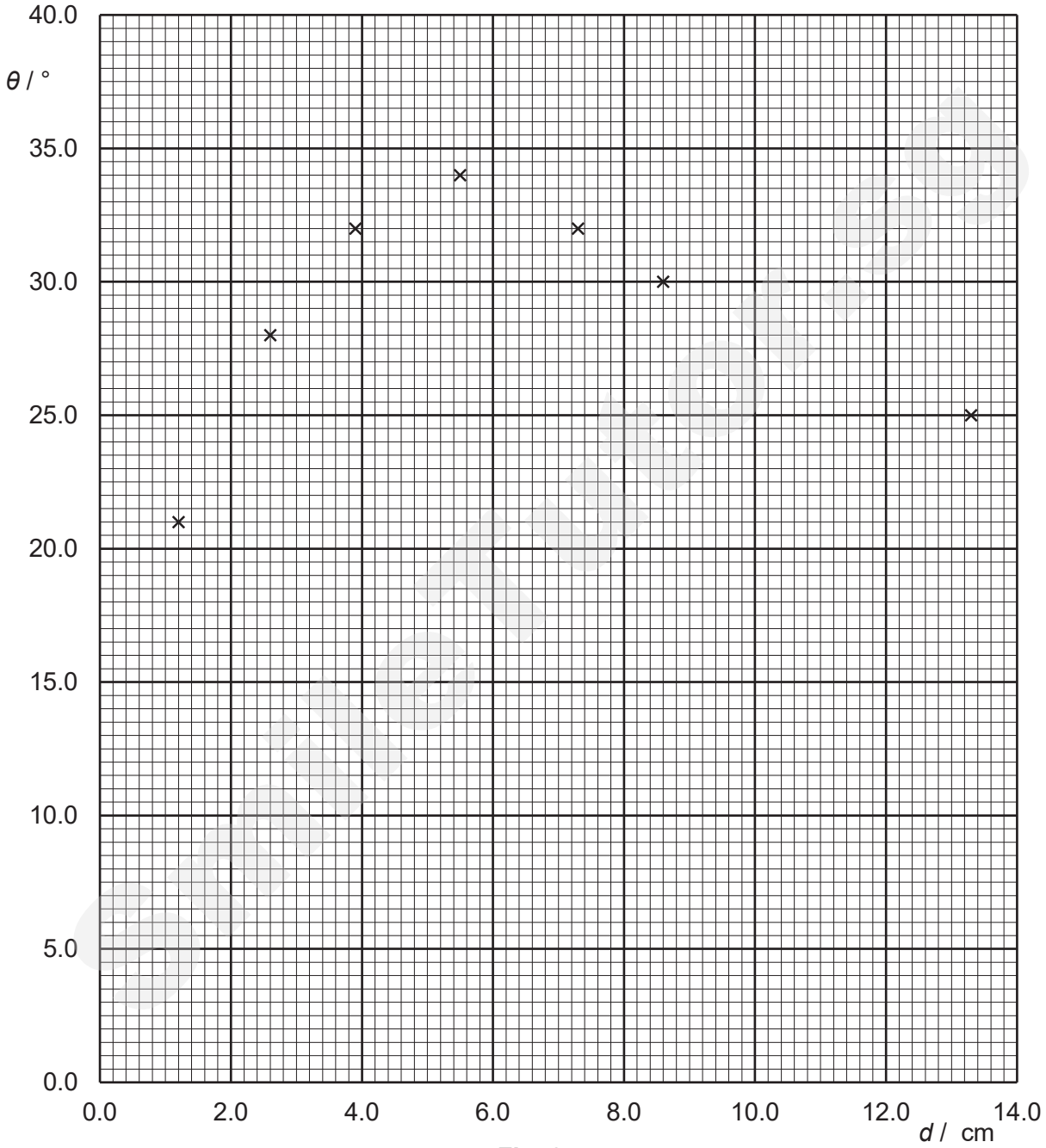


**Fig. 2.4**

**(iii)** Use your graph to determine the value of $d$ for which $\theta$ is a maximum.

$d$ for which $\theta$ is a maximum = ..... cm [1]

**[Total: 7 marks]**

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**3** In this experiment, you will investigate the current in a coil.

**(a) (i)** Use the Blu-Tack to fix the bar magnet to the mass hanger as shown in Fig. 3.1. The total mass of the mass hanger and mass should be 200 g.

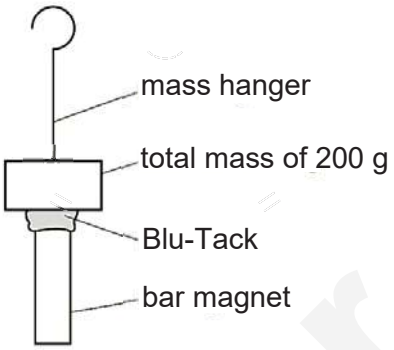


**Fig. 3.1**

**(ii)** Set up the apparatus as shown in Fig. 3.2.

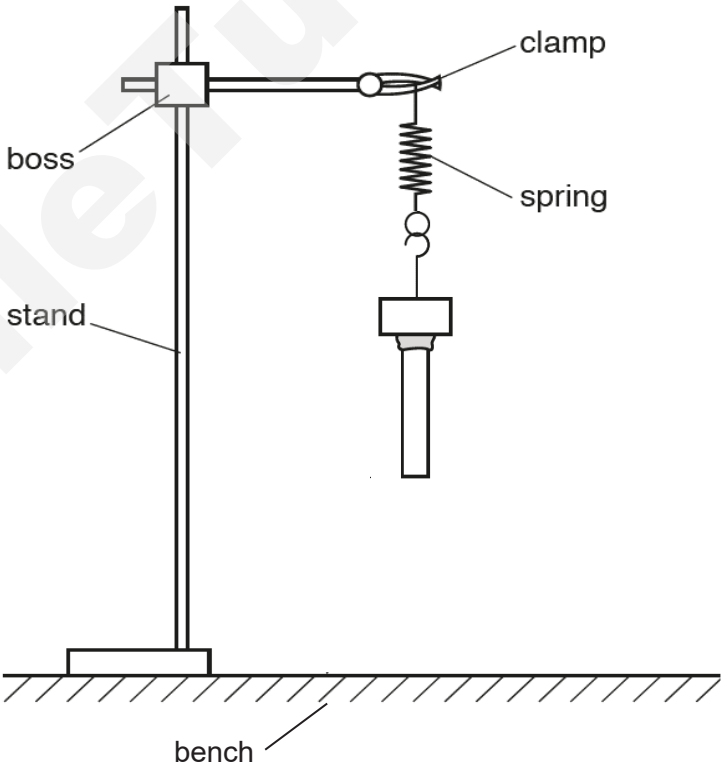


**Fig. 3.2**

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**(iii)** Pull the mass down through a short distance. Release the mass. The mass and magnet will oscillate.

Determine the period $T$ of these oscillations.

$T$ = ..... [1]

**(iv)** Calculate the frequency $f$ of the oscillations where

$$f = \frac{1}{T}.$$

$f$ = ..... [1]

**(v)** Justify the number of significant figures that you have given for your value of $f$.

.....

.....

..... [1]

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**(b)** **(i)** Take the PVC tube with **more** turns of wire.

Count and record the number $n$ of turns of wire around the tube.

$n$ = ..... [1]

**(ii)** Connect the ammeter to the ends of the wire around the tube and place the tube below the magnet.

Adjust the height of the bottom of the magnet so that it is level with the top of the tube as shown in Fig. 3.3.

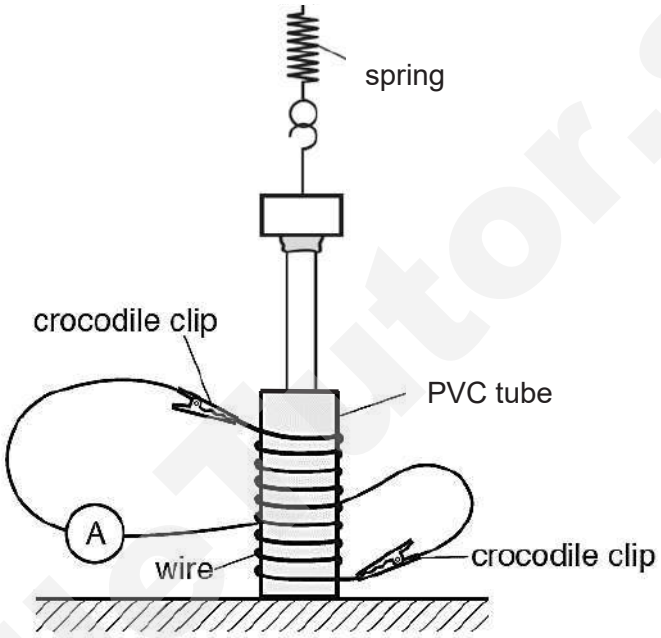


**Fig. 3.3**

**(iii)** Pull the mass down so that it rests on the top of the tube with the magnet passing centrally through the tube. Release the mass. The mass will oscillate.

Measure and record the maximum current $I$ shown by the ammeter.

$I$ = ..... [1]

**(iv)** Estimate the percentage uncertainty in your value of $I$.

percentage uncertainty = ..... [1]

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**(c)** **(i)** Remove the tube. Increase the total mass to 400 g.

Take the measurements to determine the period $T$ and frequency $f$ of the oscillations of the mass and the magnet.

$T$ = .....

$f$ = ..... [2]

**(ii)** Count and record the number $n$ of turns of wire around the tube with **fewer** turns of wire.

Keep the mass as 400 g and use the tube with **fewer** turns of wire to repeat **b(ii)** and **b(iii)**.

$n$ = .....

$I$ = ..... [2]

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**(d)** It is suggested that the relationship between $I$, $n$ and $f$ is

$$I = knf$$

where $k$ is a constant.

**(i)** Using your data, calculate two values of $k$.

first value of $k$ = ……

second value of $k$ = …… [1]

**(ii)** State whether the results of your experiment support the suggested relationship.

……

……

……

…… [1]

**(e)** **(i)** Suggest two significant sources of uncertainty or limitations of the procedure for this experiment.

1. ……

……

2. ……

…… [2]

**(ii)** Suggest two improvements that could be made to the experiment to address the errors identified in **(e)(i)**. You may suggest the use of other apparatus or a different procedure.

1. ……

……

2. ……

…… [2]

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**(f)** The current in the coil depends on speed of the oscillation of the mass and the magnet.

It is suggested that the maximum current $I_{max}$ is linearly related to the maximum speed $v_{max}$ of the mass and the magnet.

Plan an investigation to examine the relationship between $I_{max}$ and $v_{max}$.

Your account should include:

- your experimental procedure
- how you determine the maximum speed $v_{max}$
- how you would use your results to show the linear relationship.

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..... [5]

**[Total: 21 marks]**

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Candidate Name: _____ Civics Group: _____(  )

**4** A designer is drawing plans for the renovation of a flat. She is considering what material to use for the wall of each room. If the material is very dense and thick, then there is little transmission of sound from one room to another. However, the building cost will be greater.

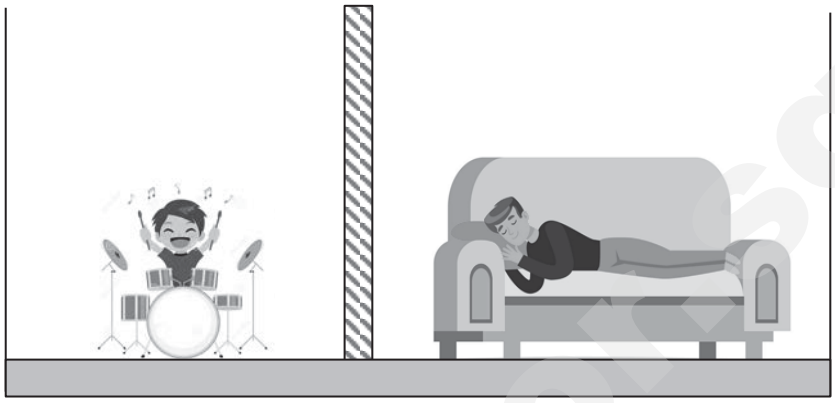

**Fig. 4.1**

The intensity of transmitted sound $I$ through a material depends upon the density $\rho$ and thickness $t$ of material. These quantities are related by the expression

$$I = k\rho^m t^n$$

where $k$, $m$ and $n$ are constants,

Design an experiment to determine the values of $m$ and $n$.

You are provided with boards of various densities and thickness, and a sound intensity meter.

You should draw a diagram to show the arrangement of your apparatus and you should pay particular attention to

**(a)** the equipment you would use

**(b)** the procedure to be followed

**(c)** the method of measuring the thickness and density of the material through which the transmitted sound passes

**(d)** the control of variables

**(e)** any precautions that should be taken to improve the accuracy and safety of the experiment.

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**Diagram**

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**[Total: 12 marks]**

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## 2019 J2 H2 Physics: Preliminary Examination (Paper 1) Solutions

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

**Q1 Ans: C**

0.59 Tm = $0.59 \times 10^{12}$ m = $0.59 \times 10^{9}$ km

t = distance / speed = $(0.59 \times 10^{9})/5.6 = 1.1 \times 10^{8}$ s

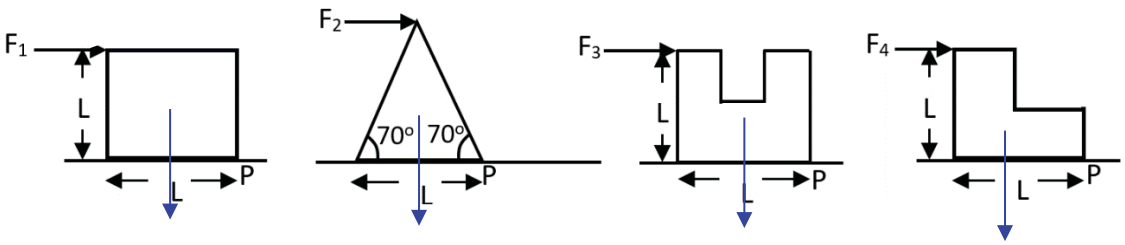
**Q2 Ans: A**

$$[\sigma]=\frac{[P]}{[A][T]^4}=\frac{\text{J s}^{-1}}{\text{m}^2\ \text{K}^4}=\text{J m}^{-2}\ \text{s}^{-1}\ \text{K}^{-4}$$

**Q3 Ans: D**

As the steel ball falls, it reaches terminal velocity and speed is constant. i.e. distance travelled per fixed time interval is constant.

**Q4 Ans: D**




Take moments about P in each case:

$F_1L = mg0.5L$ $F_1 = 0.5mg$

$F_20.5L\tan70^o = mg0.5L$ $F_2 = 0.36mg$

$F_3L = mg0.5L$ $F_3 = 0.5mg$

$F_4L = mgL'$ $L'>0.5L, F_4>0.5mg$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**Q5 Ans: B**

½ $mv^2 = mgh$

$v = \sqrt{(2gh)}$

Change in momentum = $1.2[\sqrt{(2gx2.0)} - (-\sqrt{(2gx2.8)}] = <F>x0.25$

$<F> = 66$ N

**Q6 Ans: A**

Acceleration = $50/(3.0 + 4.0) = 7.14$ m $s^{-2}$

Force on 4.0 kg mass = ma = kx

$4.0 \times 7.14 = 250x$

$x = 0.11$ m

**Q7 Ans: B**

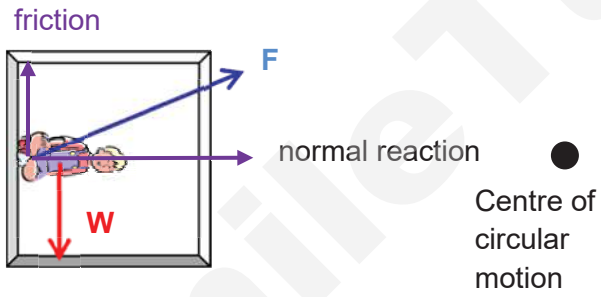
Work done by gravity = mg x vertical displacement in direction of mg

= 990 x 9.81 x (-12 x 8.3) x sin 15°

= - 250 kJ

**Q8 Ans: A**

The contact force F is the resultant of the normal reaction and friction exerted by cage on person.




**Q9 Ans: B**

Gravitational field lines are perpendicular to the equipotential lines and points from higher potential towards lower potential lines.

Magnitude of gravitational field strength can be determined by the potential gradient. ($g = -\frac{d\phi}{dr}$)

At point Y, the potential gradient is larger than that at point Z. (distance between potential lines at Y is smaller than that of Z)

**Q10 Ans: B**

Total energy = maximum KE

$$KE_{max} = \frac{1}{2}mv_0^2 = \frac{1}{2}m\omega^2 x_0^2 = \frac{1}{2}m\left(\frac{2\pi}{T}\right)^2 x_0^2$$

.

$$4.0 \times 10^{-3} = \frac{1}{2}(0.20)\left(\frac{2\pi}{T}\right)^2 (0.050)^2$$

$T = 1.6$ s



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**Q11 Ans: C**

$I \propto A^2$

$$\frac{4.0}{8.0} = \frac{(0.30)^2}{(A')^2}$$

$A' = 0.42$ mm

**Q12 Ans: D**

Wavelength $\lambda = \frac{v}{f} = \frac{320}{400} = 0.80$ m

Phase difference $= \frac{0.60}{0.80} \times 2\pi = \frac{3}{2}\pi$ rad

**Q13 Ans: B**

Using $d \sin\theta = n\lambda$

$$d = \frac{(3)(5.2 \times 10^{-7})}{\sin(51.3°)} = 2.0 \times 10^{-6} \text{ m}$$

$$\text{number of lines per mm} = \left(\frac{1}{2.0 \times 10^{-6}}\right) \times 10^{-3} = 500$$

**Q14 Ans: C**

Distance between successive minima,

$$x = \frac{\lambda D}{a} = \frac{(532 \times 10^{-9})(10.0)}{10.0 \times 10^{-3}} = 0.000532 \text{ m}$$

Number of x in 1.80 mm = 1.80/0.532 = 3.4

Therefore, total number of minima is 3 + 1 = 4

**Q15 Ans: C**

Using $pV = NkT$

Number of atoms per unit volume, $\frac{N}{V} = \frac{p}{kT} = \frac{1.2 \times 10^5}{(303.15)(1.38 \times 10^{-23})} = 2.9 \times 10^{25}$

**Q16 Ans: C**

$W_{by} = p\Delta V = 50$ J

$U = Q + W_{on} = 125 - 50 = 75$ J

**Q17 Ans: D**

$F = qE = q\frac{\Delta V}{d}$ where d is the plate separation. Between two large parallel plates , E is uniform. F is independent of x.



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**Q18 Ans: D**

Work done by the external agent = Change in potential energy
$= PE_f - PE_i$
$= (-qV_2) - (-qV_1)$
$= q(V_1 - V_2)$

**Q19 Ans: C**

The graph does not start from the origin, hence the conductor does not obey Ohm's Law.
Resistance cannot be found using gradient, only using V/I at that point.
Thus, R = 2 / 0.050 = 40 Ω

**Q20 Ans: A**

Power dissipated, $P = \frac{V^2}{R}$

Since the resistors are identical, $P \propto V^2$
R and Q are connected in parallel, hence

$V_S : V_R : V_Q$ or $V_S^2 : V_R^2 : V_Q^2$
2 : 1 : 1 or 4 : 1 : 1

Power dissipated across R = $\frac{1}{6} \times 12 = 2$ W

**Q21 Ans: D**

When the switch is closed, the p.d. across the parallel resistors will decrease. Hence the potential at **P** will decrease. The p.d. across the right resistor will increase, hence potential at **Q** will decrease to a more negative value.

**Q22 Ans: D**
B field by $W_2$ on $W_1$ is downwards. Applying FLHR, force is to the left. $W_3$ doesn't cause a force on $W_2$ as its B field on $W_2$ is parallel to the flow of current in W.

**Q23 Ans: D**
Current flows from center through the solution to the rim
Magnetic field is into the dish from top view
Fleming's left hand rule => force is "downwards" => solution spinning anticlockwise

**Q24 Ans: B**
Potential varies linearly from the center of the bar to the end of the bar. Thus, for biggest potential difference, connect voltmeter between center and end of the bar.

**Q25 Ans: A**
Mean power is independent of frequency and proportional to peak voltage square. Thus with new peak voltage to be half of the original one, mean power will be ¼ the original P


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**Q26 Ans: A**

Root mean square value of the voltage is 100 V since it is half-wave rectified. The average voltage will be lesser than the root mean square value

**Q27 Ans: B**

When frequency of the light is increased, the rate of incidence of the photons on the metal surface will decrease since the intensity remains unchanged.

As the rate of incidence of photons on the metal surface is decreased, the rate of emission of electrons will also decrease.

**Q28 Ans: A**

Find min $\Delta p$:

$\Delta x \Delta p \approx h$

$\Delta p \approx \frac{6.63 \times 10^{-34}}{1.3 \times 10^{-7}} = 5.1 \times 10^{-27}$ N s

Since direction of $\Delta x$ is vertical, the direction of $\Delta p$ must also be vertical.

**Q29 Ans: C**

**Q30 Ans B**

Let the initial count rate due to source only be $N$.

After 2 half-lives, the count rate will drop by $\frac{3}{4}N$.

Hence,

$\frac{3}{4}N = 324 - 108$

$N = 288$

Background radiation = 324 – 288 = 36



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**2019 J2 H2 Physics: Preliminary Examination (Paper 2) Solutions**

**1** **(a)** A quantity "speed" should not be defined with a unit "second". [B1]

(Comments for marker: Allow for "Speed should not be defined with a unit." or "Quantity should not be defined with second."

The speed of an object is defined as the distance travelled per unit time. [B1]

**(b)** **(i)** Gradient of the $v_y$-$t$ graph is gentler. Hence acceleration is decreasing. [M1] This suggests that there is a changing force, in this case the air resistance, that is acting on the object. Hence the air resistance is significant [A1]

Alternative:

In the $v_x$-$t$ graph, $v_x$ is decreasing with time. Hence there is a acceleration opposite to the motion / deceleration. [M1] This suggests that there is an opposing force, in this case the air resistance, that is acting on the object. Hence the air resistance is significant [A1]

Note: For both answers student should discuss about the acceleration before relating to the force.

**(ii)** $u_y = 15\ \text{m s}^{-1}$ $u_x = 12\ \text{m s}^{-1}$ [C1: Correct read-off of both values]

$$\tan\theta = \frac{u_y}{u_x}$$
$$= \frac{15}{12}$$
$$\theta = 51°$$ [A1]

**(iii)** Height
= Area under graph [M1: Evidence of obtaining area under graph to 1.3 s]
= ½ (1.3)(15)
= 9.8 m [A1: Accepted range 9.0 m to 9.8 m. Actual 9.35 m]

**(c)** At terminal speed, net acceleration is zero. [B1]

Since a table tennis ball has a smaller mass, from the equation $g = D/m$, drag force would be smaller at terminal speed. Since drag force is positively related (accept "proportional") to speed, a smaller drag force would imply a slower terminal speed. [B1]

*Alternative:*
At terminal speed, drag force equals to the weight. [B1]

Since the weight of the table tennis ball is smaller, the drag force would be smaller at terminal speed. Since drag force is positively related (accept "proportional") to speed, a smaller drag force would imply a slower terminal speed. [B1]


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**2** **(a)** Elastic collision: The total kinetic energy of the colliding bodies remains unchanged after the collision.

Or The relative speed of approach of the two bodies is equal to their relative speed of separation.

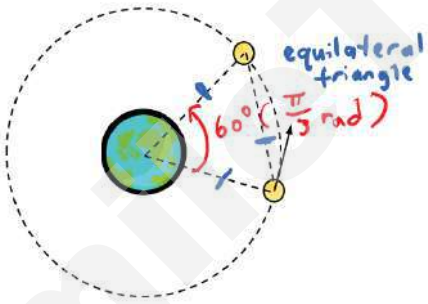
**(b)** By COLM: $2.4 \times 10^5 \text{ m} = mv_1 + 4mv_2$ [M1]
By RSS=RSA: $v_2 - v_1 = 2.4 \times 10^5$ [M1]
$2.4 \times 10^5 = v_1 + 4(2.4 \times 10^5 + v_1)$
$v_1 = -1.44 \times 10^5 \text{ m s}^{-1}$ [A1]
$v_2 = 9.6 \times 10^4 \text{ m s}^{-1}$ [A1]

**(c)** $2.4 \times 10^5 m = 5mv_o$ [M1]
$v_o = 4.8 \times 10^4 \text{ m s}^{-1}$ [A0]

**(d)** Some kinetic energy is converted to electric potential energy. [1]

**(e)** [C1] Correct application of formula for Electric Potential Energy
$2e^2/4\pi\varepsilon_o d = ½ mu^2 - ½ (5m)v_o^2$
$2(1.6 \times 10^{-19})^2/4\pi\varepsilon_o d = ½(1.67 \times 10^{-27}) (2.4 \times 10^5)^2 - ½ (5 \times 1.67 \times 10^{-27}) (4.8 \times 10^4)^2$ [C1
$2(1.6 \times 10^{-19})^2/4\pi\varepsilon_o d = 4.81 \times 10^{-17} - 0.962 \times 10^{-17} = 3.85 \times 10^{-17}$
$d = 1.2 \times 10^{-11}$ m [A1]

**3** **(a)**




Angular displacement = 1.05 rad [B1]

**(b)** **(i)** Angular velocity of Moon
$= 2\pi / 27.3 \times 24 \times 60 \times 60$
$= 2.66 \times 10^{-6} \text{ rad s}^{-1}$ [A1]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**(ii)** Let t be the time taken for the centre of masses to align again from the initial instant.
When their centre of masses align again,
if Moon has went through an angular displacement of θ,
satellite must have went through an angular displacement of θ + 2π

For Moon:

t = θ / (2π / 27.3 x 24 x 60 x 60) ---- (1)

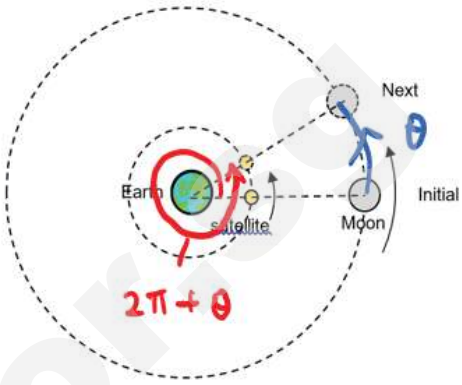
For satellite:

t = (θ + 2π) / (2π / 23.9 x 60 x 60) --- (2)

[C1 for both equations together]

Solving simultaneous equations

t = 89290 s
= 24.8 hours [A1]




Alternative method:

Find the relative angular velocity, $\omega_{satellite - moon}$ [C1]
$t = 2\pi / \omega_{satellite - moon}$ [A1]

**(c)** Gravitational force provides the centripetal force [B1]

$\frac{GMm}{d^2} = md\omega^2$ , where m is mass of satellite

$\frac{GMm}{d^2} = md(\frac{2\pi}{T})^2$ [M1] (accept r in place of d, if student defines r as orbital radius)

$T^2 = (\frac{4\pi^2}{GM})d^3$

$T = (\sqrt{\frac{4\pi^2}{GM}})\sqrt{d^3}$

hence $k = (\sqrt{\frac{4\pi^2}{GM}})$ [A1]

**(d)** As the satellite spirals down, the radius of orbit decreases, [M1]

resulting in the period decreasing based on the relationship in (b) (or "based on Kepler's Third Law", or based on $\omega = \sqrt{(GM / d^3)}$ ). [M1]

And since angular velocity = 2π / period, the angular velocity increases [A1]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**Alternative answer:**
As the satellite spirals down, the radius of orbit, r, decreases, [M1]

The kinetic energy of the satellite will increase as it's kinetic energy = GMm/ 2r and therefore it's speed v will increase. [M1]
Since v = r x angular velocity, with r decreasing but speed increasing, angular velocity must increase. [A1]

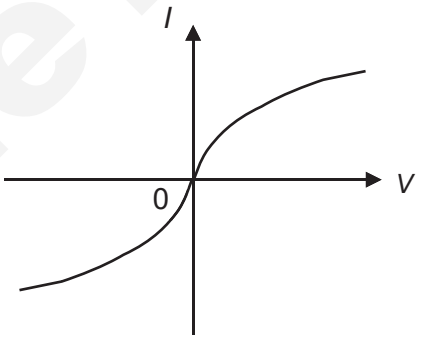
**4 (a) (i)** Very high/infinite resistance for negative voltages up to about 0.4 (or 0.5) V. [B1]
Resistance decrease from 0.4 (or 0.5) V [B1]

Values of V must be given. If student refer to gradient or rate, deduce 1 mark.

**(ii)** Read off from graph, V = 0.55 V when I = 0.40 mA

$$R = \frac{V}{I}$$
$$= \frac{0.55}{0.40 \times 10^{-3}} \quad [M1]$$
$$= 1380\ \Omega \quad [A1]$$

**(b)** Initial straight line from (0.0) into curve with decreasing gradient but not to horizontal. Repeated in negative gradient.




B1 – for correct shape for both positive V and negative V axis.

**(c) (i)**
$$P = \frac{V^2}{R}$$
$$R = \frac{10^2}{20} \quad [M1]$$
$$= 5.0\ \Omega \quad [A1]$$

**(ii)** By potential divider principle,
$$\frac{R}{R + 0.5 + 2.0} \times 12 = 2.0 \quad [M1]$$
$$R = 0.50\ \Omega \quad [A1]$$

**(d)** Resistance of the lamp increases as V increases. [B1]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**5** **(a)** The magnetic flux density of a magnetic field is defined as the force per unit current per unit length (of conductor) [A1] acting on a straight current-carrying conductor placed at right angles to the magnetic field[M1].

**(b)** **(i)** Out of paper [A1]

**(ii)** 1. magnetic force provides for centripetal force,

Bev = $mv^2/r$ [M1]

mv = Ber [M1]

p= Ber [A0]

2. p = Ber = 0.24 x 1.6x $10^{-19}$ x 0.062 [C1]

= 2.4 x $10^{-21}$ N s [A1]

**(iii)** 1. +ve at lower plate and –ve at upper plate [A1]

2. It will be deflected upwards [A1] as an increase in momentum will mean an <u>increase in velocity</u>, thus the magnetic force acting upwards will be greater than electric force acting downwards [M1]

**6** **(a)** The nuclear binding energy of a nucleus is defined as the <u>minimum energy required to completely separate a nucleus into its constituent nucleons</u>. [B1]

**(b)** **(i)**

$$BE = (\Delta m)c^2$$

$$= \left[(26 \times 1.00728) + (30 \times 1.00866) - 55.92132\right](1.66 \times 10^{-27})(3.0 \times 10^8)^2 \quad \text{[M1]}$$

$$= 7.88473 \times 10^{-11} \text{ J}$$

$$= 492.796 \text{ MeV}$$

$$\text{BE per nucleon} = \left(\frac{492.796}{56}\right) \quad \text{[M1]}$$

$$= 8.8 \text{ MeV} \quad \text{[A0]}$$

**(ii)**

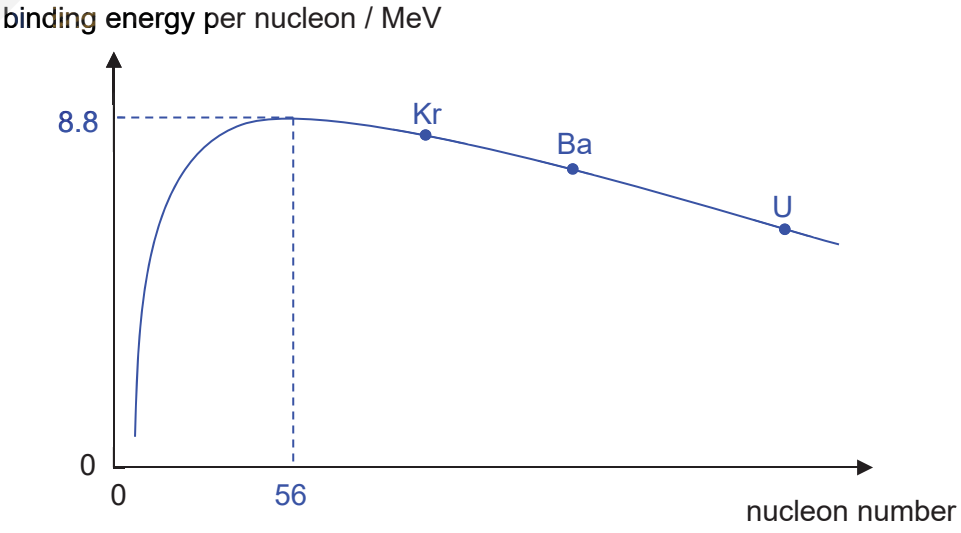


**Fig. 6.1**



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[B1] – correct shape
[B1] – label 8.8 Mev and 56 at the peak of graph

**(c) (i)** [B1] – all 3 positions marked in correct sequence, relative spacing is correct

**(ii)** Binding energy per nucleon of Ba and Kr are higher, hence products are more stable [B1]
This implies that the total binding energy of U is lower than the total binding energies of Ba and Kr. [B1]
Hence energy is released in this fission reaction.

**(iii)** $Energy\ released = BE_{products} - BE_{reactants}$
$= \left[(141\times 8.3)+(92\times 8.5)\right]-\left[235\times 7.6\right]$ [M1]
$= 166.3 = 170$ MeV [A1]

**7 (a) (i)**
$$\text{vertical velocity} = \frac{\text{change in height}}{\text{duration}}$$
$$= \frac{(7.2-5.5)\times 10^3}{400} \quad [B1]$$
$$= 4.25 \text{ m s}^{-1}$$

**(ii)** Since speed is the magnitude of the velocity,
$$v = v_x^{\,2} + v_y^{\,2}$$
$$v_x = \sqrt{v^2 - v_y^{\,2}}$$
$$= \sqrt{177^2 - 4.25^2} \quad [M1]$$
$$= 176.95 \quad [A1]$$

**(b) (i)**
$$\Delta K = \frac{1}{2}m\left(v_f^{\,2} - v_i^{\,2}\right)$$
$$= \frac{1}{2}\times 34000\times(177^2 - 160^2) \quad [M1]$$
$$= 97393000$$
$$= 9.74\times 10^7 \text{ J} \quad [A1]$$

**(ii)** highest power occurs when the aircraft is climbing and speeding up

$$P_{\text{climb}} = \frac{5.67\times 10^8}{400} = 1417545$$
$$P_{\text{speed up}} = \frac{9.74\times 10^7}{(150-50)} = 973930 \quad [M1:Calculating each power]$$
$$P_{\text{highest useful}} = 1417545 + 973930 = 2391475 = 2.39\times 10^6 \text{ W} \quad [A1]$$

**(c) (i)** It is the magnitude of energy per unit mass of fuel. [B1]


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**(ii)**

$$\text{Total energy required} = \left(E_{\text{climb}} + E_{\text{speed up}}\right) \times \frac{100}{24} \quad \text{[C1]}$$

$$= \left[\left(5.67 \times 10^{8}\right) + \left(9.74 \times 10^{7}\right)\right] \times \frac{100}{24}$$

$$= 2.768 \times 10^{9} \text{ J} \quad \text{[A1:correct calculation]}$$

$$\text{mass of fuel} = \frac{\text{total energy}}{\text{fuel energy density}} \quad \text{[C1]}$$

$$= \frac{2.768 \times 10^{9}}{45 \times 10^{6}}$$

$$= 61.5 \text{ kg} \quad \text{[A1: correct calculation]}$$

**(iii)** The mass of fuel burnt/lost is very small compared to the operating mass of the aircraft. [B1]

**(d)** **(i)**

| $u$ / m s$^{-1}$ | $h$ / m | $\rho$ / kg m$^{-3}$ | $u^2\rho$ / kg m$^{-1}$ s$^{-2}$ | $D$ / ×10$^6$ N |
|---|---|---|---|---|
| 160 | 5500 | 0.698 | 17900 | 1.160 |
| 167 | 5720 | 0.681 | 19000 | 1.231 |
| 177 | 5930 | 0.665 | 20800 | 1.348 |
| 177 | 6350 | 0.635 | 19900 | 1.29 |
| 177 | 6570 | 0.620 | 19400 | 1.257 |
| 177 | 6800 | 0.603 | 18900 | 1.225 |

**Fig 7.3**

[B1 for correct answer]

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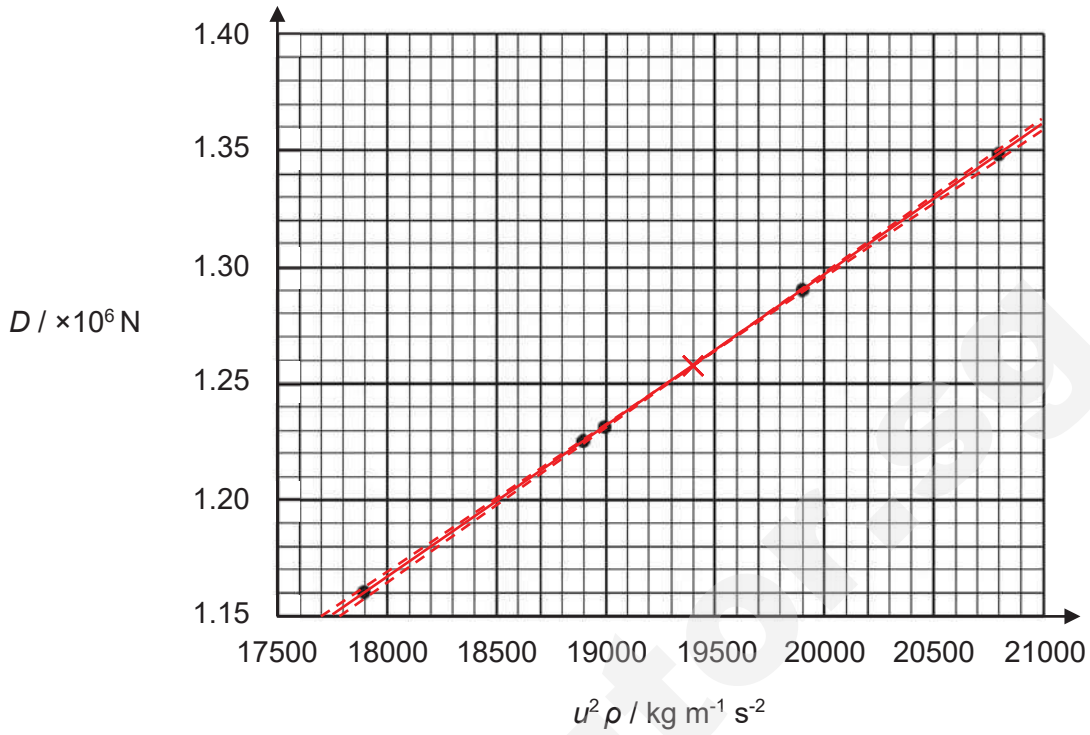


**Fig 7.4**

**(iii)**

$\frac{1}{2}C_D S = \frac{y_2 - y_1}{x_2 - x_1}$ [C1: relating $\frac{1}{2}C_D S$ to gradient]

$C_D = \frac{2}{S}\frac{(y_2 - y_1)}{(x_2 - x_1)}$

Readoffs $(17900, 1.16)$ and $(20800, 1.35)$

$C_D = \frac{2}{162}\frac{(1.35 - 1.16)\times 10^6}{(20800 - 17900)}$

$= \frac{2}{162}(65.517)$

$= 0.809$ (no units) [A1: within 0.785 to 0.825]

**(iv)** Quantitative calculation to show that the vertical intercept is close to zero. [B1]
Deduce that the expression is correct with the straight line graph. [B1]
OR
Using two sets of values read from the line of best fit, it can be shown that the ratio of $D$ and $u^2\rho$ is approximately constant [B1] (calculations must be presented)
and the expression shows that they are directly proportional to each other [B1]


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**2019 J2 H2 Physics: Preliminary Examination (Paper 3) Solutions**

**1.** **(a)** The pressure due to a fluid increases with depth in the fluid. [B1]
For a body in a fluid, there is a difference in fluid pressure over the upper and lower surface of a body, which gives rise to upthrust on the body. [B1]

**(b)** **(i)** Consider the system of object and balloon.

Total upthrust – total weight = total mass x acceleration

$1000g(V_o + 0.15) - 305.2g = 305.2a$ [C1]

$V_o = 0.217\ m^3$ [A1]

**(i) 1.** A body moving in a fluid experiences a drag force which opposes its motion. [B1] This drag force is proportional to the velocity of the body Or increases as the velocity increases [B1] The drag force causes the net force to decrease, hence acceleration decreases continuously.

**(ii) 2.** As the lifting balloon rises, the fluid pressure decreases which causes the volume of the balloon to increase [B1]. Upthrust on the bag thus increases [B1], leading to an increase in net force and acceleration.

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**2** **(a)** Work done by a force is the product of the force and displacement in the direction of the force. [B1]

**(b)** Consider a body of mass m that is raised to a vertical height h above the ground at a constant velocity by an external force F. [B1]

Since velocity is constant, *net force = 0*

$F - mg = 0$

The magnitude of the external force, $F = mg$

Work done by the external force, $W = F.s = mgh$ [B1]

Work done by *F* increases only the gravitational potential energy of the block

Final $E_p$ – Initial $E_p = mgh$

If we take the gravitational potential energy at initial height to be the reference level (i.e. $E_p$ at $h_i$ = 0 J), then an object of mass *m* raised by height *h* vertically above the reference level has potential energy of

$E_p = mgh$ (shown) [B1 for the entire highlighted portion]

**(c)** **(i)** By the conservation of energy,

loss in GPE of weight + loss in GPE of rod = work done against average resistance by ground

[C1, must clearly show that there are two losses in GPE. If calculation does not show this, zero marks for everything]

650(9.81)(1.2 + d) + 140 (9.81) (d) = 50 000 d [M1]

d = 0.18 m [A1]

**(ii)** During the collision, some energy will be lost to the surroundings as thermal energy and sound energy [B1], resulting in less energy transferred to the pole.

Can consider other specific context eg. Rocks or non-uniform soil

(For reference, the energy lost to surroundings can be due to inelastic collision, viscous forces doing work, the soil gaining kinetic energy, the rope not remaining slack and gaining elastic potential energy etc)


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**3** **(a)** A damped oscillation refers to the oscillator's energy being dissipated Or resistive/dissipative forces are present OR amplitude of oscillation decreases over time.

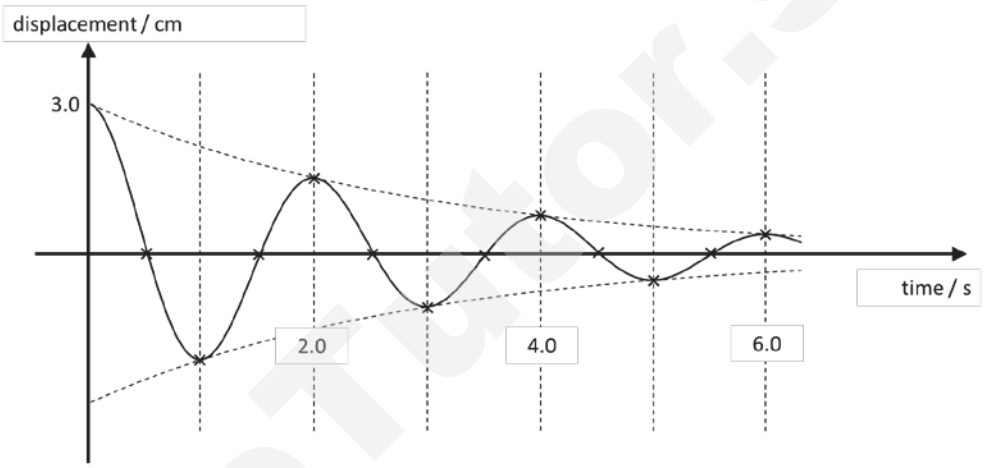
**(b)** **(i)** $a = -\omega^2 x$

$$|a_{max}| = \left| -\left(\frac{2\pi}{T}\right)^2 3.0 \times 10^{-2} \right| \quad [M1]$$

$$= 0.296 \text{ m s}^{-2} \quad [A1]$$

Accept $a_o = w^2 x_o$

**(ii)**




[B1] light damping with decreasing displacement.

[B1] initial displacement of 3.0 cm & period shown as 2.0 s.

**(c)** physical phenomenon: resonance [B1]

condition: driving frequency equals to the natural frequency of the spring-mass system [B1

**(d)** Critical damping is required for a car suspension system. [B1]

This is necessary to stop the car from oscillating as quickly as possible that could otherwise cause driver to lose control of the car/ cause excessive damage to car/ cause excessive discomfort to passengers/returns to equilibrium as quick as possible such that it ready for next hump on the road. [B1]

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**4 (a)** $\theta_{rc} \approx \frac{\lambda}{b}$

$= \frac{1.2}{250}$

$= 0.0048$ rad [M1]

Using small angle approximations,

$\theta_{rc} \approx \frac{s}{r}$ (arc length formula)

$0.0048 = \frac{1.8 \times 10^{12}}{r}$ [M1]

$r = 3.75 \times 10^{14}$ m [A1]

**(b) (i)** $n$ can only be odd numbers. [B1]

This is to ensure that the boundary conditions for the formation of a stationary wave within the well is met. [B1]

Or

This is to ensure that a node will be formed at the water surface in the well and an anti-node is formed at the opening of the well. [B1]

**(ii)** At 30.0 Hz,

$\frac{n\lambda}{4} = d$

$\frac{nv}{4f} = d$ [M1]

$(n)\left(\frac{330}{(4)30.0}\right) = d$ (1)

At 42.0 Hz,

$(n+2)\left(\frac{330}{(4)42.0}\right) = d$ (2) [M1]

Solving,

$n$ = 5

$d$ = 13.8 m [A1]

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**(iii)**



1 mark for solid line and dotted line.
1 mark for shape.
This part can still be awarded if the earlier parts are wrong.

**5 (a)** Any two of the following:

- o The gas consists of a very large number of molecules in continuous random motion.
- o There are *no intermolecular forces* except during collisions between molecules.
- o The gas molecules undergo elastic collisions with one another and with the walls of the container.
- o The *duration of collisions is negligible* compared with the time interval between collisions.
- o *Newtonian mechanics is applicable* to the motion of the molecules.
- o The *volume of the gas molecules is negligible* compared with the volume of the container.

1 mark for each assumption. (underline the statement)

**(b)** Consider one molecule of mass $m$ moving with a speed of $c_x$ in the x direction, hitting one wall of the container. Assuming collision is elastic,

Force exerted by wall on the molecule

$$= \frac{\Delta p}{\Delta t} = \frac{2mc_x}{2L/c_x} \qquad \text{[M1]}$$

$$= \frac{mc_x^2}{L}$$

By Newton's third law, force exerted by wall on molecule = force exerted by molecule on wall.

Force on wall due to $N$ molecules


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$$= \frac{mc_{x1}^2}{L} + \frac{mc_{x2}^2}{L} + \ .... + \frac{mc_{xN}^2}{L}$$
$$= \frac{Nm\langle c_x{}^2 \rangle}{L}$$ [M1 - must include reference to N3L]

Since there are a large number of molecules moving in random motion,

$\langle c_x^2 \rangle = \langle c_y^2 \rangle = \langle c^2 \rangle = \frac{1}{3}\langle c^2 \rangle$ [M1]

Therefore, pressure on wall due to *N* molecules,

$p = \frac{F}{L^2}$

$= \frac{1}{3}\frac{Nm\langle c^2 \rangle}{L^3}$ [M1] Change to B1 marks

$= \frac{1}{3}\rho\langle c^2 \rangle$ [A0]

**(c) (i)** Specific latent heat of fusion is the amount of thermal energy required per unit mass of a substance to change it from solid to liquid without any change in temperature. [A1]

**(ii)** Let *m* be the mass of ice formed.
*M* is the initial mass of water = 120 g

Heat loss forming ice = Heat removed by evaporation [C1]

$mL_f = (M - m)L_v$

$m = \frac{L_v}{L_f + L_v}M$

$= \frac{2.52 \times 10^6}{(25.2 + 3.40) \times 10^5}(120)$ [M1]

$= 105.7 \approx 106$ g [A1]

**6 (a) (i)** An incident highly energetic electron stops abruptly [B1] in a single collision with the target/metal nucleus.

All the (kinetic) energy [M1] of the electron is completely converted into a single X-ray photon. [A1]

The last A1 mark is awarded only if it is mentioned that only 1 photon is produced as a result of the KE from 1 electron. (1-1 ratio).


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**(ii)**

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

$$V = \frac{hc}{e\lambda_{min}} = \frac{\left(6.63\times10^{-34}\right)\left(3.0\times10^{8}\right)}{\left(1.6\times10^{-19}\right)\left(0.068\times10^{-9}\right)} \quad [M1]$$

$$= 18281 = 18300 \text{ V} \quad [A1]$$

**(b) (i)** Arrow from L to K shell, pointing downwards [B1]

**(ii)**

$$\Delta E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{\Delta E} = \frac{\left(6.63\times10^{-34}\right)\left(3.0\times10^{8}\right)}{(20-3.1)\left(10^{3}\right)\left(1.6\times10^{-19}\right)} \quad [M1]$$

$$= 7.35577\times10^{-11} = 7.4\times10^{-11} \text{ m} \quad [A1]$$

**(iii)** To produce $K_\alpha$ characteristic X-ray, <u>electron in the K-shell needs to be removed/ejected out of the atom</u>. This <u>requires energy of 20 keV. [M1]</u>

<u>Accelerating voltage</u> of X-ray machine is only <u>18.3 kV which is less than 20kV</u> [M1]. Hence incoming/colliding electrons (from cathode) do not have sufficient energy to eject the inner shell electron.

$K_\alpha$ characteristic X-ray <u>cannot be produced</u>. [A1]

**(c) (i)** Order of magnitude = $10^{-10}$ m [B1] {accept range of $10^{-9}$ m to $10^{-10}$ m}

For <u>significant/observable/apparent</u> diffraction to occur (to form a pattern), the slit width (i.e the spacing of between the DNA molecules) should be approximately equal to the wavelength of the X-ray used. [B1]

**(ii)** For the electron to have de Broglie wavelength of 0.11 nm,

$$p = \frac{h}{\lambda}$$

$$p = \frac{h}{\lambda} = \frac{\left(6.63\times10^{-34}\right)}{\left(0.11\times10^{-9}\right)} \quad [M1]$$

$$= 6.0273\times10^{-24} = 6.0\times10^{-24} \text{ N s} \quad [A1]$$

**7 (a)** Gravitational field is <u>a region of space</u> [B1] where a <u>mass will experience a gravitational force</u> due to the presence of another mass. [B1]

**(b)** Define *gravitational potential* at a point is the <u>work done per unit mass</u> in bringing a small test mass from infinity to that point without a change in kinetic energy. [B1]


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**(c)** **(i)**

$$\phi = -\frac{GM}{R}$$

$$\Delta\phi = \phi_B - \phi_A$$

$$= -\frac{GM}{6R} - \left(-\frac{GM}{2R}\right) \quad \text{[M1]}$$

$$= \frac{GM}{3R} \quad \text{[A0]}$$

**(ii)** loss in $E_k$ = Gain in $E_p$

$E_{k,initial}$ - $E_{k,final}$ = $m\Delta\phi$

$$(1.70 - 0.72)\times 10^{12} = 4.7\times 10^{4} \times \frac{GM}{3R}$$

$$0.98\times 10^{12} = 4.7\times 10^{4} \times \frac{4.0\times 10^{14}}{3R} \quad \text{[M1]}$$

$$R = 6.39\times 10^{6} \text{ m [M1]}$$

Distance A to B = $4R$ = 2.56 x $10^7$ m [A1]

assumption: Ignoring gravitational force due to other bodies. [B1]

**(iii)** Gravitational force provides for centripetal force on rocket.

$$\frac{GMm}{(6R)^2} = \frac{mv^2}{6R}$$

$$v^2 = \frac{GM}{6R}$$

$$v = \sqrt{\frac{4.0\times 10^{14}}{6\times 6.39\times 10^{6}}} \quad \text{[M1]}$$

$$= 3230 \text{ m s}^{-1} \quad \text{[A1]}$$

**(d)** ***Electric field strength*** at a point is the electric force per unit positive charge placed at that point. [B1]

**(e)** Similarity [B1 for any of the following]
1) Both field lines are radial from the centre of the sphere.
2) Both field lines intersects perpendicular to the surface of the sphere.
3) Field lines are equally spaced at the surface of the sphere.
4) Further from the sphere, the spacing of lines increases (indicating that field strength becomes weaker away from charge)

Difference [B1]
1) Gravitational field lines are directed towards centre of sphere while electric field lines are directed away from the centre of sphere.

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**(f)** **(i)**

$$E = \frac{Q}{4\pi\varepsilon_0 r^2} \quad \text{[C1]}$$

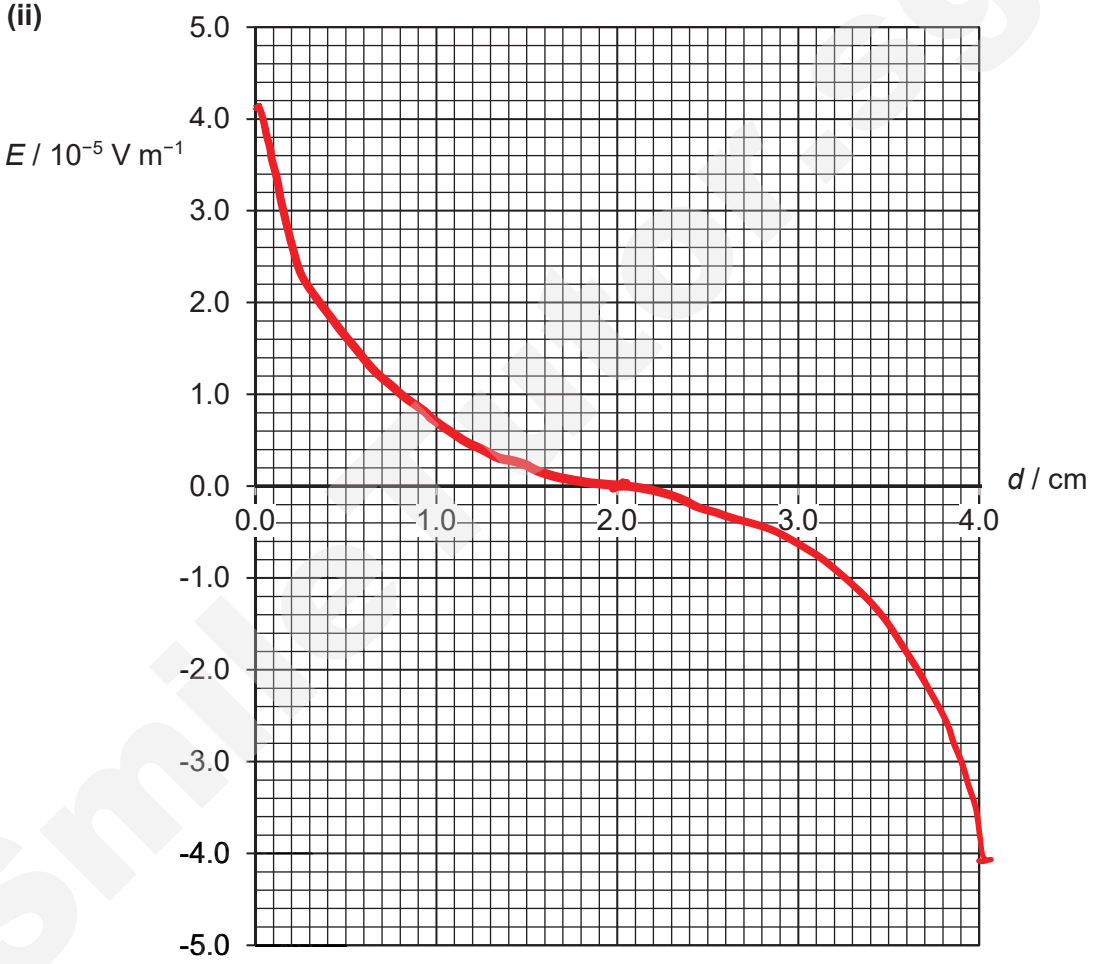
$$E \text{ at A} = E_1 - E_2$$

$$4.1\times10^{-5} = \frac{Q}{4\pi\varepsilon_0 r_1^2} - \frac{Q}{4\pi\varepsilon_0 r_2^2}$$

$$= \frac{Q}{4\pi\varepsilon_0 (0.01)^2} - \frac{Q}{4\pi\varepsilon_0 (0.05)^2} \quad \text{[M1]}$$

$$Q = 4.75\times10^{-19} \text{ C} \quad \text{[A1]}$$

**(ii)**




[B1] smooth curve & generally asymmetrical about horizontal axis

[B2] zero E at d= 2.0 cm, correct intercepts at 4.1 x $10^{-5}$ & -4.1 x $10^{-5}$

**(iii)** By Newton 2nd law, $F_{net}$ = qE = ma, the acceleration of the charge is proportional to the electric field strength.

Hence, from A to midway between A & B, the charge accelerates (towards the right) at a decreasing rate until it reaches zero at midway. [B1]

Thereafter, the charge accelerates (in opposite direction) from zero at an increasing rate towards B. [B1]

Alternative answer to 2nd mark: Thereafter, the charge decelerates at an increasing rate towards B.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**8** **(a)** **(i)** The root mean square value of an alternating current that passes through a resistor is the value of an equivalent steady direct current that would produce the same rate of heating in the resistor as the alternating current .

Pure definition only 1 mark [B1].
Contextualising [B1]

**(ii)**

**1.** $V_o = \sqrt{2} \times V_{r.m.s}$
$= \sqrt{2} \times 230 = 325 \text{ V } [A1]$

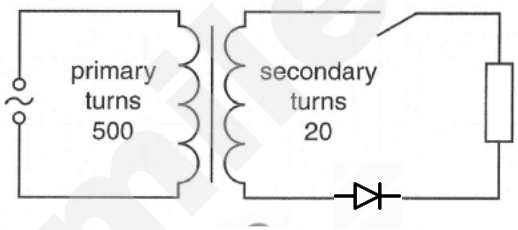
**2.** $\omega = 2\pi f = 2\pi \times (\frac{1}{20 \times 10^{-3}})[C1]$
$= 314 \ rad \ s^{-1} [A1]$

**3.** $V = 325 \sin(314t)$ [A1]

**(iii)**

$$P_{mean} = \frac{V^2_{r.m.s}}{R} = \frac{(\frac{V_o}{\sqrt{2}})^2}{R}[M1]$$
$$= \frac{V_o^2}{2R}[A0] = \frac{P_o}{2}$$

**(iv)**




**[B1]** for correct set up and symbol used

A step down transformer can be used to reduce the voltage of the power supply [B1].

A diode can then be used to convert the AC to DC (or rectification mentioned) [B1].

**(b)** **(i)** Current flow from B to A if circuit is closed. As coil is taken as battery, current flow from –ve to +ve.Thus, B is labelled "-" and A "+"[B1]

**(ii)** **correct shape** [M1] – accept both positive or negative cos or sine graph, 2 complete cycles within 1.0 s with period labelled as 0.50 s [A1]

**(iii)** Since the velocity varies sinusoidally with time, the rate of magnetic flux linkage also varies sinusoidally with time. [M1]

Since induced emf is proportional to the rate of change of magnetic flux linkage. Thus, by Faraday's law, emf varies sinusoidally with time [A1].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**(c)** **(i)** As the circuit is now closed, induced current will flow through the coil. [B1] By Lenz's law, the induced current will flow in such a way to **produce an effect** to oppose the change in magnetic flux linkage experienced by the coil [M1]. This will create a damping effect on the magnet and it will eventually stop oscillating. [A1]

Alternative answer: using COE to explain: As the circuit is now closed, induced current will flow through the coil [B1].The mechanical energy of the magnet is converted to electrical energy of coil [M1], hence the amplitude of oscillation decreases and will eventually becomes zero [A1].

**(ii)** Shape- Cosine square or sine square graph [M1] with decreasing amplitude and constant (or slightly longer) period [A1]

Dependent on answer given in b(ii)

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# TAMPINES MERIDIAN JUNIOR COLLEGE

## JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME: Mark scheme

CIVICS GROUP: _____ (  )

## H2 Physics 9749/04

Paper 4 Practical

**17 September 2019**

**2 hours 30 minutes**

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

**READ THESE INSTRUCTIONS FIRST**

Write your name, class and index number in the spaces at the top of this page, page **9** and **15**.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **ALL** the questions.

You are allowed 1 hour to answer Questions 1 and 2; and you are allowed another 1 hour to answer Question 3.

Question 4 is a question on the planning of an investigation and does not require apparatus.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| 1 | /15 |
| 2 | / 7 |
| 3 | /21 |
| 4 | /12 |
| Total | /55 |

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1 In this experiment, you will investigate an electrical circuit.

**(a) (i)** You have been provided with a length of resistance wire attached to a metre rule, a light bulb and two identical resistors labelled Y.

Connect the circuit as shown in Fig. 1.1.

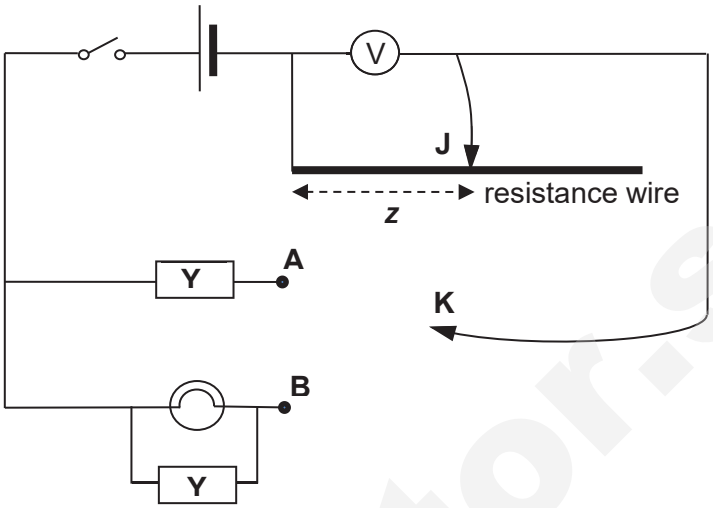


**Fig. 1.1**

J and K are crocodile clips.

**(ii)** Connect J to a point half-way along the wire. Measure and record □.

[1] value of z with correct d.p. and unit (to precision of 0.1 cm).

□= ……40.0 cm [1]

**(iii)** Estimate the percentage uncertainty in your value of □.

Percentage uncertainty
= 0.2 / 40.0 x 100%
= 0.50 %

[1] Correct calculation of percentage uncertainty
- rounded off to 2 s.f.
- d.p. of Δz and z same (same precision)
- Δz between 0.2 cm to 0.5 cm and to 1 s.f.
- % sign to appear in answer

percentage uncertainty = ……0.50% [1]

**(iv) 1** Connect K to A. Close the switch and record the voltmeter reading $V_A$.

$V_A$ = ……0.451 V

**2** Open the switch. Connect K to B. Close the switch and record the voltmeter reading $V_B$.

$V_B$ = ……0.867 V

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3 Determine the value of $\frac{1}{V_B} - \frac{1}{V_A}$

[1] Correct calculation of $1/V_B - 1/V_A$ based on values of $V_B$ and $V_A$ in (iv)1. And (iv)2.
- correct s.f. (least s.f. with reference to $V_B$ and $V_A$ in (iv)1. and (iv)2.)
- correct unit ($V^{-1}$)

$\frac{1}{V_B} - \frac{1}{V_A}$ = .....-1.06 $V^{-1}$

[1]

**(b)** Vary □and repeat **(a)(iv).**

| z / cm | $V_A$ / V | $V_B$ / V | $\frac{1}{□}$ / $cm^{-1}$ | $\frac{1}{V_B} - \frac{1}{V_A}$ / $V^{-1}$ |
|---|---|---|---|---|
| 10.0 | 0.162 | 0.345 | 0.100 | -3.27 |
| 20.0 | 0.271 | 0.554 | 0.0500 | -1.88 |
| 30.0 | 0.367 | 0.729 | 0.0333 | -1.35 |
| 40.0 | 0.451 | 0.867 | 0.0250 | -1.06 |
| 50.0 | 0.520 | 0.997 | 0.0200 | -0.920 |
| 60.0 | 0.584 | 1.092 | 0.0167 | -0.797 |

Table of Data

[2] Correct setting up of apparatus and follow instructions correctly
- 6 set or more data (2 marks), 5 sets (1 mark), less than 5 ( 0 marks)

- Maximisation of range of z (within 40.0 cm to 80.0 cm). Minus 1 mark if not within range.

- Correct trend: 1. $V_B$ must be larger than $V_A$ (minus 2 marks if $V_B < V_A$). 2. As z increases, $V_B$ and $V_A$ should increase (allow one anomaly in table data).

- Ignore if $V_B$ or $V_A$ is negative but the values must be negative through the column (if not, subtract 1 mark). This will result in a positive gradient instead, which is correct.
- deduct 1 mark if data in (a) is not included in table.

[1] Correct quantity and units in headers
- deduct mark if student did not stick to symbol given in qn ($V_A$ and $V_B$).

[5]

[1] Correct d.p for raw data. Should be 3.dp for voltage in V. Deduct if $V_A$ or $V_B$ >1.5 – not possible with a 1.5 V batt.

[1] Correct calculation and s.f for derived data.

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**(c)** $V_A$, $V_B$ and z are related by the expression

$$\frac{1}{V_B} - \frac{1}{V_A} = \frac{P}{\square} + Q$$

where $P$ and $Q$ are constants.

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

Plot a graph of $\frac{1}{V_B} - \frac{1}{V_A}$ vs $\frac{1}{\square}$. A straight line with P as gradient and Q as vertical intercept should be obtained.

Gradient = $y_1-y_2/x_1-x_2$ = -29.7
y-intercept = $y_1$ - $mx_1$ = -0.338

P = - 29.7 cm $V^{-1}$
Q = - 0.338 $V^{-1}$

[1] Correct linearization (if no statement given, can be awarded based on graph plotted)
[1] Gradient triangle covers more than ½ of BFL. Correct read-off of gradient coordinates Correct calculation, units and s.f. for P. Deduce if gradient coordinates is marked with a cross.
[1] Correct calculation units and s.f. for Q. Allow ecf from wrong calculation of P

Graph plotting
[1] Correct axis label (with units) and choice of scale (1:2, 2.5, 4, 5 and 10 are all acceptable) – graph covers more than half of graph paper; arrow of axis pointing in direction of increasing value.
[1] All data plotted accurately within half the smallest square
[1] Line of best fit drawn correctly. Anomalous point needs to be circled and labelled as "anomalous", maximum of 1 anomaly.

$P$ = ..... - 29.7 cm $V^{-1}$

$Q$ = .....- 0.338 $V^{-1}$

[6]

**(d)** Sketch a second graph to represent the results if $Q$ increases. Label this graph **W**.

[1] Correct graph of straight line with same gradient but vertical intercept shifted up. Must be labelled W (no marks if did not label).

[1]

**[Total: 15 marks]**

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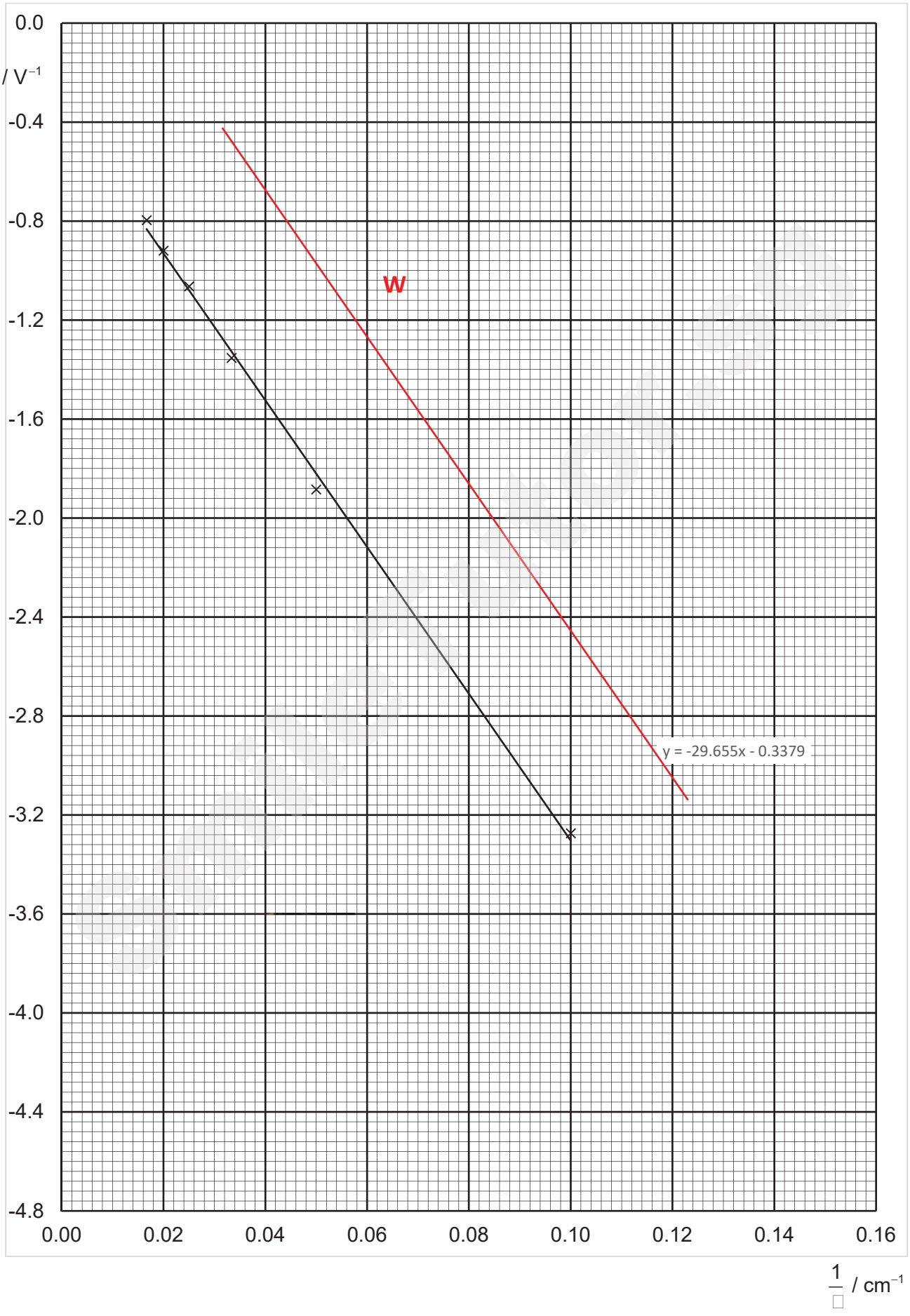


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**2** In this experiment, you will investigate the stability of a container of water as the height of water in the container is changed.

**(a) (i)** You are provided with two plastic bottles, of which one is empty, and the other is partially filled with water.

Each bottle has a 30 cm rule fixed to one side. You should **not** remove the rule from the bottles during the experiment.

Place the empty bottle so that the bottom of the rule is just touching the card that has been taped to the bench. The arrangement is shown in Fig. 2.1.

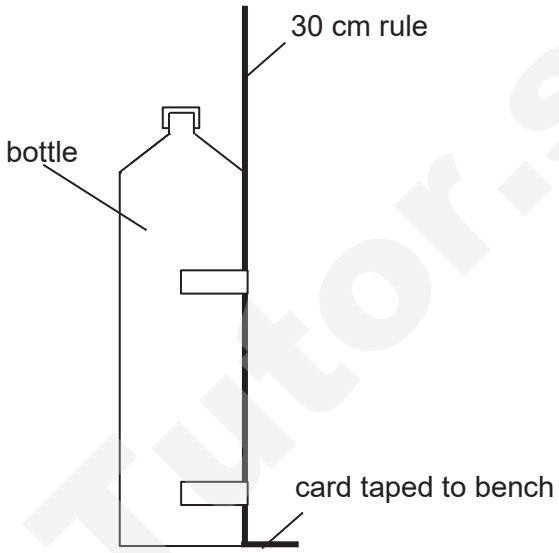


**Fig. 2.1**

**(ii)** Place the standing protractor scale behind the bottle so that the left-hand edge of the scale is aligned with the rule. The arrangement should now be as shown in Fig. 2.2.

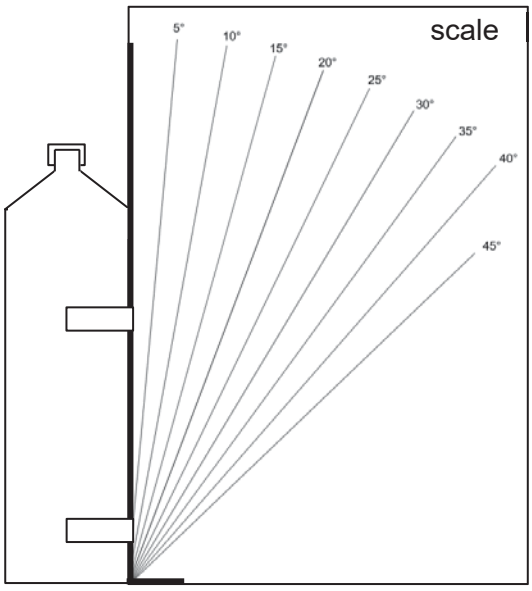


**Fig. 2.2**

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**(b)** **(i)** Gently push the top of the bottle in the direction shown in Fig. 2.3 so that the bottle begins to tilt.

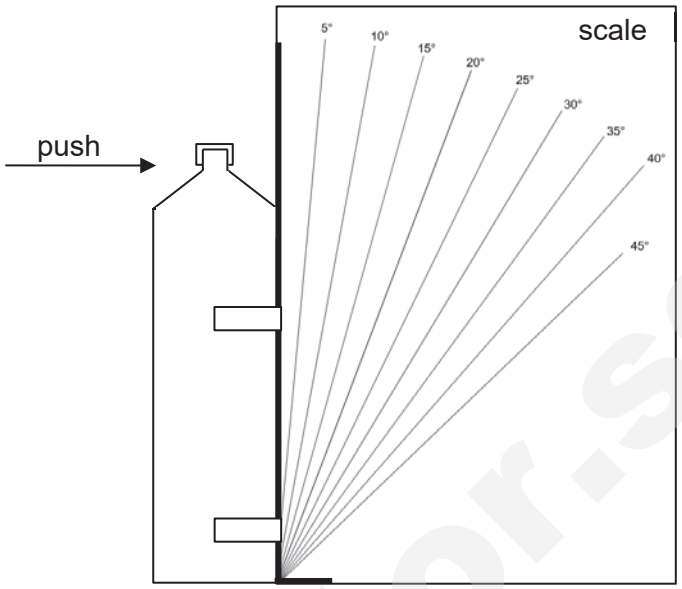


**Fig. 2.3**

Continue pushing until the bottle falls over. Measure and record the angle $\theta$ at which the bottle just falls over.

$\theta_1 = 12°$ $\theta_2 = 12°$ $\langle\theta\rangle = 12°$

[1] correct d.p. and units for $\theta$ with evidence of repeat.
Accepted range: $\theta < 15°$

.....12° [1]

**(ii)** Using the other bottle with water of depth $d$ inside, repeat **(b)(i)**. Measure and record your values of $d$ and $\theta$ below.

$d_1 = 11.0$ cm $d_2 = 11.0$ cm $\langle d \rangle = 11.0$ cm

$\theta_1 = 28°$ $\theta_2 = 28°$ $\langle\theta\rangle = 28°$

[1] correct d.p. and units for $d$ with evidence of repeat.
Accepted range: 10.6 cm ≤ d ≤ 11.5 cm
$\theta$ must be more than in (b)(i); otherwise do not penalise for other errors in recording of $\theta$.

.....11.0 cm
.....28° [1]

**(iii)** State one significant source of error in the measurement of $d$.

- meniscus effect of the water makes it difficult to read the water level.
- uneven shape of the bottle leads to parallax error when reading the water level.

..... [1]

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**(c)** The experiment is repeated with different depth of water $d$ in the bottle.

The variation with $d$ of $\theta$ is shown in Fig. 2.4.

**(i)** Plot the data obtained in **(b)(i)** and **(b)(ii)** in Fig. 2.4.

**(ii)** Complete Fig. 2.4 by drawing the line of best fit. [3]

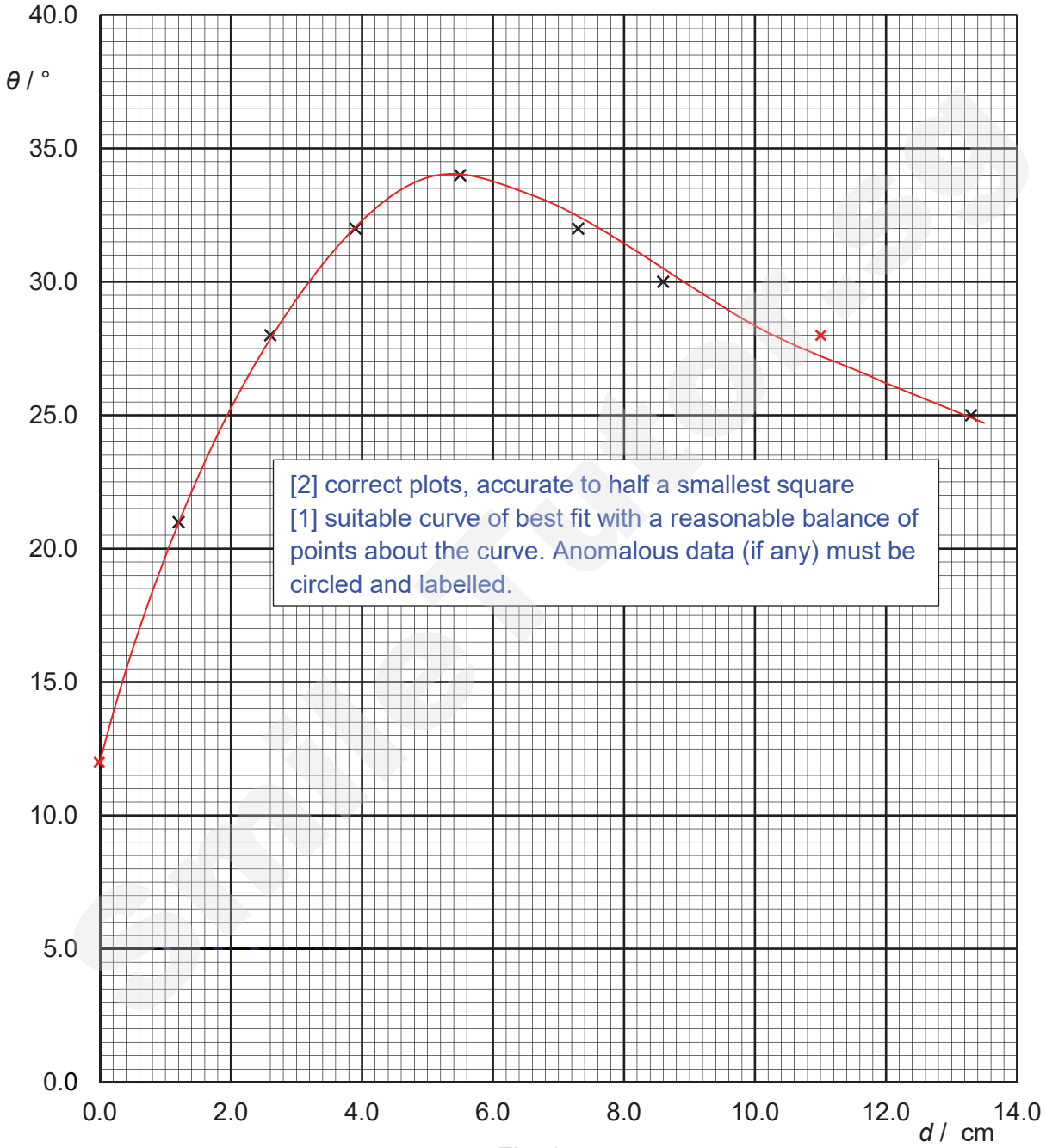


**Fig. 2.4**

**(iii)** Use your graph to find the value of $d$ for which $\theta$ is a maximum.

$d$ for which $\theta$ is a maximum = ..... cm 5.4 cm [1]

[1] Correct read-off accurate to half a smallest square.

**[Total: 7 marks]**

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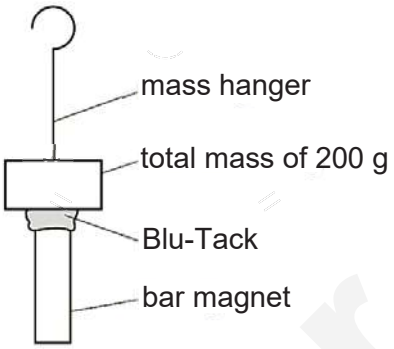
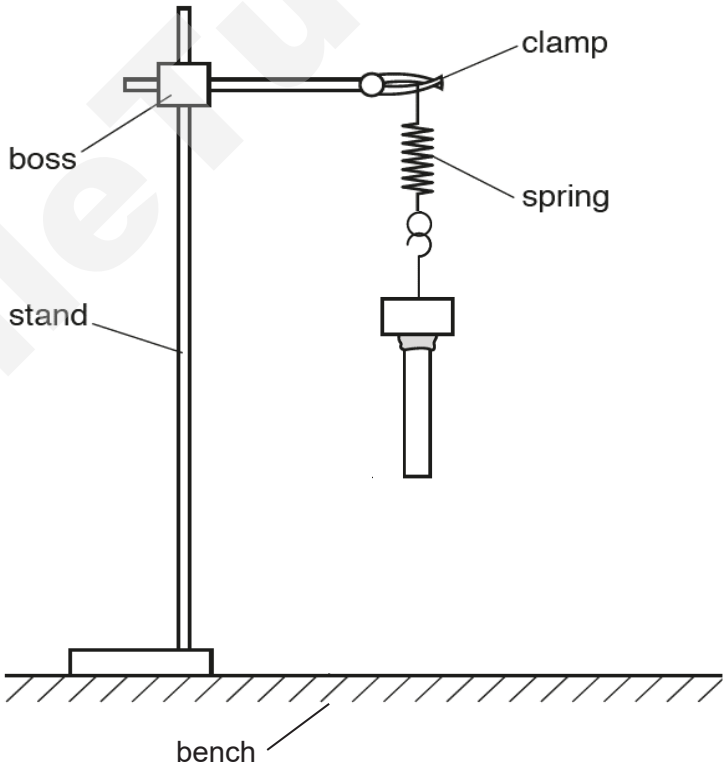
Candidate Name:_____ Civics Group: _____( )

| | | | |
|---|---|---|---|
| **3** | In this experiment, you will investigate the current in a coil. | | |
| | **(a)** | **(i)** | Use the Blu-Tack to fix the bar magnet to the mass hanger as shown in Fig. 3.1. The total mass of the mass hanger and mass should be 200 g. |
| | | |  **Fig. 3.1** |
| | | | |
| | | **(ii)** | Set up the apparatus as shown in Fig. 3.2.  **Fig. 3.2** |

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**(iii)** Pull the mass down through a short distance. Release the mass. The mass and magnet will oscillate.

Determine the period $T$ of these oscillations.

For $N = 20$ oscillations

$t_1 = 13.4$ s $\quad t_2 = 13.6$ s

$T = (13.6+13.4)/(2 \times 20) = 0.675$ s

[1] $NT \geq 10$ s; correct d.p. of $t$ (1 d.p.); repeat readings; correct s.f. and units of $T$.

$T =$ ..... [1]

**(iv)** Calculate the frequency $f$ of the oscillations where

$$f = \frac{1}{T}.$$

$f = 1/0.675 = 1.48$ Hz

[1] Correct calculation with correct s.f. and units of $f$.

$f =$ ..... [1]

**(v)** Justify the number of significant figures that you have given for your value of $f$.

Values of $f$ is recorded in 3 significant figures because raw timings ($t_1$ and $t_2$) or $NT$ or $T$ were recorded to 3 significant figures.

.....

..... [1]

No mark given if simply state 'raw readings' or 'values in calculation' without stating what these values were.

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**(b) (i)** Take the PVC tube with **more** turns of wire.

Count and record the number $n$ of turns of wire around the tube.

Can accept decimal place; 14 <= n <15

$n$ = ……14.5…… [1]

**(ii)** Connect the ammeter to the ends of the wire around the tube and place the tube below the magnet.

Adjust the height of the bottom of the magnet so that it is level with the top of the tube as shown in Fig. 3.3.

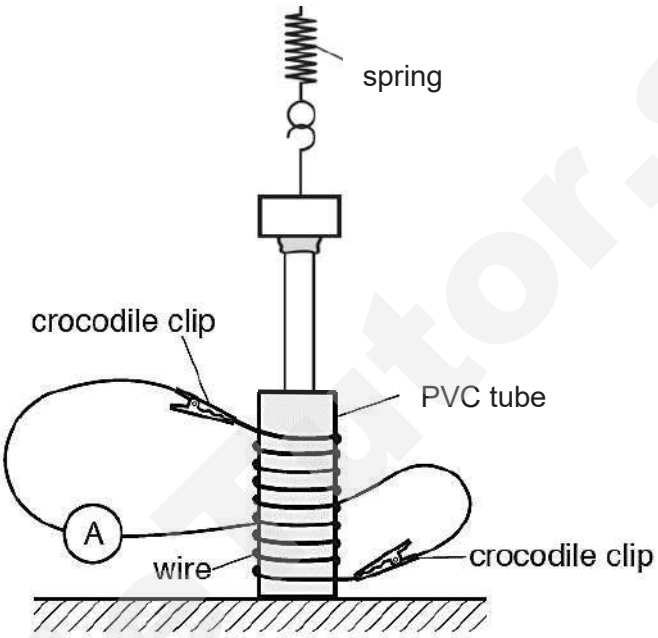


**Fig. 3.3**

**(iii)** Pull the mass down so that it rests on the top of the tube with the magnet passing centrally through the tube. Release the mass. The mass will oscillate.

Measure and record the maximum current $I$ shown by the ammeter.

$I_1$ = 2.6 mA $I_1$ = 2.6 mA

$\langle I \rangle$ = 2.6 mA

correct d.p. of $I$ (1 d.p.); Repeated readings not expected (since asking for maximum current) and unit of $I$

$I$ = …… [1]

**(iv)** Estimate the percentage uncertainty ~~in your value of $I$~~.

$\frac{\Delta I}{I} \times 100\% = \frac{0.2}{2.6} \times 100\% = 7.7\%$

~~[1] 0.2 mA ≤ $\Delta I$ ≤ 0.5 mA (fluctuation due to spring~~ mass not straight while oscillating, slow response of ammeter) ; percentage uncertainty correctly calculated.

[-1] either percentage uncertainty not 2 s.f.

[-1] either absolute uncertainty not 1 s.f.

[-1] either ($\Delta I$ and $I$) differs in d.p.

percentage uncertainty = …… [1]

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**(c) (i)** Remove the tube. Increase the total mass to 400 g.

Take the measurements to determine the period $T$ and frequency $f$ of the oscillations of the mass and the magnet.

For $N$ = 20 oscillations

$t_1$ = 17.9 s $t_2$ = 17.8 s

$T$ = (17.9+17.8)/(2 x 20) = 0.893 s

$f$ = 1/0.893 = 1.12 Hz

[1] $NT \geq 10$ s; correct d.p. of $t$ (1 d.p.); repeat readings; correct s.f. and units of $T$.

[1] **$T$ must be larger than (a)(iii).**

No mark for $f$.

$T$ = .....

$f$ = ..... [2]

**(ii)** Keep the mass as 400 g and use the tube with **fewer** turns of wire to repeat **(b)(i)**, **b(ii)** and **b(iii)**.

n = 7

$I_1$ = 1.1 mA $I_1$ = 1.1 mA

$\langle I \rangle$ = 1.1 mA

[1] Values of n and $I$

Do not double penalise: wrong d.p. of $I$ ; no repeat readings; and wrong unit of $I$

[1] second $I$ □ *first* $I$

$n$ = .....

$I$ = ..... [2]

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**(d)** It is suggested that the relationship between $I$, $n$ and $f$ is

$$I = knf$$

where $k$ is a constant.

**(i)** Using your data, calculate two values of $k$.

$2.6 = k_1\ (14.5)\ (1.48)$; $k_1 = 0.121$ mA s

$1.1 = k_2\ (7)\ (1.12)$; $k_2 = 0.140$ mA s

[1] $k$ values are calculated correctly with correct s.f. (least of $I$ and $f$ *or plus one*) and units (e.g. mA s or A s ).

first value of $k$ = ……

second value of $k$ = …… [1]

**(ii)** State whether the results of your experiment support the suggested relationship.

Percentage difference = $\frac{0.140 - 0.121}{0.121} \times 100\% = 16\%$

Since the percentage difference of 16% is more than the percentage uncertainty of $I$ of 7.7% in (b)(iii). Hence, the results does not support the suggested relationship.

[1] calculate percentage difference; compare with percentage uncertainty in (b)(iii); conclude.

…… [1]

**(e)** **(i)** Suggest two significant sources of uncertainty or limitations of the procedure for this experiment.

1) Two readings are not enough to draw a (valid) conclusion (not "not enough for accurate results", "few readings")

2) Reason for difficulty with oscillation, e.g. magnet struck top of tube or magnet not passing through all turns or some turns are not near magnet or magnet oscillates outside of coil.

3) Difficulty judging end or start of (complete) oscillation, affecting time taken for oscillations.

4) Difficulty with the current readings with reason e.g. because of the positive and negative values/ meter does not refresh quickly enough/ current small/ resistance of connecting leads high/ maximum current lasts for a short time

5) Difficulty with the practical setup e.g. tube fell over/ magnet fell off/ spring moving along clamp.

6) n is not a whole number.

…… [2]

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| | | | | |
|---|---|---|---|---|
| | | | | |
| | | **(ii)** | Suggest two improvements that could be made to the experiment to address the errors identified in **(e)(i)**. You may suggest the use of other apparatus or a different procedure. | |
| | | | 1) Take many readings (for different values of n or f) and plot a graph or take more values of k and compare (not “repeat readings” on its own). | |
| | | | 2) Method of improving difficulty with oscillation e.g. use wider tube/ shorter tube/ bunch up coils/ longer magnet. | |
| | | | 3) Method of improving timing e.g. put a marker with position (except at the ends)/ video with timer(or replay frame by frame)/ position or motion sensor placed below. | |
| | | | 4) Method to reduce difficulties with current e.g. use (centre-zero) analogue ammeter/ data logger with current sensor or probe/use more turns of wire/smaller masses/stiffer spring/stronger magnet/ sand contacts of wire/ video ammeter and replay to find maximum current. | |
| | | | 5) Named method of attaching to table/holder e.g. clamp tube/tape magnet to weight/ tape spring to clamp/ tape tube to table | |
| | | | 6) Calculate *n* from the length of wire and the diameter of the tube. | |
| | | | ……. | [2] |

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| | | | |
|---|---|---|---|
| | **(f)** | The current in the coil depends on speed of the oscillation of the mass and the magnet.<br><br>It is suggested that the maximum current $I_{max}$ is linearly related to the maximum speed $v_{max}$ of the mass and the magnet.<br><br>Plan an investigation to examine the relationship between $I_{max}$ and $v_{max}$.<br><br>Your account should include:<br>• your experimental procedure<br>• how you determine the maximum speed $v_{max}$<br>• how you would use your results to show the linear relationship. | |
| | | ..... | [5] |

**[Total: 21 marks]**

| Annotation | Rubrics | Max | Actual |
|---|---|---|---|
| Basic Procedure | Describe use of setup based on Fig. 3.3 and vary the masses to or amplitudes or spring constant obtain different maximum speeds of oscillations. | 1 | |
| Measurements | M1:<br>Use of correct apparatus that can lead to calculating/measuring speed (e.g. lightgates with ruler/ data-logger with motion sensors/ video recording with time frame and distance benchmark [e.g. ruler])<br>and use of ammeter to record maximum current or inferred from Fig. 3.3. | 1 | |
| Analysis | A1: State criteria to verify a linear relationship (i.e. plot $I_{max}$ against $v_{max}$. If graph obtained is straight line, then relationship is linear. 5 or more sets of data need) | 1 | |
| Reliability | R1: Correct identification of position where maximum speed occurs (equilibrium position, e.g. correct placement of lightgates)<br><br>R2: Distance between lightgates to be small, to get better estimate of the instantaneous velocity.<br><br>R3: Correct calculation of maximum speed, using distance/time (either via lightgates/video recording) OR using motion sensors to plot displacement-time graph (determine from steepest gradient of graph). Accept SHM equation, determine T and $x_0$.<br><br>R4: If data-logger with velocity sensor attached, the position of the velocity sensor should be adjusted to ensure that it had picked up the largest speed for oscillation of each mass. (e.g. shifted towards left or right/up or down) | 2 | |

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Candidate Name: _____ Civics Group: _____( )

**4** A designer is drawing plans for the renovation of a flat. She is considering what material to use for the wall of each room. If the material is very dense and thick, then there is little transmission of sound from one room to another. However, the building cost will be greater.

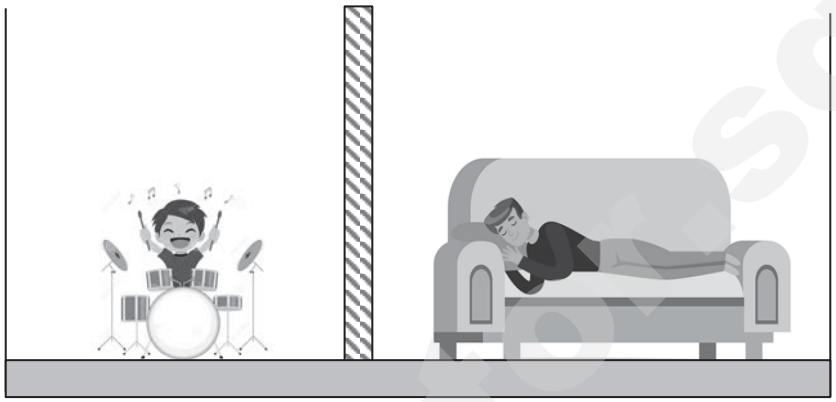

**Fig. 4.1**

The intensity of transmitted sound $I$ through a material depends upon the density $\rho$ and thickness $t$ of material. These quantities are related by the expression

$$I = k\rho^m t^n$$

where $k$, $m$ and $n$ are constants,

Design an experiment to determine the values of $m$ and $n$.

You are provided with boards of various densities and thickness, and a sound intensity meter.

You should draw a diagram to show the arrangement of your apparatus and you should pay particular attention to

**(a)** the equipment you would use

**(b)** the procedure to be followed

**(c)** the method of measuring the thickness and density of the material through which the transmitted sound passes,

**(d)** the control of variables

**(e)** any precautions that should be taken to improve the accuracy and safety of the experiment.

**[Total: 12 marks]**

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General comments:
1) Most students did not ensure all equipment are well supported (e.g. use of retort stand or resting on tabletop). Most of equipment is "hanging in the air".
2) Most students did not place a signal generator in the diagram. Many simply drew a box and call it sound generator.
3) Most students were able to describe BP1 and BP2 clearly, with related A1 and A2 mentioned.
4) A handful of students did not analyse the graphs referencing to BP1 or BP2.

| Annotation | Rubrics | Max | Actual |
|---|---|---|---|
| Basic Procedure | In the process of measuring intensity $I$,<br>BP1: mention of keeping density $\rho$ constant, vary thickness $t$<br>BP2: mention of keeping thickness $t$ constant, vary density $\rho$<br><br>Marks given only when it is clearly stated which variable is being varied, and which variable is kept constant.<br><br>Simply using board of same material or different material does not imply anything about density. Student must be clear and not leave the examiner guessing. | 2 | |
| Diagram | D1: Correct diagram to include a board between a suitable sound source (e.g. signal generator connected to speaker (through amplifier) and a sound detector (e.g. sound intensity meter; microphone with CRO). Equipment to be well supported.<br><br>Students need to refer to practical planning manual to be familiar with components sketching.<br><br>Note: CRO is used to determine period or frequency of a wave. For this experiment, if CRO is to be used, it has be calibrated accordingly to determine the amplitude of wave detected. | 1 | |
| Control | C1: Keep distance between sound source and sound detector constant (include method of ensuring that distance is constant).<br>C2: Intensity of sound source kept constant (include method of measuring).<br>C3: Any other valid points<br><br>Students must describe method of controlling the variable (e.g. using a metre rule, using an intensity meter etc).<br><br>Student should note that as thickness of board is changing, distance between sound source and sound detector is not the same as distance between sound source and board + board and sound detector. | 1 | |

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| | | | |
|---|---|---|---|
| Measurements | M1: Measure thickness $t$ using appropriate instrument (accept vernier caliper, metre rule)<br>M2: Determine density $\rho$ through measuring dimensions (length $\ell$, breadth $b$, thickness $t$) and mass of board using appropriate instrument. Apply $\rho = \frac{m}{\ell.b.t}$<br>M3: Measure intensity $I$ using sound intensity meter (or equivalent)<br><br>Most students could score M1 and M3 marks.<br><br>Students need to refer to question "… how to measure density of". The methods, instruments, and related equations must be explicitly described to gain a M2 mark.<br><br>Note: The density of a block does not depend on its physical dimensions such as height, width or thickness. | 3 | |
| Analysis of data | A1: Based on six or more points, plot a suitable graph of lg $I$ vs lg $t$ (keeping $\rho$ constant). Gradient = $n$<br>A2: Based on six or more points, Plot a suitable graph of lg $I$ vs lg $\rho$ (keeping $t$ constant). Gradient = $m$<br>[Deduct 1 mark if no mention of obtaining 6 or more points]<br><br>A handful of students did not mention about conducting experiments to gather at least 6 sets of data. This is necessary before you can plot a suitable graph to obtain the relationship.<br><br>Some students did the analysis without clear reference to which data set (link to BP) they are using. | 2 | |
| Other (Reliability) | R1: Conduct experiment in a quiet room to prevent interference from external source<br>R2: Place the sound source in an enclosure with sound absorbent material, with one wall being the board<br>R3: Align the sound source and detector<br>R4: Measure thickness for two or more points on the board. Take average value.<br>R5: At the start, using thickest and densest board, determine the intensity of source required so that sound detector can still detect sound. Use this intensity of source throughout experiment.<br>R6: Any other valid points<br><br>Students who mentioned a quiet room or enclosure are awarded with either R1 or R2 (not both). | 2 | |
| Safety precaution | S1: Avoid turning on the sound too loudly / wear earplug when conducting experiment. | 1 | |

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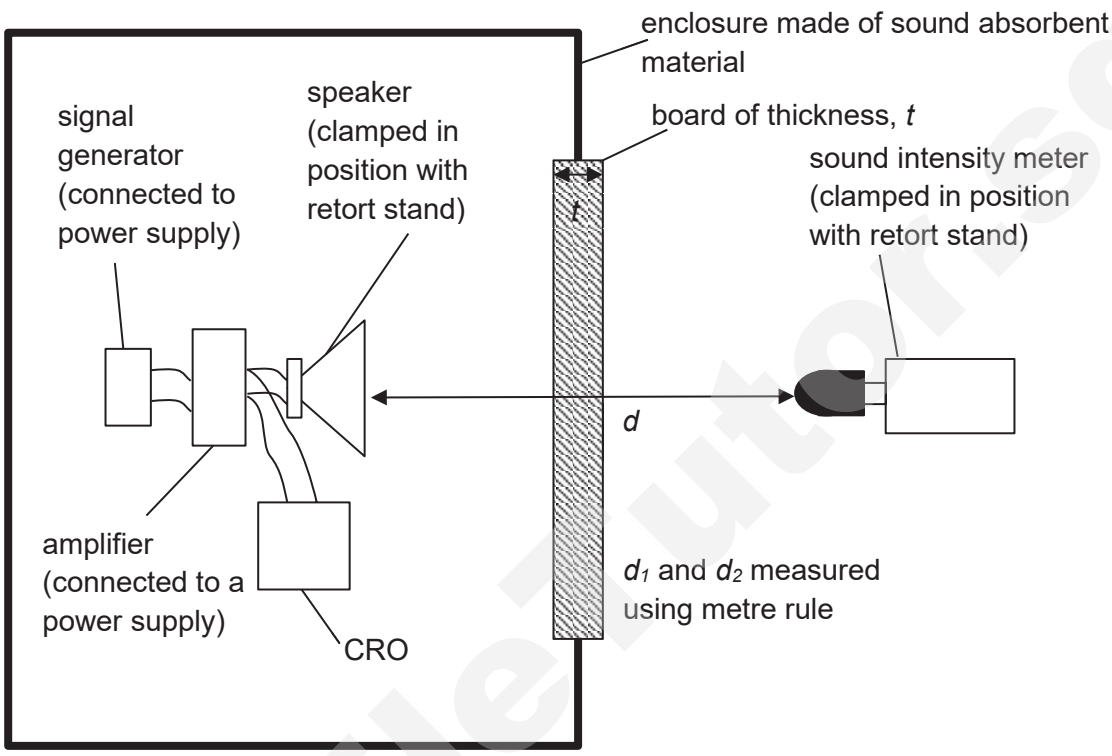
| | | | |
|---|---|---|---|
| | S2: Any other valid points.<br><br>Most students were able to relate the safety aspect of this experiment. | | |

**Diagram** [D1]




**Independent Variable:** i. thickness of board $t$; ii. density of board $\rho$

**Dependent Variables:** intensity of transmitted sound $I$

**Control Variables:** distance of speaker and sound intensity meter from board, $d$.

Procedure:

1. Set up the apparatus as shown in the diagram above.
2. Measure and record the distance $d$ using a metre rule. $d$ must be kept constant for the whole experiment. [C1]

Determine thickness and density of board

3. Using a vernier caliper (or metre rule), measure the thickness of the board [M1] at two different points. Take the average to find the average thickness of the board $t$. [R3]
4. Using a metre rule, measure the length $\ell$ and breadth $b$ of the board.
5. Place the board on a electronic weigh balance to measure its mass $m$.
6. Density of board ρ can be calculated with $\rho = \frac{m}{\ell . b . t}$ . [M2]

Measure Intensity of Transmitted Sound

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7. Turn on the signal generator and amplifier. Measure and record the frequency *f* and amplitude of signal *A* using the CRO. Keep *f* and *A* constant throughout the experiment. [C2]
8. Measure and record the reading on the sound intensity meter $I$. [M3]

Vary *t*, keep *ρ* constant

9. Using boards of different thickness *t* but same density *ρ*, repeat steps 2 to 8 to obtain six different sets of readings.
10. Plot a graph of ln $I$ against ln *t* to obtain a straight-line graph with gradient *n*. Calculate the gradient to determine *n*. [A1]

Vary *ρ*, keep *t* constant

11. Using boards of different density *ρ* but same thickness *t*, repeat steps 2 to 8 to obtain six different sets of readings.
12. Plot a graph of ln $I$ against ln *ρ* to obtain a straight-line graph with gradient *m*. Calculate the gradient to determine *m*. [A2]

Reliability

- Conduct the experiment in a quiet environment so that there will not be interference from external noise. [R1]
- Sound source to be placed in an enclosure with walls of sound absorbent material where one wall is the board as shown in diagram. [R2]
- Align the sound source and detector in a straight line to ensure. [R3]
- At the start, using thickest and densest board, determine the intensity of source required so that sound detector can still detect sound. Use this intensity of source throughout experiment. [R5]

Safety

- Do not turn on the sound too loudly to avoid damaging the ear / Wear an earplug when conducting the experiment. [S1]

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# TEMASEK JUNIOR COLLEGE

2019 Preliminary Examination
Higher 2

## PHYSICS

**9749/01**

Paper 1 Multiple Choice

**19 September 2019**
**1 hour**

Additional Materials: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, civics group and index number on the Answer Sheet in the spaces provided.

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

**Read the instructions on the Answer Sheet very carefully.**

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


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**Data**

| | |
|---|---|
| speed of light in free space | $c = 3.00 \times 10^8$ 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 | $\phi = -Gm/r$ |
| temperature | $T/\text{K} = T/^\circ\text{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_o \sin\omega t$ |
| velocity of particle in s.h.m. | $v = v_o \cos\omega t$ |
| | $= \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = Q/(4\pi\varepsilon_0 r)$ |
| alternating current / voltage | $x = x_0 \sin\omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** Which of the following gives an unreasonable estimate of the mentioned physical quantity?

**A** The magnetic field of the Earth is 0.025 T

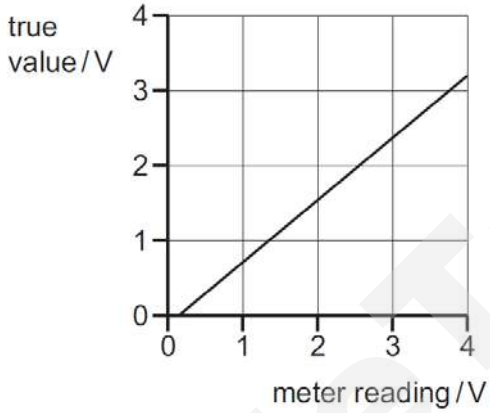
**B** The terminal potential difference of a car battery is 12.0 V

**C** The separation between atoms is $1.0 \times 10^{-10}$ m

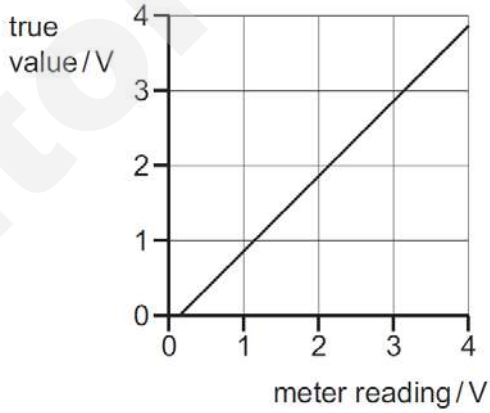
**D** The power rating of a typical fluorescent lamp is 15 W

**2** A voltmeter gives readings that are larger than the true values and has a systematic error that varies with voltage. Which graph shows the calibration curve for the voltmeter?

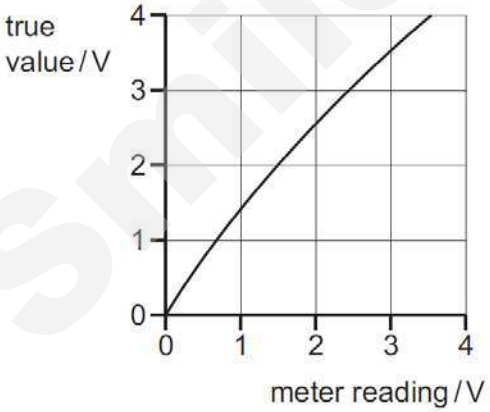
**A**



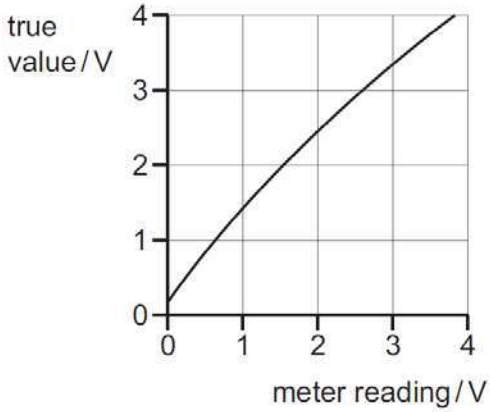

**B**




**C**




**D**

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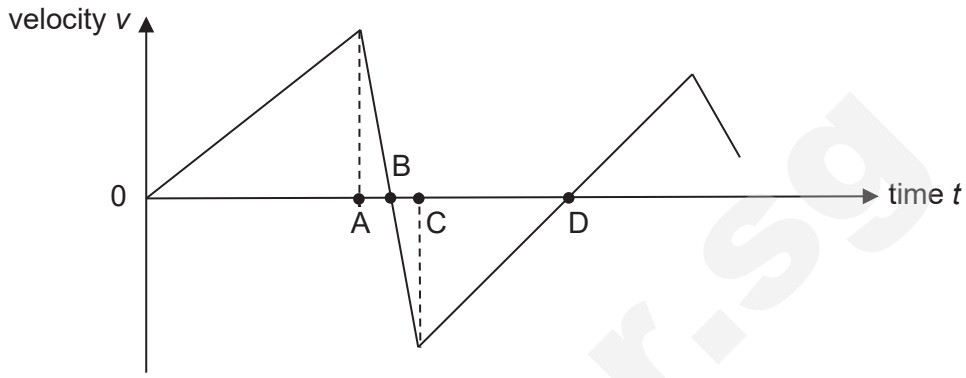
**3** At time $t$ = 0 s, a ball was released from rest above a floor. In the velocity-time graph shown below, at which time does the ball reach its maximum height after bouncing from the floor?




**4** While sitting on a tree branch 10.0 m above the ground, a monkey drops a chestnut. When the chestnut has fallen 1.5 m, the monkey throws a second chestnut vertically downwards.

What is the initial speed of the second chestnut if both chestnuts were to land at the same time?

**A** 5.4 m $s^{-1}$ **B** 7.1 m $s^{-1}$ **C** 14 m $s^{-1}$ **D** 15 m $s^{-1}$

**5** Blocks A and B each of mass 2.0 and 1.0 kg respectively are connected by a massless spring and arranged on a frictionless table as shown in Fig. 5(a). After that, they are rearranged as shown in Fig 5(b).

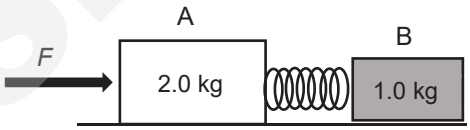


Fig. 5 (a)

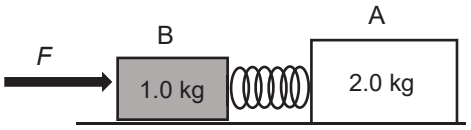


Fig. 5 (b)

What is the ratio of the compression of the spring in Fig. 5 (a) to that in Fig. 5 (b)?

**A** 1 : 2 **B** 2 : 1 **C** 1 : 3 **D** 1 : 1

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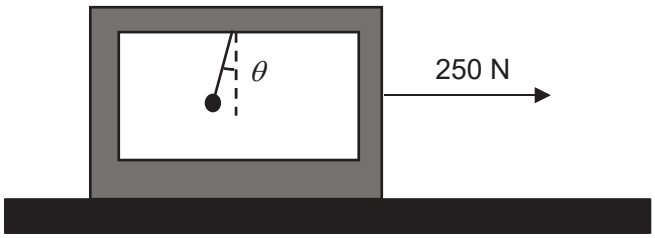
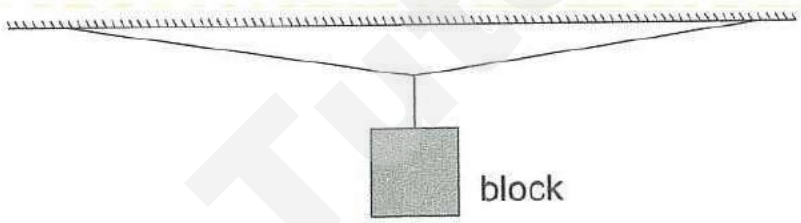
**6** A block with a pendulum bob hanging lies on a rough horizontal surface. The total mass of the block and the pendulum bob is 100 kg. A force of 250 N is applied to the block and the pendulum bob makes an angle θ to the vertical axis.




What is the magnitude of $\theta$ if a constant frictional force of 60 N is acting on the block?

**A** 11° **B** 14° **C** 76° **D** 79°

**7** A block of weight $W$ is suspended by two strings of equal length. The strings are almost horizontal.




What is correct about the tension $T$ in one string?

**A** $T \geq \frac{W}{2}$

**B** $T = \frac{W}{2}$

**C** $\frac{W}{2} < T < W$

**D** $T > W$

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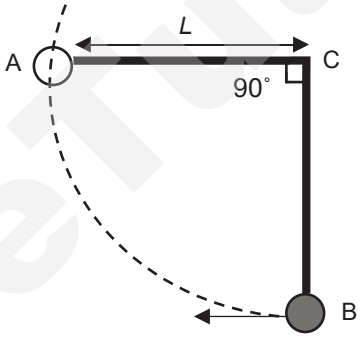
**8** A car of mass 1400 kg is travelling on a straight, horizontal road at a constant speed of 25 m $s^{-1}$. The output power from the car's engine is 30 kW. The car then travels up a slope at 2.0° to the horizontal, maintaining the same constant speed.




What is the output power of the car's engine when travelling up the slope?

**A** 12 kW
**B** 31 kW
**C** 42 kW
**D** 65 kW

**9** A simple pendulum consists of a bob of mass *m* at the end of a light and inextensible thread of length L. The other end of the thread is fixed at C. the bob swings through point B with a velocity v and just reaches A, where the string is just taut.




What is the tension in the thread when the bob is at position B?

**A** *mg** **B** 2*mg** **C** 3*mg** **D** 4*mg*

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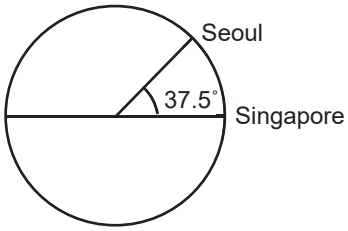
**10** Singapore is on the Equator. Seoul is at a latitude of 37.5° N as depicted in the diagram below.




The centripetal acceleration at Singapore due to the Earth's rotation about its axis is $a_{Singapore}$. The centripetal acceleration at Seoul due to the Earth's rotation about is axis is $a_{Seoul}$. What is the ratio $\frac{a_{Singapore}}{a_{Seoul}}$?

**A** 0.79 **B** 1.00 **C** 1.26 **D** 9.81

**11** The table below gives the gravitational potential values at various points in the field of a planet.

| Distance from surface / km | Potential / kJ kg$^{-1}$ |
|---|---|
| 0 | - 544.6 |
| 220 | - 369.2 |
| 230 | - 345.8 |
| 240 | - 322.5 |
| Infinity | 0 |

What is the gravitational acceleration at a height of 230 km above the surface of 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$^{-2}$

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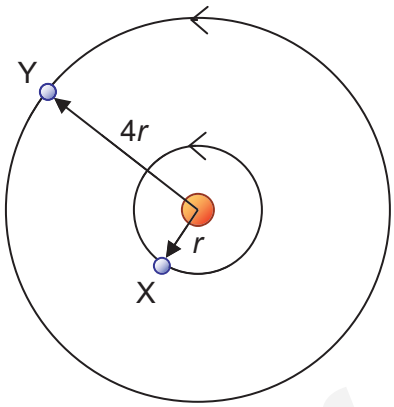
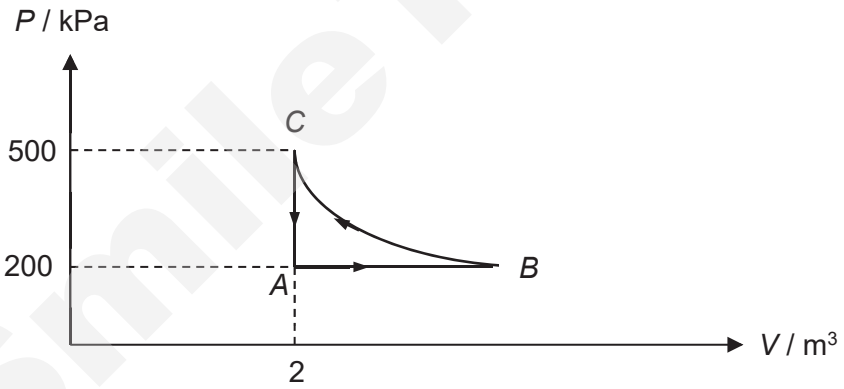
**12** Two planets travel around a star in the same direction, in circular orbits. Planet X completes one revolution in time *T*. The radii of the orbits are in the ratio 1 : 4.




How many revolutions does planet Y make in the same time *T*?

**A** 0.125 **B** 0.25 **C** 0.5 **D** 8

**13** The figure below shows a constant mass of an ideal gas undergoing the cyclic process *ABCA* given in the *PV* diagram. The path *BC* is isothermal.




What is the approximate work done on the gas in one complete cycle?

**A** 0 kJ **B** 400 kJ **C** 600 kJ **D** 1000 kJ

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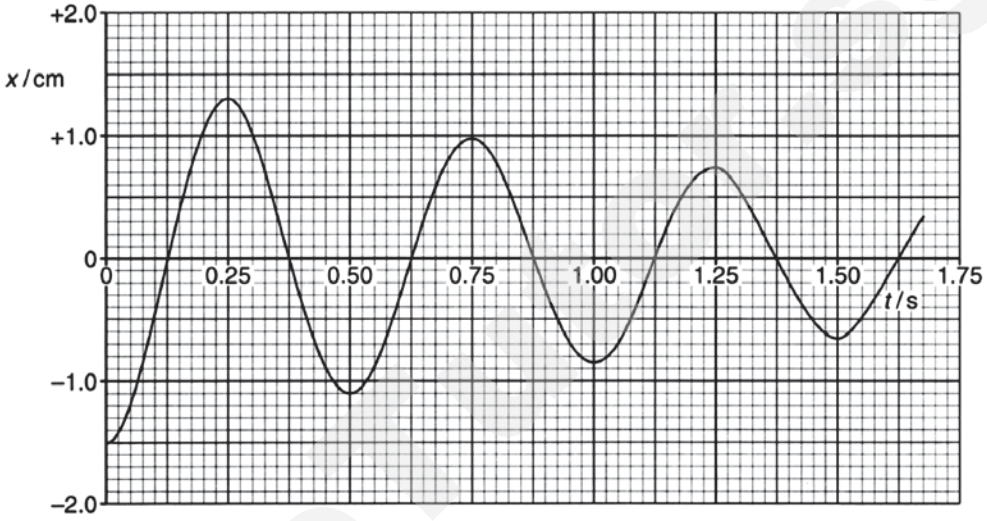
**14** An ideal gas of volume $V$ at a temperature of 200 K and pressure $2p$ is mixed with another volume of the same ideal gas, $2V$, at a temperature of 300 K and pressure $3p$.

If the mixture has a volume $V$ at a temperature of 100 K, what is its pressure?

**A** $1.6p$ **B** $2.5p$ **C** $3.0p$ **D** $4.0p$

**15** An object 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 1.50 s?

**A** $2.9 \times 10^{-3}$ J
**B** $4.6 \times 10^{-3}$ J
**C** $7.2 \times 10^{-3}$ J
**D** $8.3 \times 10^{-3}$ J

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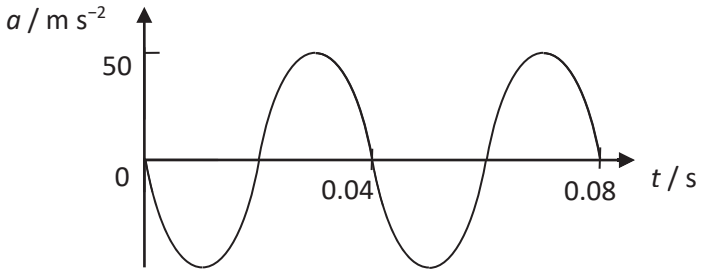
**16** A body performs simple harmonic motion with period $T$. The graph shows the variation with time $t$ of its acceleration $a$.




What is the ratio of the body's displacement to its amplitude at time $t = \frac{5T}{8}$?

**A** −0.71 **B** 0.71 **C** −0.87 **D** 0.87

**17** Green light is emitted by two point sources. The light passes through a narrow slit and is received by an observer. The images of the two sources just failed to be resolved. What change allows for the images to be resolved?

**A** Replacing the narrow slit with a circular aperture of same size.

**B** Moving the two sources further from the slit.

**C** Using red light.

**D** Using violet light.

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**18** Plane-polarized light is incident normally on a polarizer which is able to rotate in the plane perpendicular to the light as shown below.

Diagram 1

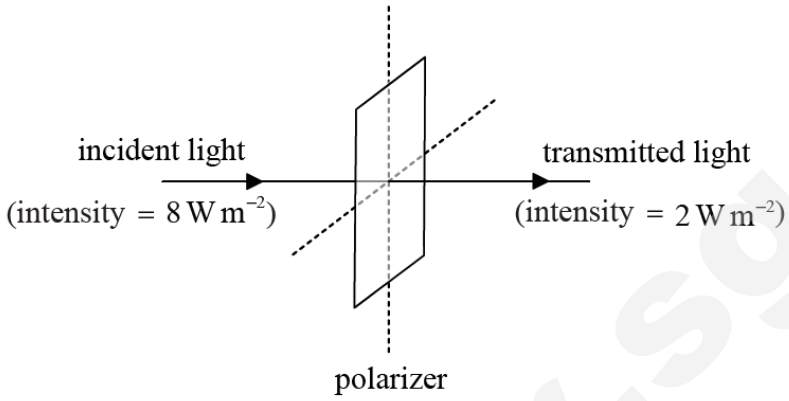
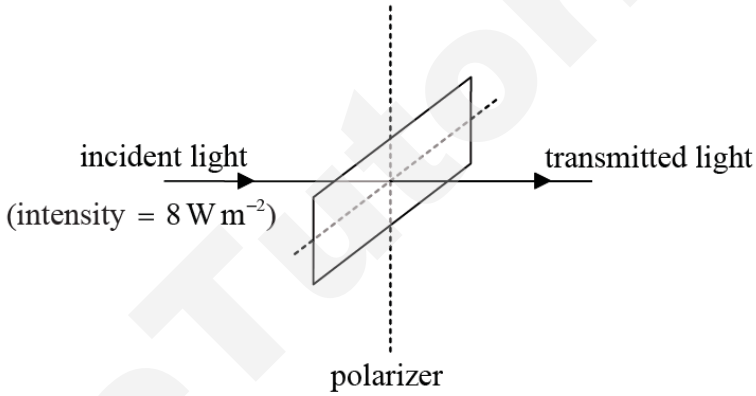



Diagram 2




In diagram 1, the intensity of the incident light is 8 W m$^{-2}$ and the transmitted intensity of light is 2 W m$^{-2}$.

Diagram 2 shows the polarizer rotated 90$^{o}$ from the orientation in diagram 1.

What is the new transmitted intensity?

**A** 0 W m$^{-2}$

**B** 2 W m$^{-2}$

**C** 6 W m$^{-2}$

**D** 8 W m$^{-2}$



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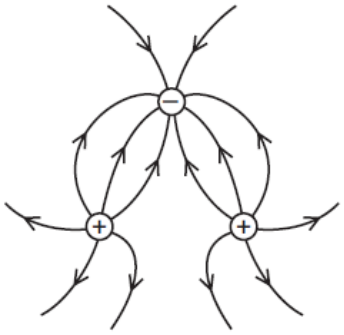
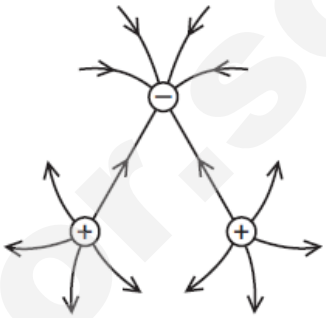
**19** Two positive charges and one negative charge, all of equal magnitude, are set at the corners of an equilateral triangle.

Which diagram best represents the electric field surrounding the charges?

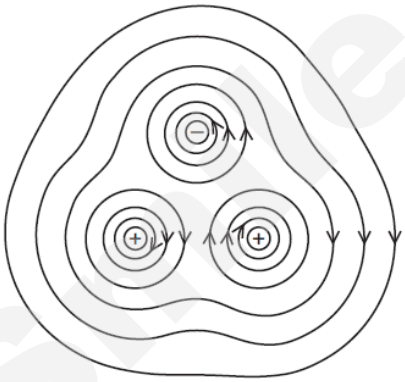
**A**



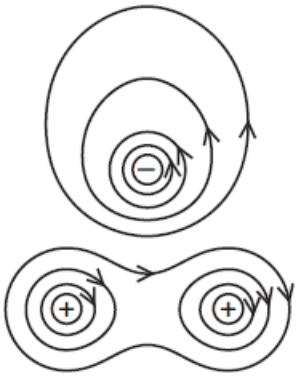
**B**



**C**



**D**



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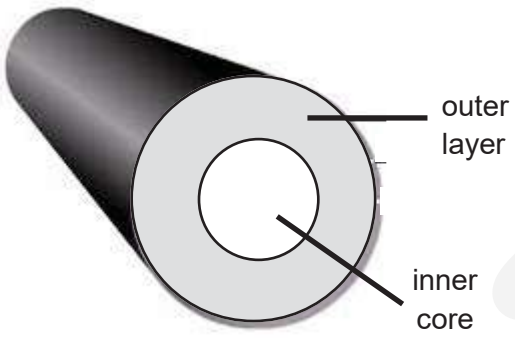
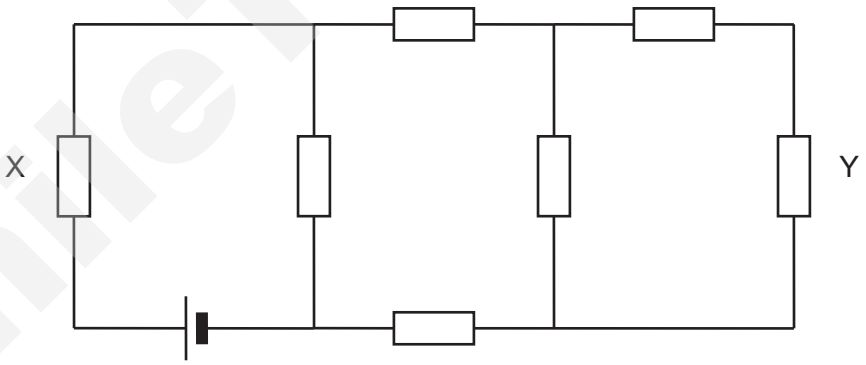
**20** A cylindrical electrical wire which is 10 m in length consists of an inner cylindrical core made of copper and an outer layer made of aluminium as shown in the figure. The diameter of the inner core is 0.0050 m and the diameter of the whole rod is 0.010 m.




Given that the resistivity of copper is 1.7 x $10^{-8}$ Ω m and the resistivity of aluminium is 2.7 x $10^{-8}$ Ω m, what is the overall resistance of the electrical wire?

**A** 0.0030 Ω **B** 0.0060 Ω **C** 0.0090 Ω **D** 0.013 Ω

**21** An ideal battery is connected to a network of identical resistors as shown.




If the current in resistor Y is $I$, what is the current in resistor X?

**A** 19 $I$ **B** 11 $I$ **C** 7 $I$ **D** $I$



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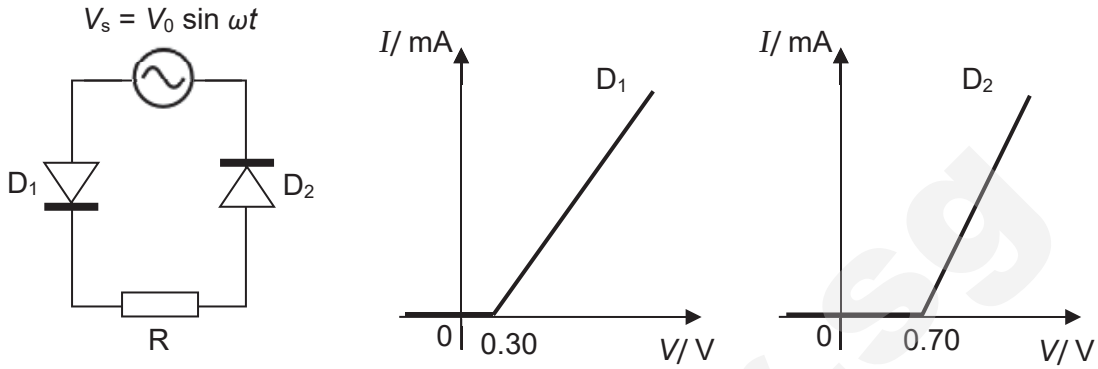
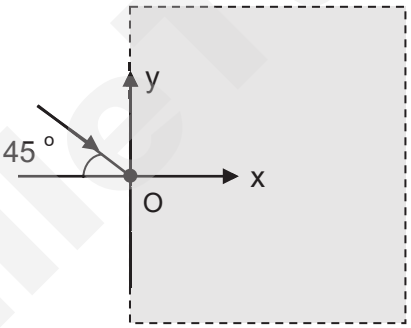
**22** The circuit diagram shows two diodes $D_1$ and $D_2$ connected to a sinusoidal-alternating supply $V_s$ and a resistor R. $D_1$ and $D_2$ have forward threshold peak voltages of 0.30 V and 0.70 V respectively. The $I$-$V$ characteristics of $D_1$ and $D_2$ are as shown.



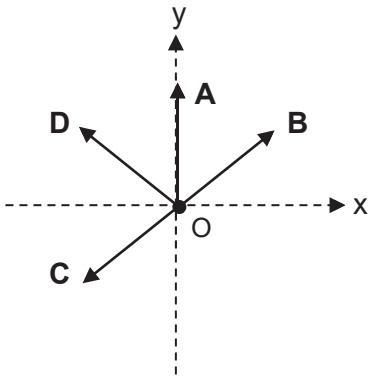

For a current to flow through R, the value of $V_0$ must exceed

**A** 0.30 V **B** 0.70 V **C** 1.0 V **D** 1.4 V

**23** An electron enters a region at Point O at an angle of 45 $^{o}$ to the x-axis as show. The shaded region contains a magnetic field which is directed into the plane of the page.




An electric field can be applied such that the electron is able to pass through the region undeflected. Which of the following correctly shows the direction of the electric field from O?

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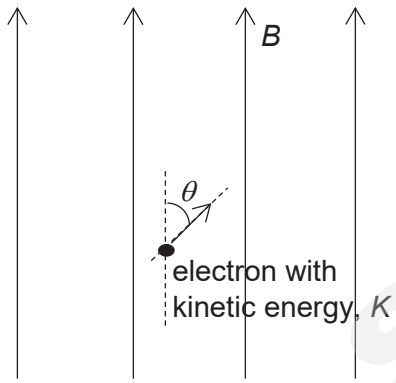
**24** An electron is emitted at an angle $\theta$ to the direction of uniform magnetic field, *B* with kinetic energy *K*, as shown in the diagram below.




Which of the following describes the electron's subsequent trajectory?

**A** It turns into the page and moves in a helical path upwards with radius proportional to $\sqrt{K}$ .

**B** It turns into the page and moves in a helical path upwards with radius proportional to *K*.

**C** It turns out of the page and moves in a helical path upwards with radius proportional to $\sqrt{K}$ .

**D** It turns out of the page and moves in a helical path upwards with radius proportional to *K*.

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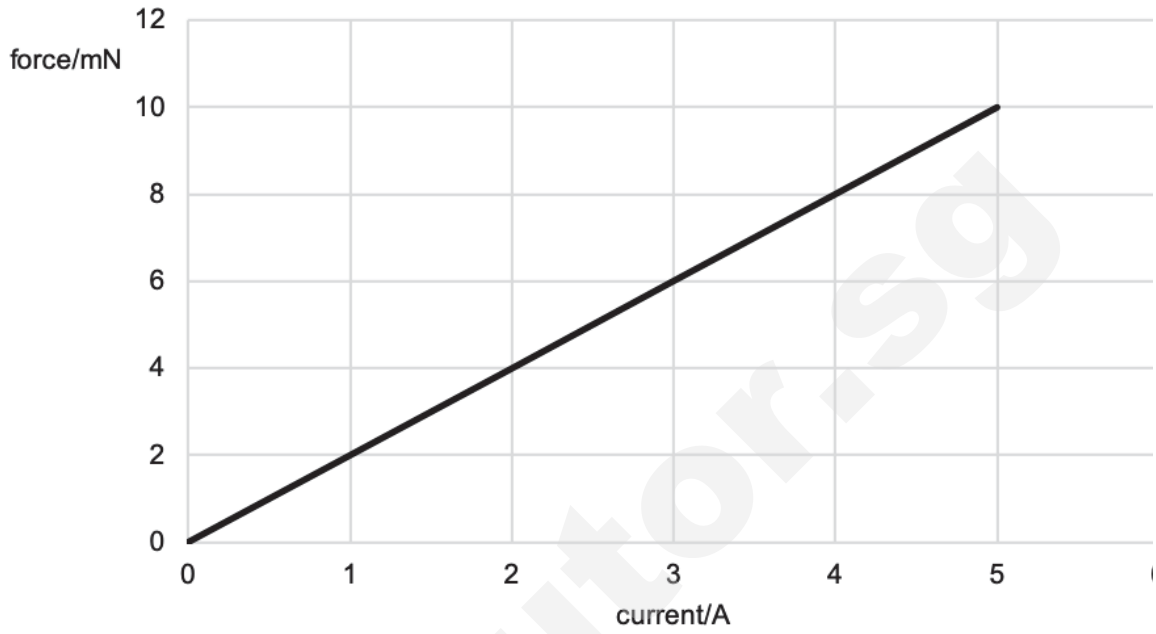
**25** A wire of length 0.50 m, forming part of a complete circuit, is positioned at right angles to a uniform magnetic field. The graph shows how the force is acting on the wire due to the magnetic field varies as the current in the wire is increased.




The circuit is switched off. The same piece of wire is then strummed such that it vibrates with an amplitude of $1.5 \times 10^{-3}$ m and at an angular frequency of 630 rad $s^{-1}$.

What is the maximum e.m.f. induced across the wire?

**A** $9.3 \times 10^{-4}$ V **B** $1.86 \times 10^{-3}$ V **C** 0.63 V **D** 1.86 V

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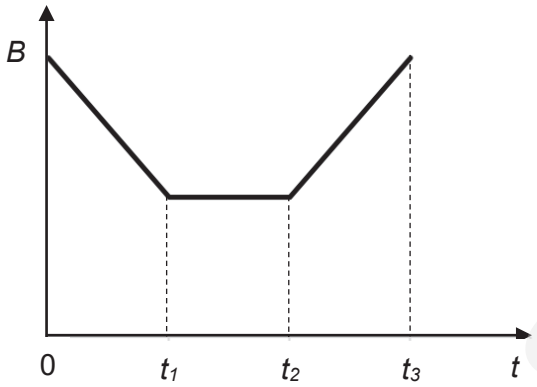
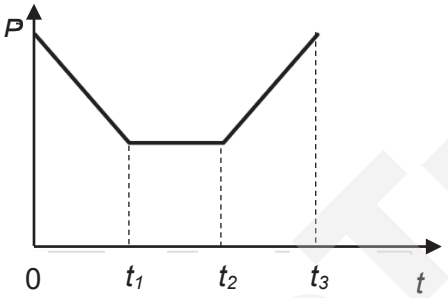
**26** A coil of wire of one turn only with negligible resistance is connected to a resistor. A magnetic field $B$ whose magnitude changes with time $t$ as shown in the graph below is applied perpendicularly to the coil.

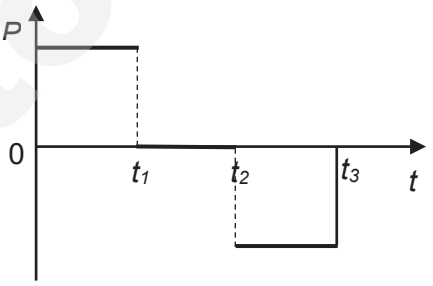



Which of the following graphs best shows the variation of the heating power $P$ in the resistor with time $t$?

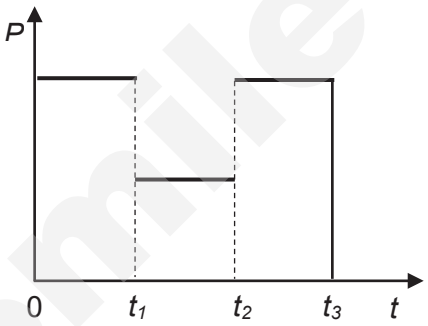
**A**



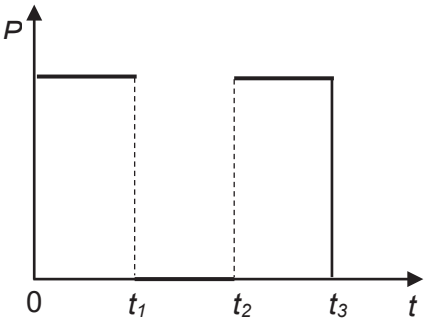

**B**




**C**




**D**

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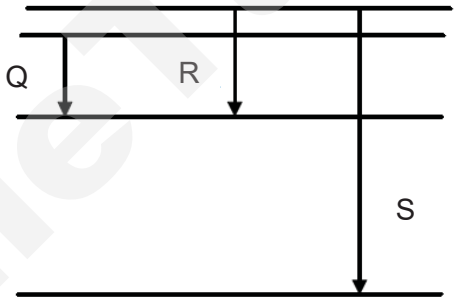
**27** In an experiment to demonstrate the photoelectric effect, light of intensity $L$ and frequency $f$ is incident on a metal surface. The maximum photoelectric current is $I$ and the stopping potential is $V_s$.

What change if any occurs in the maximum photoelectric current and in the stopping potential when light of the same intensity $L$ but of frequency $2f$ is incident on the surface?

| | Maximum photoelectric current | stopping potential |
|---|---|---|
| **A** | $I$ | greater than $2V_s$ |
| **B** | less than $I$ | greater than $2V_s$ |
| **C** | $I$ | less than $2V_s$ |
| **D** | less than $I$ | less than $2V_s$ |

**28** The diagram below, which is drawn to scale, shows some of the atomic energy levels of a fictitious element. The three transitions shown result in radiation in the ultraviolet (UV), red and yellow regions of the spectrum. Which one of the choices below correctly identifies the transitions?




| | UV | red | yellow |
|---|---|---|---|
| **A** | Q | R | S |
| **B** | S | Q | R |
| **C** | R | S | Q |
| **D** | S | R | Q |

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**29** Nucleus P decays in two stages to produce nucleus Q.

Which decay sequence will result in the highest number of neutrons in nucleus Q?

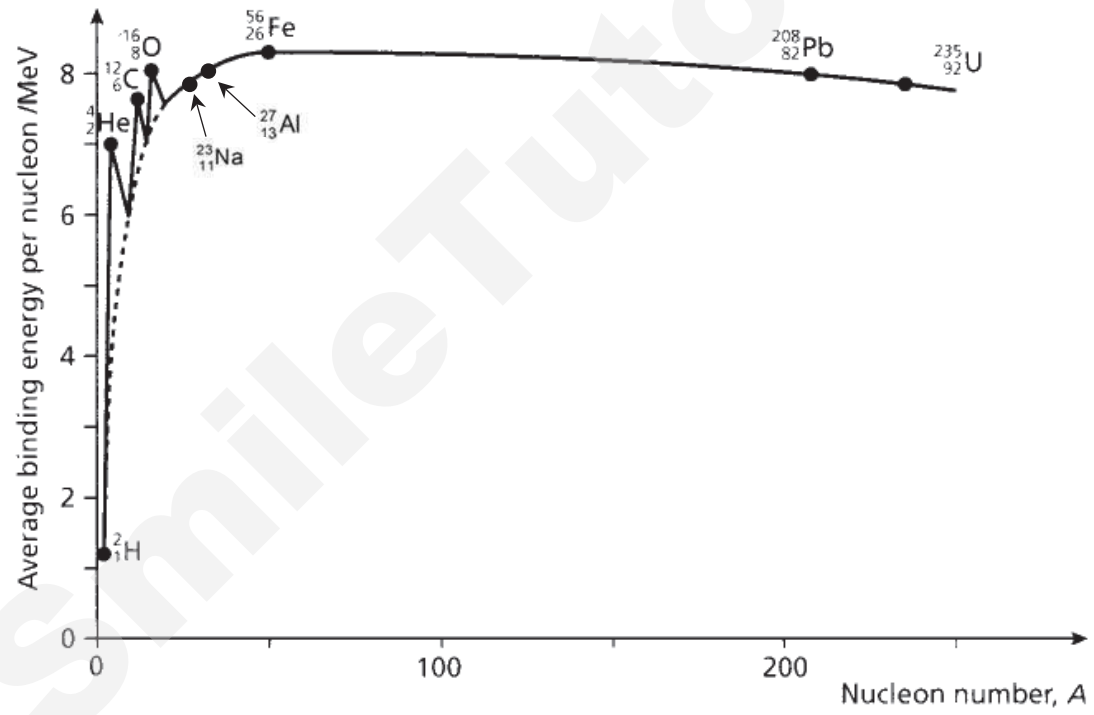
**A** a β-particle followed by a $\gamma$-ray

**B** an α-particle followed by a $\gamma$-ray

**C** an α-particle followed by a β-particle

**D** a β-particle followed by another β-particle

**30** The diagram shows a graph of the binding energy per nucleon for a number of naturally occurring nuclides plotted against their nucleon number.




Which of the following statements is a correct deduction from the graph?

**A** Of the nucleus plotted, $^{2}_{1}H$ is the most stable.

**B** $^{27}_{13}Al$ will not spontaneously emit an alpha particle to become $^{23}_{11}Na$.

**C** Energy will be released if a nucleus with a nucleon number greater than about 56 undergoes fusion with any other nucleus.

**D** Energy will be released if a nucleus with a nucleon number less than about 56 undergoes fission as a result of particle bombardment.

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# TEMASEK JUNIOR COLLEGE
## 2019 JC2 Preliminary Examination
## Higher 2

NAME

CG

# PHYSICS 9749/02

**Paper 2 Structured Questions**

**27 Aug 2019**
**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your civics group and name in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.

You may use 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 | |
| s.f. | |
| Total | |



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**Data**

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

**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$ |
| | $v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -Gm/r$ |
| temperature | $T/\text{K} = T/^\circ\text{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t = \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = Q/(4\pi\varepsilon_0 r)$ |
| alternating current / voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** When an object moves relative to a fluid, the fluid exerts a retarding force on the object. This drag force $F$ is due to the viscosity of the fluid. Under non-turbulent conditions, the drag force on a sphere moving in a tube of fluid is given by

$$F = 6\pi\eta rv$$

where $r$ is the radius of the sphere, $\eta$ is the viscosity of the fluid and $v$ is the velocity of the sphere.

**(a)** Show that the base units of viscosity $\eta$ are kg $m^{-1}$ $s^{-1}$.

[1]

**(b)** A sphere of diameter (2.0 ± 0.1) cm falls under non-turbulent conditions through a fluid of viscosity (0.13 ± 0.02) kg $m^{-1}$ $s^{-1}$. Using a ruler and a stopwatch, a student measured the velocity through the liquid to be 2.7 $ms^{-1}$ and estimates that the percentage uncertainty in this measurement to be 5%.

**(i)** Determine the drag force $F$ acting on the sphere. State your answer with its uncertainty.

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$F$ = ..... ± ..... N [3]

**(ii)** In order to improve the accuracy of $F$, explain which one of the measurements should be improved.

.....

..... [1]

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**2** **(a)** With a suitable definition of the unit of force, Newton's second law can be written as the following relationship

force = mass x acceleration

for a body of constant mass.

Using this definition together with Newton's third law, deduce the principle of conservation of momentum.

.....

.....

.....

.....

.....

..... [2]

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**(b)** In an experiment, an $\alpha$-particle of mass $m$ and initial velocity $v_0$ is directed head-on towards a stationary heavy nucleus of mass $M$ from afar. The variations with time of the velocities of the $\alpha$-particle and the nucleus are shown in Fig. 2.1.

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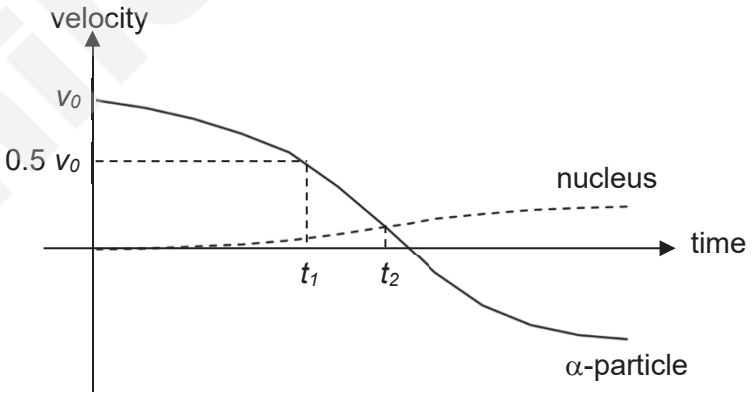


**Fig. 2.1**

**(i)** Write down, in terms of $m$ and $v_0$, an expression for the momentum of the nucleus at time $t_1$.

[1]

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**(ii)** Explain how you obtained the expression in **(b)(i)**.

.....

.....

.....

..... [2]

**(iii)** The $\alpha$-particle is closest to the nucleus at time $t_2$. The velocity of the $\alpha$-particle at this time is $v$.

Determine the velocity $v$ of the $\alpha$-particle in terms of $m$, $M$ and $v_0$.

velocity = ..... [2]

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**(c)** In a separate experiment, an alpha particle collides head-on with a stationary nitrogen-14 atom. The nitrogen atom moves off in the same direction as the approaching alpha particle with a speed of 0.005 $c$, where $c$ is the speed of light.

Discuss quantitatively whether the interaction is elastic in nature if the initial speed of the alpha particle is 0.02 $c$.

[3]

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**3** A cyclist is moving up a slope that has a constant gradient. The cyclist takes 8.0 s to climb the slope. The variation with time $t$ of the speed $v$ of the cyclist is shown in Fig. 3.1.

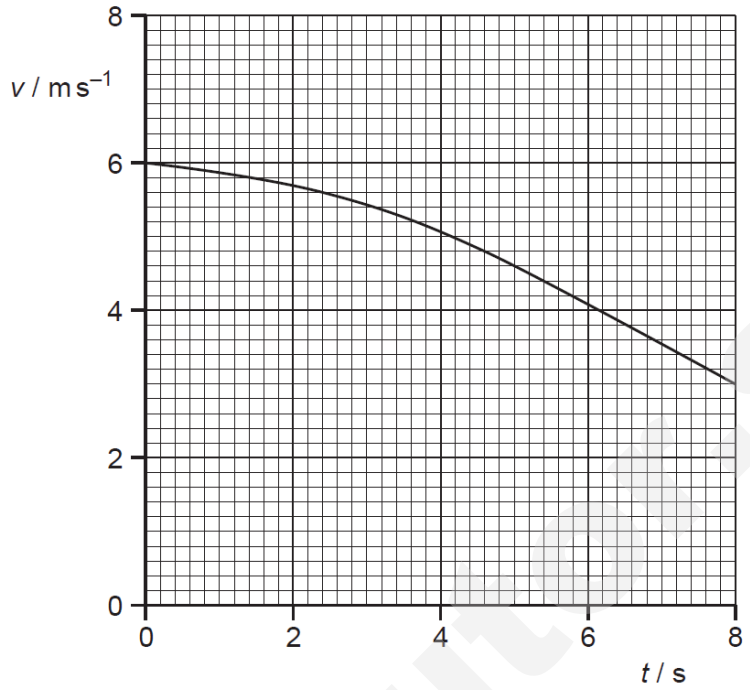


**Fig 3.1**

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**(a)** Use Fig. 3.1 to estimate the total distance moved up the slope.

total distance = ..... m [1]

**(b)** The bicycle and cyclist have a combined mass of 92 kg. The vertical height through which the cyclist moves is 1.30 m.

For the movement of the bicycle and cyclist between $t$ = 0 and $t$ = 8.0 s,

**(i)** use Fig. 3.1 to calculate the change in kinetic energy.

change in kinetic energy = ..... J [1]

**(ii)** calculate the change in gravitational potential energy.

change in gravitational potential energy = ..... [1]

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**(iii)** calculate the useful work done by the cyclist to climb the slope, assuming that he pedals continuously so that the useful power delivered to the bicycle is 75 W.

work done = ..... J [1]

**(c)** In reality, some energy is used to overcome frictional forces.

**(i)** Use your answer in **(b)** to determine the total energy converted in overcoming frictional forces.

total energy to overcome frictional forces = ..... J [2]

**(ii)** Hence, determine the average magnitude of the frictional forces.

average frictional force = ..... N [1]

**(d)** Suggest why the magnitude of the total resistive force would not be constant.

.....

.....

.....

.....

..... [2]

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**4** **(a)** Explain qualitatively why a body travelling in a circle with constant speed experiences an acceleration towards the centre of the circle.

.....

.....

.....

..... [2]

**(b)** A toy plane with a mass of 0.40 kg, as shown in Fig 4.1, has a taut wire of length 5.0 m attached to it when it flies in a horizontal circle. The taut wire is inclined 60˚ to the horizontal and fixed to a point O. The wings of the toy plane are horizontal, creating a vertical upward lift on the plane.

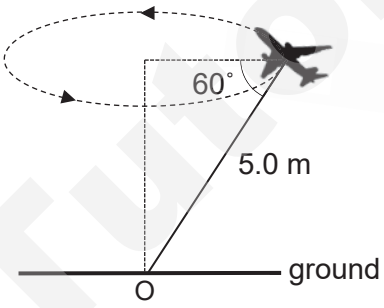


**Fig 4.1**

**(i)** If each revolution takes 3.5 s, show that the centripetal acceleration of the toy plane is 8.1 m $s^{-2}$.

[1]

**(ii)** Calculate the tension *T* in the taut wire.

*T* = ..... N [2]

**(iii)** Hence calculate the upward lift *L* on the toy plane due to the air.

*L* = ..... N [2]

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**(iv)** In another arrangement, the taut wire is now fixed to a point O attached to the ceiling with the toy plane flying in a horizontal circle as shown in Fig. 4.2.

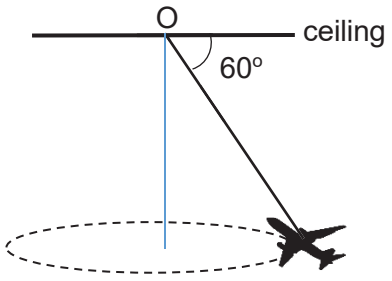


**Fig. 4.2**

Discuss how your answer to **(a)(iii)** will change if the wings of the toy plane are horizontal and the wire remaining at 60° to the horizontal with the time taken for each revolution unchanged.

.....

.....

.....

..... [2]

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**5** **(a)** The value of the gravitational potential $\phi$ at a point in the Earth's field is given by the equation

$$\phi = -\frac{GM}{r}$$

where $M$ is the mass of the Earth and $r$ is the distance of the point from the centre of the Earth such that $r$ is greater than the radius of the Earth $R_E$.

Explain why the potential has a negative value.

.....

.....

.....

..... [1]

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**(b)** Fig. 5.1 shows the equipotential lines for Earth, where point A is at a potential of $-4.0 \times 10^7$ J kg$^{-1}$ and points B and C are at a potential of $-5.0 \times 10^7$ J kg$^{-1}$.

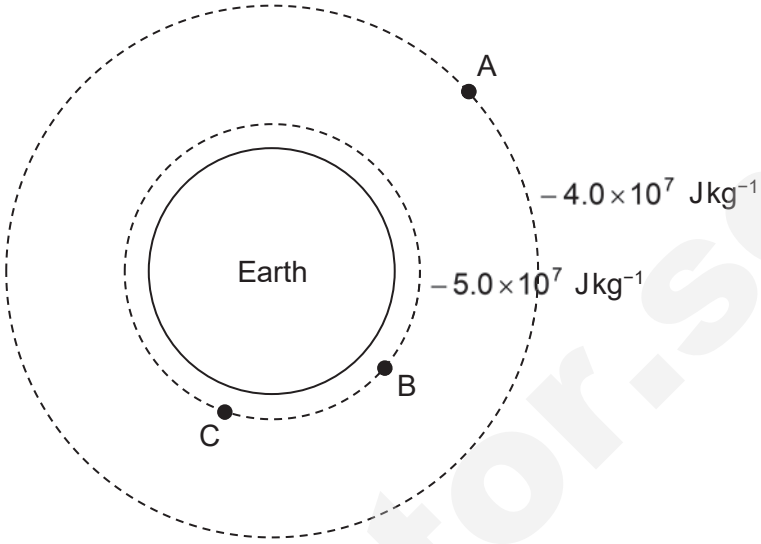


**Fig. 5.1**

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**(i)** On Fig. 5.1, draw the equipotential line for the gravitational potential of $-4.5 \times 10^7$ Jkg$^{-1}$.

[1]

**(ii)** Calculate the work done by the gravitational force in bringing a body of mass 3000 kg from A to B.

work done = ..... J [2]

**(iii)** The work done by the gravitational force in moving any mass along the equipotential line is zero. Explain why this is so.

.....

.....

[1]

.....

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**(c)** A satellite of mass 1500 kg is launched from the surface of the Earth into a circular orbit around the Earth at a height of 6800 km above the Earth's surface. At this height the satellite has an orbital period of $8.5 \times 10^3$ s. The radius of the Earth is 6400 km.

**(i)** A student uses the equation *gain in potential energy* = *mgh* to determine the increase in the potential energy of the satellite.

Suggest why this equation cannot be used and state whether the student's answer would be less than, equal to, or greater than the actual gain in potential energy.

.....

.....

..... [2]

**(ii)** Calculate the kinetic energy of the satellite.

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kinetic energy = ..... J [2]

**(iii)** State an advantage of having a satellite in a geostationary orbit round the Earth and explain whether the satellite orbiting at a height of 6800 km above the Earth's surface is in a geostationary orbit.

.....

.....

.....

..... [2]

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**6** **(a)** Fig. 6.1 shows a potential divider arrangement used for product testing that consists of a fixed resistor of resistance 4.0 kΩ and a variable resistor of maximum resistance 20 kΩ with a slide contact connected to terminal S.

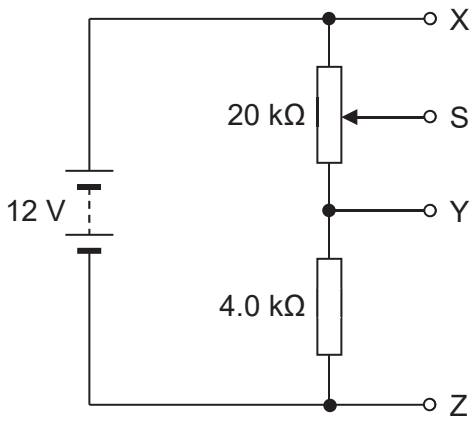


**Fig 6.1**

The e.m.f. of the battery is 12 V and it has negligible internal resistance. It is possible to obtain different continuously-variable ranges by selecting, as the output, particular pairs of terminals from S, X, Y and Z.

**(i)** Calculate the voltage range obtainable between the terminals S and X.

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voltage range = .....to..... V [2]

**(ii)** Hence, or otherwise, calculate the voltage range between the terminals S and Z.

voltage range = .....to..... V [1]

**(iii)** The slide contact S is set at the mid-point of the 20 kΩ resistance track. If a voltmeter of resistance of 10 kΩ is then connected between S and Y, calculate the reading on the voltmeter.

voltmeter reading = ..... V [2]

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**(b)** To test a special bicycle lock that comes with an alarm, an ideal voltmeter is connected to the lock. When the lock detects that someone is tampering with it, it will emit a loud siren and two warning lights will start flashing. The siren and warning lights are connected to a cell as shown in Fig. 6.2. The siren has a resistance of 1.5 Ω and each warning light has a resistance of 2.4 Ω.

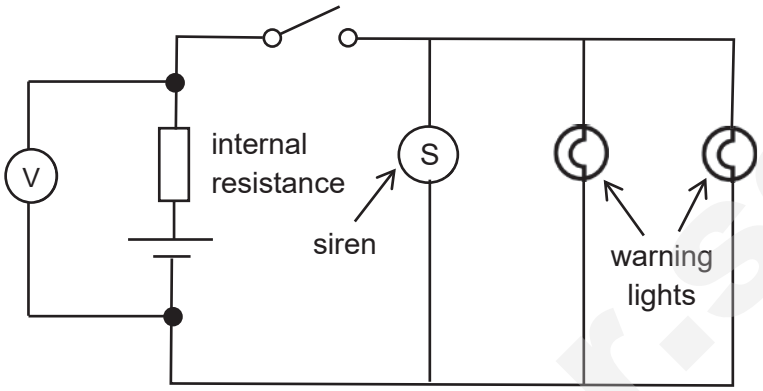


**Fig 6.2**

**(i)** When the switch is opened, the voltmeter reading is 3.0 V. When the switch is closed, the voltmeter reading changes to 1.7 V.

Determine the internal resistance of the battery.

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internal resistance = ..... Ω [3]

**(ii)** If another battery with the same electromotive force but which has significantly higher internal resistance is used, state and explain the impact on

**1.** the loudness of the siren

.....

.....

**2.** the brightness of the warning lights

.....

..... [2]

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**7** In 1991, Japan successfully built the first working prototype of a magneto-hydrodynamic propulsion (or electromagnetic propulsion) boat, Yamato 1, shown in Fig 7.1. The boat is propelled by applying a magnetic field to seawater, which causes the induction of a magnetic force.



**Fig. 7.1**

Fig. 7.2 shows a simplified diagram of the electromagnetic propulsion tube engine. A pair of very powerful electromagnets is placed across the propulsion tube. Seawater is propelled through the tube when the engine is switched on. The cross-section of the tube is a rectangle of side 30.0 cm by 10.0 cm.

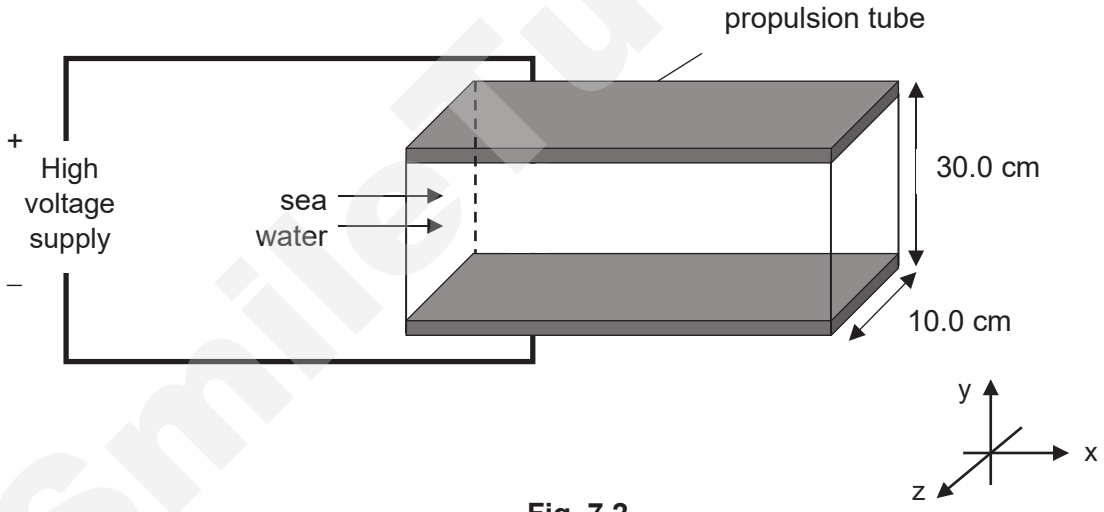


**Fig. 7.2**

**(a)** Draw, on Fig. 7.2, the direction of the current inside the tube when the voltage supply is switched on. Label it as $I$. [1]

**(b)** In order to propel the seawater into the tube towards the positive x-direction, state the direction of the magnetic field inside the tube.

.....[1]

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**(c)** Given the current supplied is adjusted to be 10.0 A, calculate the magnetic flux density required to provide an average force of 16.0 kN.

magnetic flux density = ..... T [2]

**(d)** State two possible disadvantages of this propulsion technology.

**(i)**

.....

.....

.....

**(ii)**

.....

.....

..... [2]

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**8** Read the following article and then answer the questions that follow.

**Solar Vehicles**

A solar vehicle is an electric vehicle powered completely or significantly by direct solar energy. Usually, photovoltaic cells contained in solar panels convert the sun's energy directly into electric energy. The term "solar vehicle" usually implies that solar energy is used to power all or part of a vehicle's propulsion. Solar power may be also used to provide power for communications or controls or other auxiliary functions. Solar vehicles are not sold as practical day-to-day transportation devices at present, but are primarily demonstration vehicles and engineering exercises, often sponsored by government agencies.

The design of a solar vehicles is severely limited by the amount of energy input into the car. Solar cars are built for solar car races and also for public use. Even the best solar cells can only collect limited power and energy over the area of a car's surface. This limits solar cars to ultralight composite bodies to save weight.

In an experiment, a prototype model of a solar powered vehicle was put to a 200 km test run. Solar vehicles weighing more than 1000 kg are generally impractical. To keep the vehicle light and efficient, the motor and battery are often carefully selected. For the prototype, the selected motor has an average power output of 1.1 kW with a corresponding efficiency of 92%. It is also capable of delivering a power output of 4.5 kW for peak performance. The selected battery operates at 50 V and has a charge capacity of 60 A h.

Solar cars are often fitted with gauges and wireless telemetry, to carefully monitor the car's energy consumption, solar energy capture and other parameters. Wireless telemetry is typically preferred as it frees the driver to concentrate on driving, which can be dangerous in such a small, lightweight car. The solar cells used has an electrical efficiency (ability of solar cell to convert solar energy to electrical energy) of 26 %. The total surface area of solar cells collecting solar energy was kept to an optimum value of 7.7 $m^2$. The 200 km journey was eventually completed with an average speed of 67 km $h^{-1}$. During the test run, an average solar energy intensity of 0.90 kW $m^{-2}$ was recorded.

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**(a)** Calculate the total amount of energy collected by the solar cells during its 200 km journey.

total energy = ..... J [3]

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**(b)** Calculate the amount of energy in **(a)** which was transformed into electrical energy.

electrical energy = ..... kW h [2]

**(c)** When the motor was operating at *average power output*, show that the total power being supplied by the battery is 1.2 kW.

[2]

**(d)** The surface area of a solar cell is $6.4 \times 10^{-3}$ $m^2$. Determine

**(i)** how many cells can be fitted onto the solar vehicle,

no of solar cells = ..... [1]

**(ii)** how much energy does each cell, assumed identical, collect during the 200 km journey.

energy collected by each cell = ..... J [2]

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**(e)** If the total resistive force on the vehicle is directly proportional to the square of the speed of the vehicle, determine the constant speed with which the vehicle is travelling when it operates at its *peak power.*

speed = ..... km $h^{-1}$ [3]

**(f)** By reference to **(c)**, calculate the discharge current from the fully charged battery under conditions of darkness.

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discharge current = ..... A [1]

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**(g)** Hence, calculate the time for the battery to become fully discharged.

Time taken = ..... hr [2]

**(h)** You are told that the average solar energy intensity received is 0.90 kW $m^{-2}$. Name two factors which could affect its actual value.

**1.** .....

.....

**2.** .....

..... [2]

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**(i)** Solar powered vehicles tend to be flat and wide. Give one reason for each of the two features stated.

**1.** .....

.....

**2.** .....

..... [2]

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# TEMASEK JUNIOR COLLEGE

2019 Preliminary Examination
Higher 2

| | | | |
|---|---|---|---|
| CANDIDATE NAME | | | |
| CIVICS GROUP | | INDEX NUMBER | |

## PHYSICS

**9749/03**

Paper 3 Longer Structured Questions

**17 September 2019**
**2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

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

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

**Section A**
Answer **all** questions.

**Section B**
Answer **one** question only.

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

At the end of the examination, fasten all your work securely together, if additional writing material had been used. The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| Total | |


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**Data**

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

**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$ |
| | $v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -Gm/r$ |
| temperature | $T/\text{K} = T/^\circ\text{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t = \pm\omega\sqrt{x_0^2 - x^2}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = Q/(4\pi\varepsilon_0 r)$ |
| alternating current / voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

**1** **(a)** Fig. 1.1 shows an insulated cylinder fitted with a perfectly fitting piston and a heater. There is negligible friction between the cylinder and the piston. The cylinder contains a fixed mass of ideal neon gas.

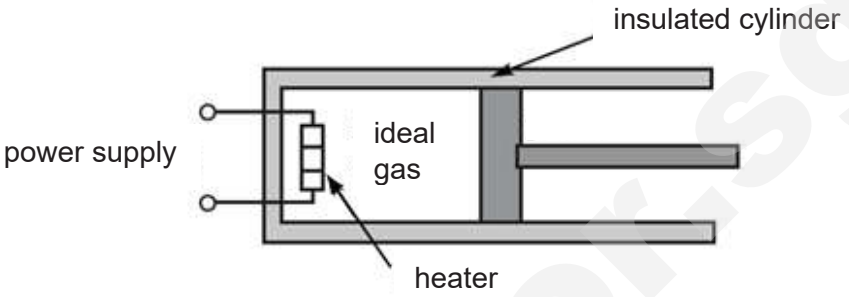


**Fig. 1.1**

The following two experiments are performed.

**Experiment 1** The heater provides 150 J of energy with the piston fixed in position. The temperature rise of the gas is found to be 29 K.

**Experiment 2** The heater supplies 150 J of energy with the piston free to move so that the gas expands at constant pressure. The temperature rise of the gas is now 18 K.

**(i)** Explain why the temperature rise is different in the two experiments.

.....

.....

.....

..... [2]

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**(ii)** Complete Fig. 1.2 to show the values of each of the quantities for experiments 1 and 2. You may present your working using the space provided below.

| | thermal energy supplied to gas/J | work done on gas /J | increase in internal energy of gas/J |
|---|---|---|---|
| Experiment 1 | | | |
| Experiment 2 | | | |

**Fig. 1.2** [4]

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**(b)** Some argon gas is now introduced into the cylinder and the gas mixture is heated to a temperature of 100°C. The gases are assumed to be ideal.

**(i)** Calculate the average kinetic energy of each gas molecule.

average kinetic energy = ..... J [2]

**(ii)** The mass of a neon atom is $3.35 \times 10^{-26}$ kg.

Calculate the root-mean-square speed of argon atom, given that an argon atom is 1.8 times more massive than a neon atom.

root-mean-square speed = ..... $m\ s^{-1}$ [2]

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**2** Fig. 2.1 shows a mass-spring system placed on a frictionless slope. The slope has an angle of $\theta$ from the horizontal. When a block of mass $m$ is hung, the spring stretches by an extension of $e$ and the mass remains in equilibrium. The spring is further extended by $x$ downwards, along the slope, and released for the mass-spring system to oscillate. The spring constant is $k$.

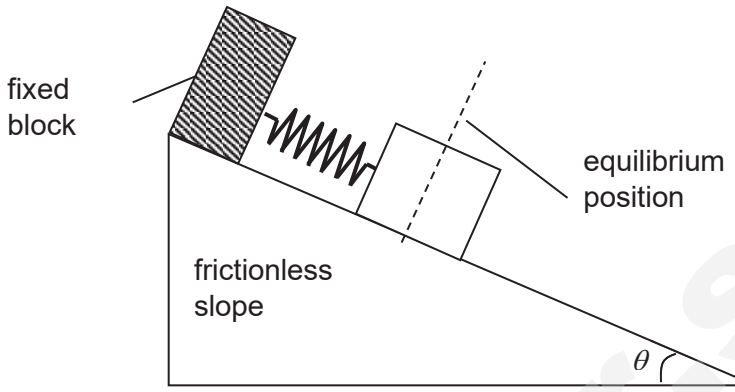


**Fig. 2.1**

**(a)** By using Newton's second law, show that the acceleration $a$ of the block at the lowest point is given by $a = -\frac{k}{m}x$.

[3]

**(b)** Explain how the expression in **(a)** shows the mass-spring system is oscillating in simple harmonic motion.

.....

.....

..... [2]

**(c)** The amplitude of oscillation of the mass-spring system is 3.0 cm.

Calculate the position of the mass from equilibrium when the speed of the mass is 25 % of the maximum speed.

position = ..... cm [2]

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**(d)** A student removes the fixed block and attach a variable frequency oscillator to the mass-spring system, as shown in Fig. 2.2.

Fig. 2.3 shows the variation of the amplitude of mass with the frequency of the oscillator.

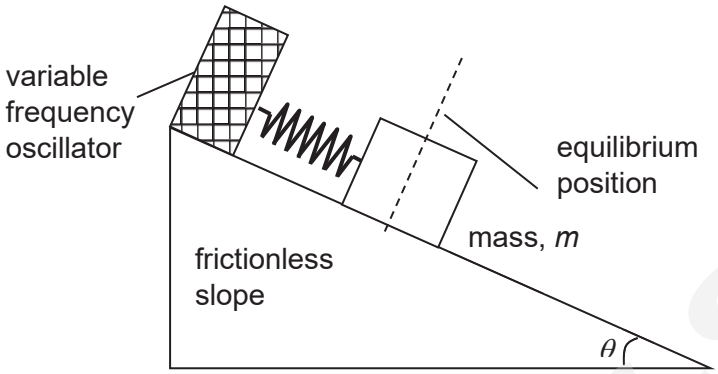


**Fig. 2.2**

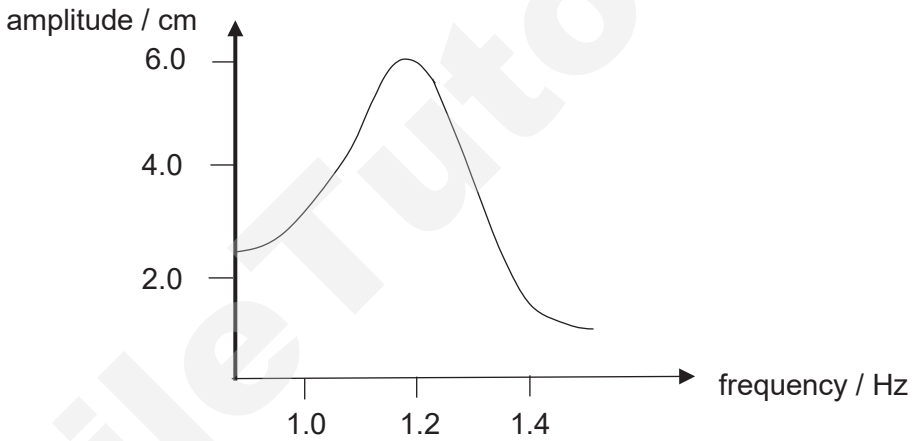


**Fig. 2.3**

**(i)** Explain the phenomenon illustrated in Fig. 2.3.

.....

.....

.....

.....

..... [2]

**(ii)** Calculate the magnitude of maximum acceleration of the mass.

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

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**3** **(a)** Fig. 3.1 shows an electron moving horizontally with a speed of $1.5 \times 10^7$ m $s^{-1}$ into a pair of horizontal parallel electric plates.

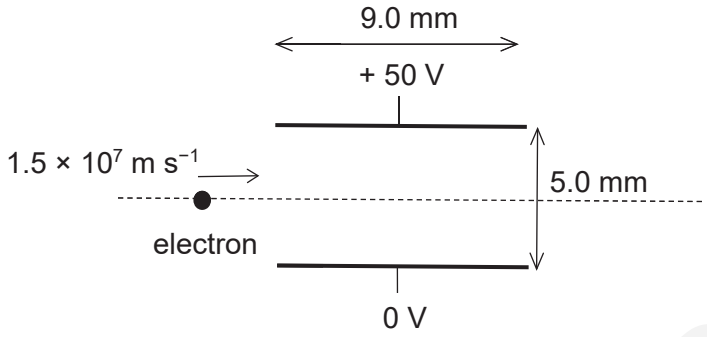


**Fig. 3.1**

**(i)** Describe and explain the subsequent motion of the electron in Fig. 3.1.

.....

.....

.....

.....

..... [2]

**(ii)** Calculate the magnitude of acceleration of the electron when it is between the electric plates.

acceleration = ..... m $s^{-2}$ [2]

**(iii)** Calculate the angle which the electron deviates from its initial path, when it leaves the parallel electric plates.

angle = ..... ° [3]

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**(b)** Fig. 3.2 shows another electron placed at rest near two positive charges, each of charge $+1.6 \times 10^{-19}$ C.

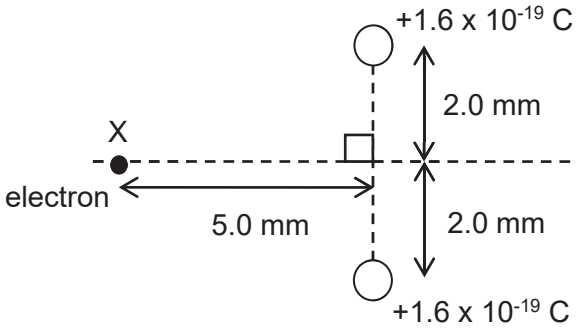


**Fig. 3.2**

**(i)** Describe and explain the subsequent motion of the electron in Fig. 3.2.

.....

.....

.....

.....

.....

.....

..... [2]

**(ii)** Calculate the magnitude of the resultant electric force acting on the electron when it is placed at position X in Fig. 3.2.

resultant electric force = ..... N [3]

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**4** A hair dryer sold in Singapore is rated at 240 V r.m.s., 1000 W. An exchange programme student plans to bring the blower to the United States of America (USA), where the voltage is 120 V r.m.s.

**(a)** Explain why the current from the mains is alternating current rather than direct current.

.....

.....

.....

..... [2]

**(b)** Explain what is meant by the *root mean square* (r.m.s.) *value* of the current.

.....

.....

.....

..... [2]

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**(c)** It was suggested that the student bring along a transformer to USA in order to operate the blower. Determine a suitable transformer's turns ratio $\frac{N_s}{N_p}$.

$\frac{N_s}{N_p}$ = ..... [1]

**(d)** Determine the peak current which the transformer will draw from the USA outlet when the blower is operating at 1000 W. State any assumption you have made in your working.

peak current = ..... A [3]

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**5** The EZ-Link card is a "contactless" smartcard used for transportation payments in Singapore.

Fig. 5.1 shows part of the internal circuitry of an EZ-Link card. It consists of a transmitter which connects to 3 wire loops around the edge of the card. The transmitter requires electrical energy to communicate with an external device such as a card reader. However, there is no internal power source in the card. The area of the EZ-Link card is $4.00 \times 10^{-3}$ m$^2$.

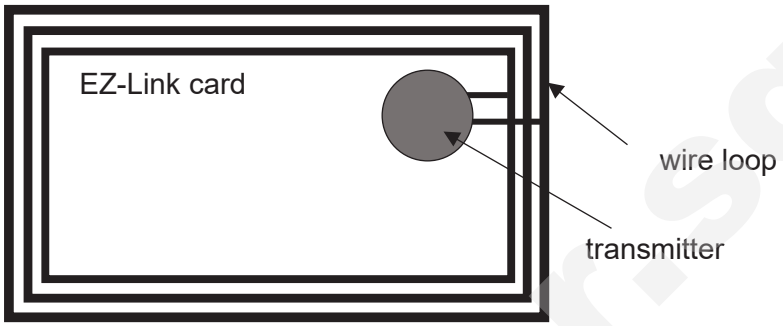


**Fig. 5.1**

Fig. 5.2 shows a card reader which produces a sinusoidal magnetic field of frequency, $f$, $13.6 \times 10^6$ Hz.




**Fig. 5.2**

**(a)** State Faraday's law of electromagnetic induction.

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**(b)** Using Faraday's law, explain how electrical energy is generated to power the transmitter of the EZ-Link card when it is tapped onto the card reader.

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..... [3]

**(c)** The card reader generates a magnetic field, $B$ given by the equation $B = B_0 \sin(2\pi ft)$.

**(i)** Show clearly that the magnitude of the peak e.m.f. generated in the card is given by $1.02 \times 10^6 B_0$.

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[3]

**(ii)** Calculate the peak magnetic flux density $B_0$ if the card needs a r.m.s. voltage of 10.0 mV to operate.

$B_0$ = ..... T [2]

**(d)** The system is designed such that it can work if the card is tapped with either face. Explain briefly why this is possible.

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**6** Figure 6.1 shows the end of an electron diffraction tube.

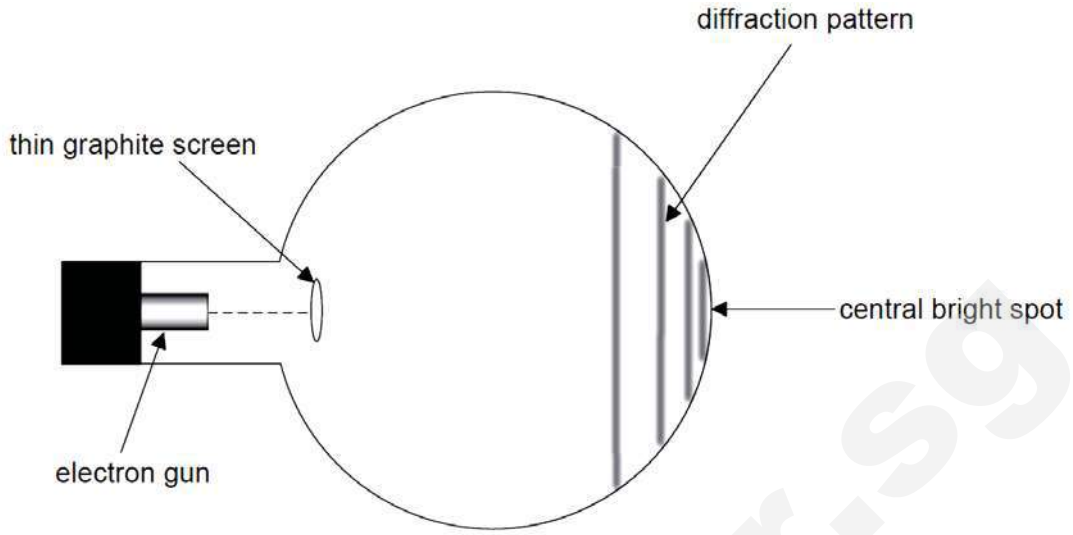


**Fig. 6.1**

A diffraction pattern of concentric circles forms when diffracted electrons are incident on a fluorescent layer at the end of the tube.

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**(a)** **(i)** Explain the meaning of the term diffraction

.....

.....

..... [1]

**(ii)** State the condition necessary for electrons to produce observable diffraction when passing through matter, e.g. a thin sheet of graphite.

.....

.....

..... [1]

**(b)** An electron with charge − $q$ and mass $m$ is made to accelerate from rest in the above evacuated tube through a potential difference of 120 V.

**(i)** State what is meant by the *de Broglie wavelength*.

.....

.....

..... [1]

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**(ii)** Calculate the de Broglie wavelength of the electron.

de Broglie wavelength = ..... m [4]

**(iii)** The potential difference $V$ is now increased slightly. State and explain how the diffraction pattern that forms would change.

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..... [3]

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## Section B

Answer **one** question in this section in the spaces provided.

**7** Fig 7.1 shows two microwave transmitters **A** and **B** 0.20 m apart. The transmitters emit microwaves of frequency 10 GHz, of equal amplitude and in phase. A microwave detector is placed at **O** at a distance of 4.0 m from **AB**.

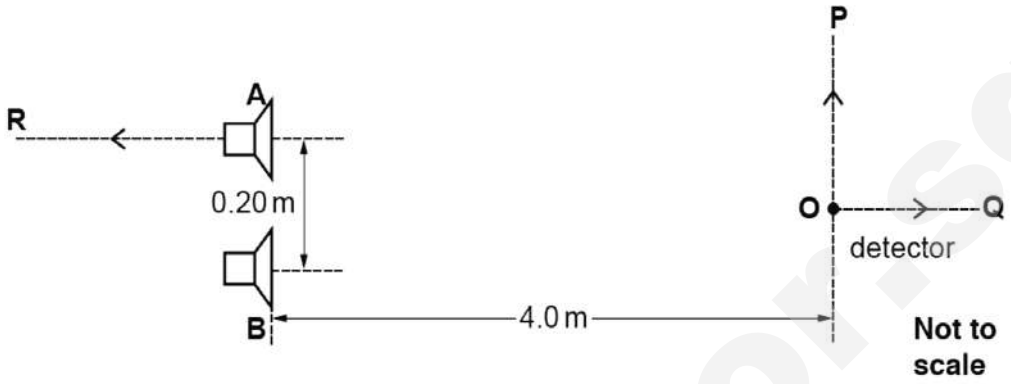


**Fig. 7.1**

Interference of the waves from the two transmitters is detected only when the transmitters are coherent.

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**(a)** Explain the meaning of the term interference.

.....

..... [1]

**(b)** The length of the detector aerial is half a wavelength. Calculate the length of the aerial.

aerial length = ..... m [2]

**(c)** **(i)** **1.** Explain why the amplitude of the detected signal changes when the detector is moved in the direction **OP**.

.....

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.....

.....

..... [3]

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**2.** Calculate the distance between adjacent maximum and minimum signals.

distance = ..... m [2]

**(ii).** Explain why the amplitude of the detected signal changes when the detector is moved in the direction of **OQ**.

.....

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..... [2]

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**(iii)** **1.** Explain why the amplitude of the detected signal decreases to a minimum before increasing again as transmitter **A** is moved a small distance in the direcxtion **AR** with the detector fixed at **O**.

.....

.....

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..... [1]

**2.** Calculate the distance **A** is moved to cause this minimum signal at **O**.

distance = ..... m [2]

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**(d)** State, with a reason, the effect on the intensity of the signal detected at O when each of the following changes is made:

**(i)** The amplitude of the waves emitted from **A** and **B** are doubled.

.....

.....

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..... [2]

**(ii)** The two microwave transmitters **A** and **B** emits waves that are anti-phase to each other.

.....

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..... [2]

**(iii)** The detector **O** is rotated 90° about the axis through **OQ**.

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**8** **(a)** Define binding energy.

.....

..... [2]

**(b)** $^{226}_{88}Ra$ is a stationary radioactive isotope which decays to $^{222}_{86}Rn$ with the release of an alpha particle. Given:

Mass of $^{226}_{88}Ra$ = 226.025 *u*

Mass of $^{4}_{2}He$ = 4.00260 *u*

Mass of $^{222}_{86}Rn$ = 222.018 *u*

Mass of proton = 1.00783 *u*

Mass of neutron = 1.00867 *u*

**(i)** Calculate the binding energy per nucleon of $^{226}_{88}Ra$ in MeV.

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binding energy per nucleon = ..... MeV [3]

**(ii)** Calculate the energy released in the above decay reaction in MeV.

energy released = ..... MeV [2]

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**(c)** $^{222}_{86}Rn$ is found in atmospheric air and it is also a radioactive element. The radioactive decay of $^{222}_{86}Rn$ is a *random* and *spontaneous* process.

**(i)** Explain what is meant by *random* and *spontaneous* process.

.....

.....

.....

..... [2]

**(ii)** $^{222}_{86}Rn$ is one of the rarest element on Earth. Suggest reasons for this.

.....

.....

.....

..... [2]

**(iii)** $^{222}_{86}Rn$ is considered to be an unacceptable health hazard when the activity of $^{222}_{86}Rn$ is greater than 200 Bq in 1.0 $m^3$ of air. The decay constant of $^{222}_{86}Rn$ is $2.1 \times 10^{-6}$ $s^{-1}$.

Calculate the minimum mass of $^{222}_{86}Rn$ in 1.0 $m^3$ of air above which the health hazard becomes unacceptable.

minimum mass = ..... kg [3]

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**(d)** Carbon-14 is a radioactive isotope of carbon and it undergoes beta decay.

An archaeologist found a fragment of an ancient basket made from wood. The carbon-14 activity of the wood in the basket is 8.5 % that of an equal carbon sample from present day wood. Carbon-14 has a half-life of 5700 years.

**(i)** Calculate the age of the basket

age = ..... years [2]

**(ii)** Calculate the probability of decay per second of a carbon-14 nuclide.

probability of decay per second = ..... $s^{-1}$ [1]

**(iii)** Explain whether Carbon-14 can be used to measure the age of a stone.

.....

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..... [2]

**(iv)** State and explain what happens to the number of protons and neutrons in the nucleus after it undergoes beta decay.

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..... [1]

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# TEMASEK JUNIOR COLLEGE
## 2019 JC2 Preliminary Examination
## Higher 2

NAME

CG

# PHYSICS 9749/04

Paper 4 Practical

**4 September 2019**

Candidates answer on the Question Paper.

**2 hours 30 minutes**

Additional Materials: As listed in the Confidential Instructions

**READ THESE INSTRUCTIONS FIRST**

Write your name and C.G. in the spaces provided at the top of this page.
Write in dark blue or black pen on both sides of the papers.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

You will be allowed a maximum of one hour with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| **1** | /15 |
| **2** | /8 |
| **3** | /20 |
| **4** | /12 |
| **Total** | /55 |

This booklet consists of **18** printed pages and **2** blank pages.

**[Turn over**

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**1** In this experiment, you will determine the resistivity of two wires with different cross-sectional areas.

**(a)** Measure and record the diameter $d_1$ of wire 1.

$d_1$ = ..... [1]

**(b)** Calculate the cross-sectional area $A_1$ of wire 1.

$A_1$ = ..... [1]

**(c)** Repeat **(a)** and **(b)** to obtain the diameter and cross-sectional area for wire 2.

$d_2$ = .....

$A_2$ = .....

**(d)** Connect the circuit shown in Fig. 1.1. The wires should be connected into the circuit using crocodile clips placed close to the ends of the wires. The length of each wire, $L$ between the crocodile clip should be the same at around 35 cm.

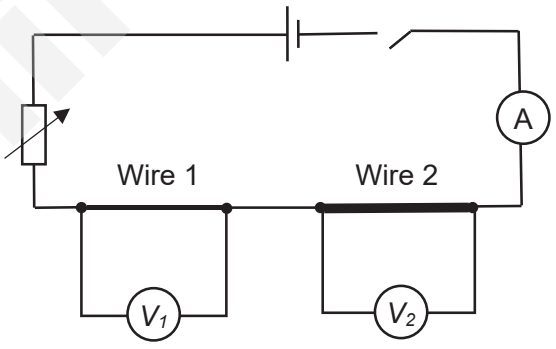


**Fig. 1.1**

**(e)** Close the switch. Adjust the rheostat to obtain a minimum current value $I$ in the ammeter. Record the corresponding $V_1$ and $V_2$ values in the voltmeters.

$I$ = ……

$V_1$ = ……

$V_2$ = ……
[2]

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**(f)** Adjust the rheostat and obtain at least 6 sets of readings for $I$, $V_1$ and $V_2$. For each set of readings, the length of each wire $L$ should be constant at approximately 35 cm.

[3]

**(g)** Theory suggests that $V_1$, $V_2$ and $I$ are related by the expression

$$V_1 + V_2 = \rho L\left(\frac{1}{A_1} + \frac{1}{A_2}\right) I$$

where $\rho$ is the resistivity of the wires.

Plot a suitable graph to determine the value of $\rho$.

$\rho$ = ……..…… [2]



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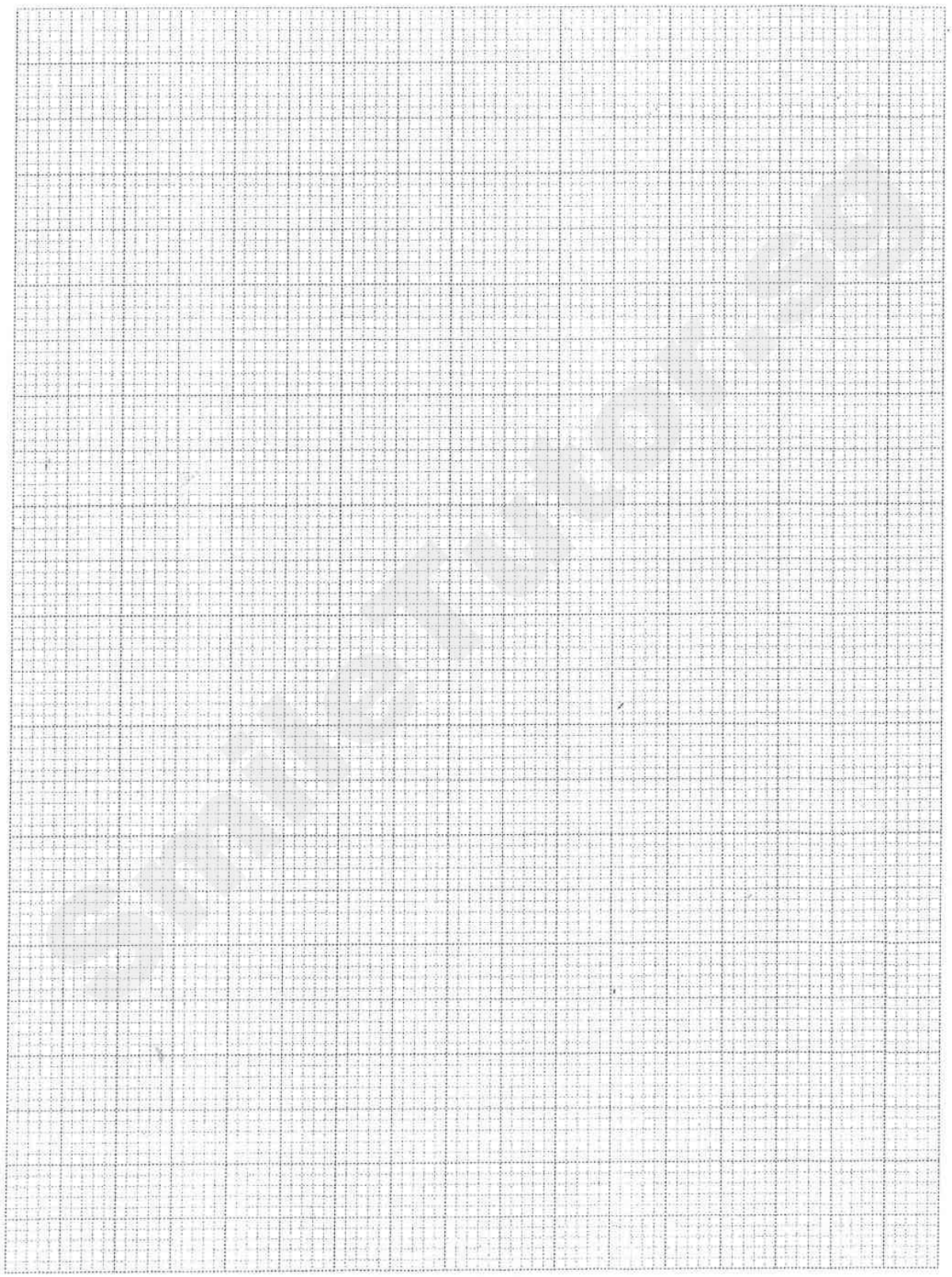

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**(h)** Using the given apparatus, suggest a way to obtain the ratio of cross-sectional areas of the wires without measuring the diameters of the wires.

.....

.....

..... [2]

**(i)** The experiment is repeated and the emf of the battery is doubled.

Sketch on your graph in **(g)**, to show how the new graph would look like. Label the graph Z. [1]

[Total: 15 ]

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**2** In this experiment, you will investigate the motion of a partially-filled bottle.

(a) (i) Place the stand in a tray and suspend the empty bottle from the nail, as shown in Fig. 2.1.

Check that the bottle swings freely.

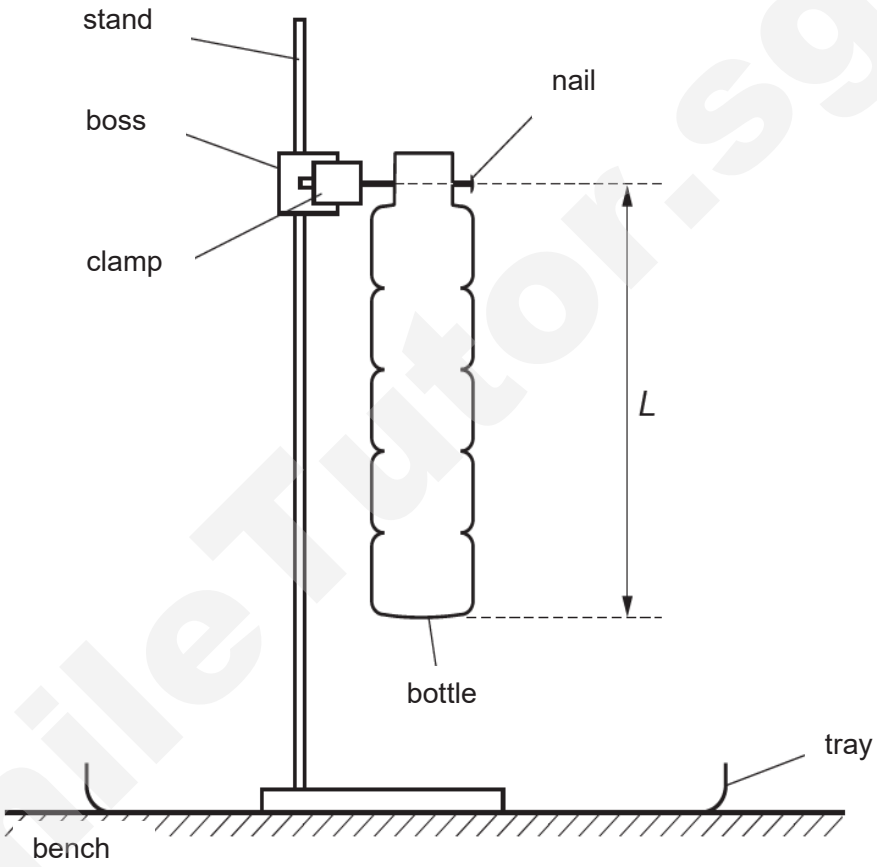


**Fig 2.1**

(ii) Measure and record the distance *L* from the base of the bottle to the nail, as shown in Fig. 2.1.

*L* = .....

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(b) (i) Pour water into the bottle until it is approximately half full, as shown in Fig. 2.2.

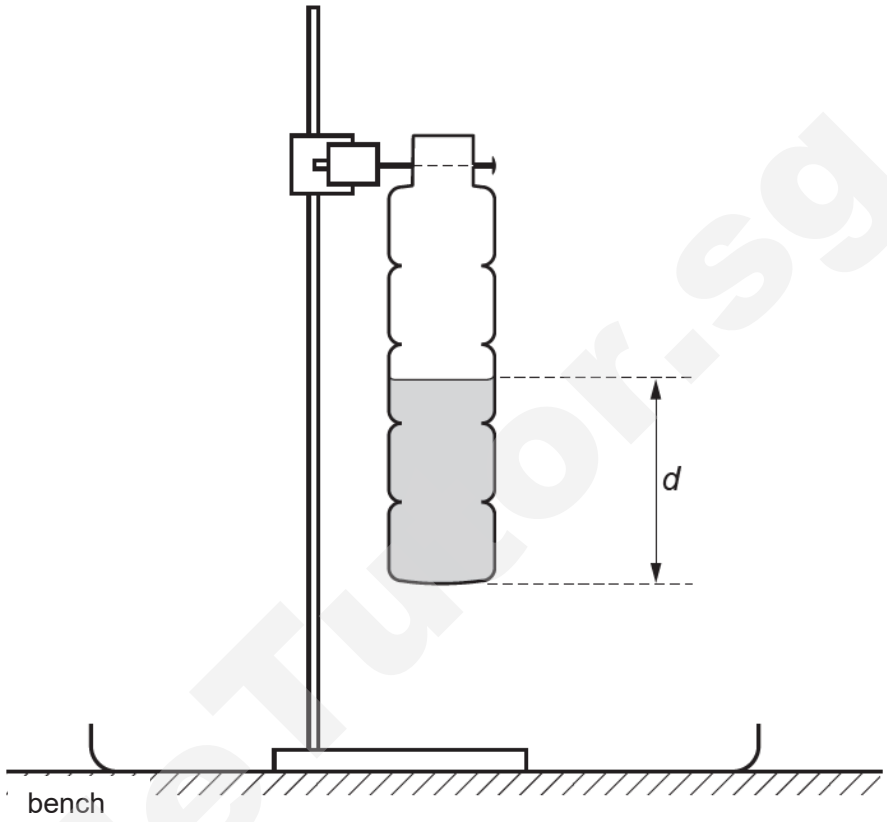


**Fig 2.2**

(ii) With the bottle hanging vertically, measure and record the distance *d* from the base of the bottle to the water surface, as shown in Fig. 2.2.

*d* = ..... [1]

(iii) Calculate the ratio *c* using the relation $c = \frac{d}{L}$.

*c* = .....

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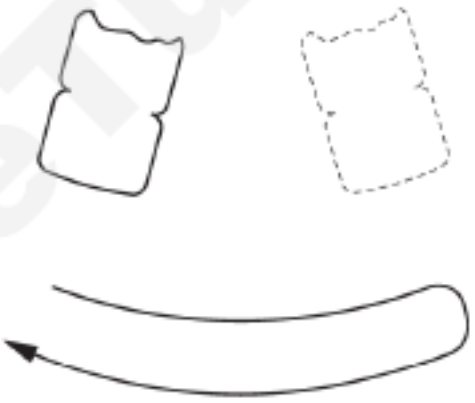
(iv) Hence, calculate the value of $q$ using the relationship $q = \dfrac{\frac{c^2}{3} - c + 1}{1 - \frac{c}{2}}$.

$q$ = ..... [1]

(c) (i) Push the base of the bottle approximately 4 cm to one side and then release it so that it swings, as shown in Fig. 2.3.

Ensure that the stand does not fall over when the bottle is swinging.



one complete swing

**Fig. 2.3**

(ii) Measure and record the total time $t$ for 10 complete oscillations.

$t$ = ..... [1]

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(iii) Estimate the percentage uncertainty in your value of $t$.

percentage uncertainty = ..... [1]

(d) (i) Pour more water into the bottle until it is approximately ¾ full.

(ii) Repeat **b(ii)**, **b(iii)**, **b(iv)**, **c(i)** and **c(ii)**.

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$d$ = .....

$c$ = .....

$q$ = .....

$t$ = ..... [2]

(e) It is suggested that the relationship between $t$ and $q$ is

$$t^2 = kq$$

where k is a constant.

(i) Using your data, calculate two values of $k$.

first value of $k$ = .....

second value of $k$ = ..... [1]

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(ii) Explain whether your results supported the suggested relationship in **(e)**.

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..... [1]

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**3** This investigation considers the angles formed by the threads in a pulley system when it is in equilibrium.

**(a)** In this set-up, there are two threads – a long thread AB and a short thread CD, as shown in Fig.3.1. Two pulleys P and Q are identical.
Tie end A to the 100 g mass. Pass the thread AB through pulleys P and Q and tie end B to the 50 g mass.

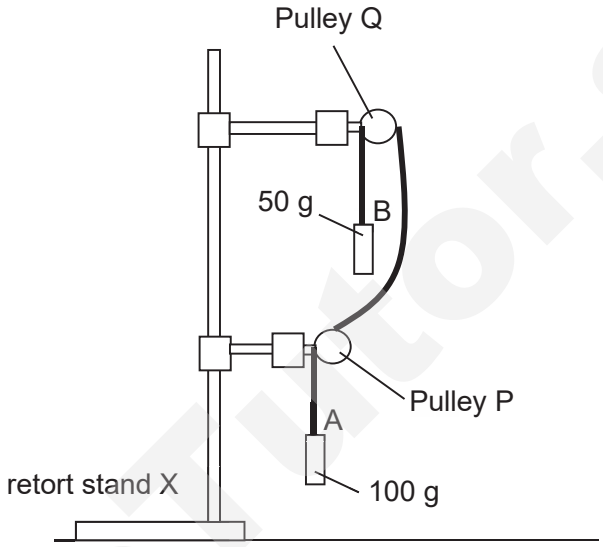


**Fig. 3.1**

**(b)** Tie thread CD as shown in Fig.3.2. **Thread CD must be kept horizontal** throughout the whole experiment.

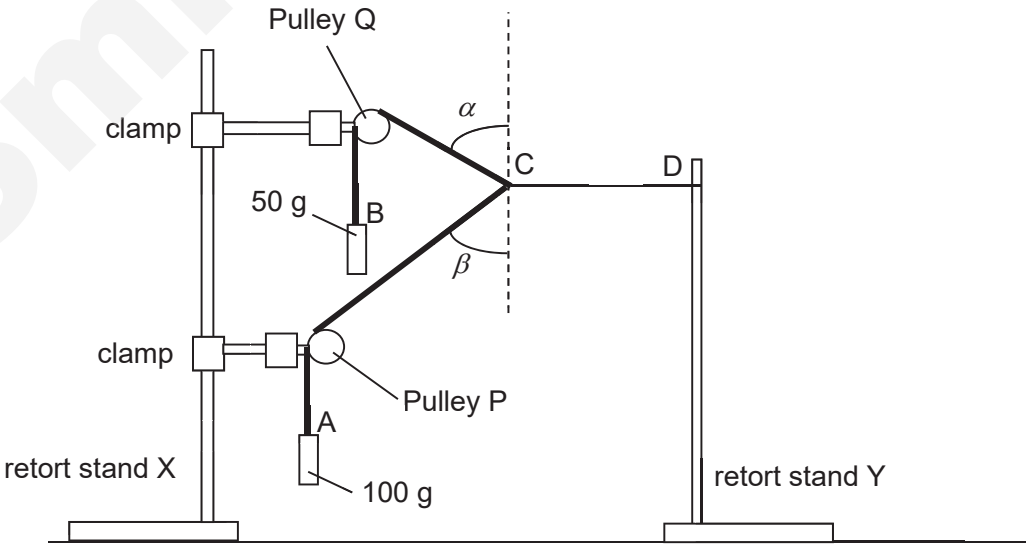


**Fig. 3.2**

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**(c)** Measure the angles $\alpha$ and $\beta$.

$\alpha$ = .....

$\beta$ = ..... [2]

**(d)** Estimate the percentage uncertainty in $\alpha$.

percentage uncertainty in $\alpha$ = ..... [2]

**(e)** State one significant source of error that may have affected the accuracy of the readings of angles $\alpha$ and $\beta$.

.....

..... [1]

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

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..... [1]

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**(g)** It is suggested that cos $\alpha$ is directly proportional to cos $\beta$. Move the retort stand Y to the right and adjust thread CD so that it is horizontal. Obtain one more set of values of $\alpha$ and $\beta$ to investigate this suggestion. State and explain whether you agree with this suggestion.
Present your measurements and calculated results clearly. Plotting of graph is not required.

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**(h)** A student suggests that when there is an increase in the ratio of the mass hung at end A to the mass hung at end B of thread AB, the cos $\alpha$ increases proportionally to cos $\beta$. Suggest how you would verify this.

.....

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.....

..... [3]



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**(i)** It is suggested that if thread BC in Fig.3.2 is kept vertical (i.e. $\alpha = 0^o$) by removing pulley Q and the 50 g mass, and angle β is kept constant, tension $T_3$ in thread CD would vary proportionately with tension $T_1$ in thread CA.

Explain how you would investigate this relationship by rearranging the apparatus provided and using any other apparatus found in the laboratory.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show proportionality

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[Total: 20 marks]

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**4** With increasing levels of noise in the environment, it is recognized that measures need to be taken to reduce noise particularly in homes and working environment. Noise near busy roads or airports is of great concern, and the level of noise insulation provided by windows must be considered.

Double glazed windows consist of two glass sheets separated by a layer of air as shown in Fig. 4.

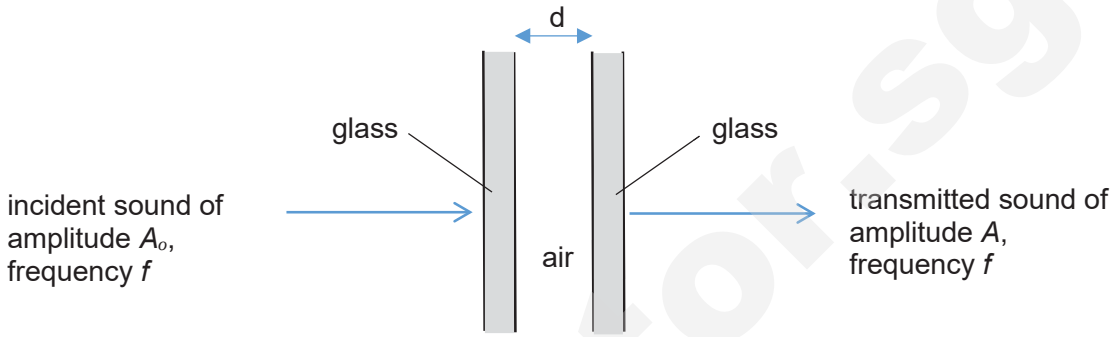


**Fig. 4**

The amplitude of sound transmitted $A$, through an air spacing $d$, between the two panes of glass, for a specific frequency of sound, $f$ within the audible range is given by

$$A = A_o\, d^{\,m}\, f^{\,n}$$

where $A_o$, $m$ and $n$ are constants.

Design an experiment to determine the values of $m$ and n.

You are provided with sheets of glass with fixed thickness.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to

**(a)** the equipment to be used

**(b)** how you would measure the frequency and amplitude of the transmitted sound

**(c)** how you would set and measure the spacing between the two sheets of glass

**(d)** the procedure to be followed

**(e)** the control of variables

**(f)** any precautions that would be taken to improve the accuracy of the experiment

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**Diagram**

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**2019 TJC Prelim H2 Physics Paper 1 Suggested Solutions**

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

**1. A**

**2. A**

Angle of slope A is not 45° so its systematic error varies with true value.

**3 D** A: ball make initial contact with floor
B: ball come to a complete rest
C: ball bounces off from the floor
D: ball reaches is momentarily at rest and at max height after first bounce

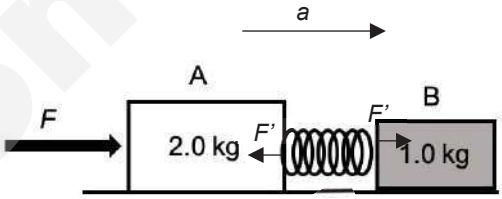
**4 B** $t$ = time taken for 1st chestnut to fall through 10 m
$t_1$ = time taken for 1st chestnut to fall through first 1.5 m
$t_2$ = time taken for 1st chestnut to fall through last 8.5 m
= time taken for 2nd chestnut to fall through 10 m

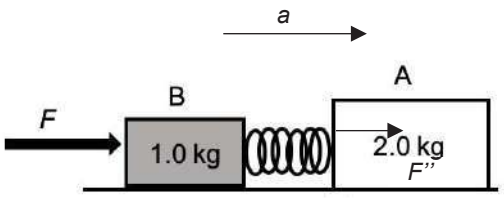
$10 = ½ (9.81) t^2$ → $t = 1.428$ s
$1.5 = ½ (9.81) t_1^2$ → $t_1 = 0.553$ s

$t_2 = t - t_1 = 0.875$ s

Let u be the initial speed of 2nd chestnut.
$10 = u (0.875) + ½ (9.81)(0.875)^2$ → $u = 7.1$ m s$^{-1}$

**5 A**




$F = ma = (2.0 + 1.0) a$

$a = \frac{F}{3}$

$F' = kx_1 = \frac{F}{3} \Rightarrow x_1 = \frac{F}{3k}$

$F'' = \frac{F}{3} \times 2$

$kx_2 = \frac{2F}{3} \Rightarrow x_2 = \frac{2F}{3k} = 2\, x_1$

$\Rightarrow x_1 : x_2 = 1 : 2$

**6 A** $250 - 60 = 100\, a$
$a = 1.9$ m s$^{-2}$
$T \cos 11^\circ = mg$ — (1)
$T \sin 11^\circ = ma$ — (2)

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$\frac{(2)}{(1)}: \tan\theta = \frac{a}{g} = \frac{1.9}{9.81}$

$\Rightarrow \theta = 11°$

**7 D** Let θ be the angle of one of the string with the horizontal. Since the system is in equilibrium, resolving the forces vertically,

$$2T\sin\theta = W$$

$$\Rightarrow \quad \sin\theta = \frac{W}{2T}$$

When θ is very small, sin θ < ½

$$\Rightarrow \quad \frac{W}{2T} < \frac{1}{2}$$

$$\Rightarrow \quad T > W$$

**8 C** $P_D = F_D \times v$

$\Rightarrow F_D = \frac{30\times10^3}{25} = 1200$ N

Since it is moving at constant speed, $F_R = F_D \Rightarrow F_R = 1200$ N

On the slope, $F_D = mg\sin\theta + F_R$ since moving at constant speed

$\Rightarrow F_D = 1400\times9.81\times\sin 2^o + 1200 = 1679$ N

$P_D = F_D \times v = 1679\times25 = 42$ kW

**9 C** By conservation of energy,
total energy at B = total energy at A
$mgr = ½mv_B^2$
$\Rightarrow v_B = \sqrt{2gL}$

At B,
resultant force = $\frac{mv^2}{L}$ = T – mg
$\Rightarrow \frac{m(2gL)}{L}$ = T – mg
2mg = T – mg
T = 3mg

**10 C** At Singapore, R = $R_{Earth}$
$\Rightarrow a_{Singapore} = R_{Earth}\,\omega^2$

At Seoul, R = $R_{Earth}\cos 37.5^\circ$
$\Rightarrow a_{Seoul} = R_{Earth}\cos 37.5^\circ\,\omega^2$

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$$\frac{a_{\text{Singapore}}}{a_{\text{Seoul}}} = \frac{R_{Earth}\omega^2}{R_{Earth}\cos 37.5^\circ\,\omega^2} = \frac{1}{\cos 37.5^\circ} = 1.26$$

**11 B** $g = -\frac{dV}{dr} = -\frac{-322.5-(-369.2)}{240-220} = \frac{46.7}{20} = 2.34\ m\,s^{-2}$

**12 A**

$GMm / r^2 = m\,r\,\omega^2$

$GM / r^3 = \omega^2$

$GM / r^3 = (2\pi / T)^2$

$T^2 = (4\pi^2 / GM)\, r^3$

$T^2 \propto R^3$

$T_X^2 / r_X^3 = T_Y^2 / r_Y^3$

$T^2 / r_X^3 = T_Y^2 / (4\, r_X)^3$

$T_Y = 8\,T$

So planet Y's orbital period is 8 times that of X. Planet Y completes only $\frac{1}{8}$ of an orbit for every 1 orbit of Planet X.

Hence in time T, planet Y only completes 0.125 of a revolution.

**13 B**

Isothermal Process: Since $T_B = T_C$,

use PV= constant

$200 \times V_B = 500 \times 2$, $V_B = 5\ m^3$.

Net work done is area enclosed by ABC in the PV graph.

Net WD = + ve

$\approx (0.5 \times (500\text{-}200) \times 3)$ (approximate)

Net work done on gas is less than +450 kJ

**14 C**

Number of moles of an ideal gas, n = pV/RT

Total number of moles = (2p)(V)/(200R) + (3p)(2V)/(300R) = $p_m(V)/(100R) \Rightarrow p_m = 3.0p$

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**15 C**

$E_T = ½ m\omega^2 x_o^2$

At t = 0 s, $x_o$ = 1.50 cm
$E_T = ½ (0.5)(2\pi/0.5)^2(1.50 \times 10^{-2})^2 = 8.88 \times 10^{-3}$ J

At t = 0 s, $x_o$ = 0.65 cm
$E_T = ½ (0.5)(2\pi/0.5)^2(0.65 \times 10^{-2})^2 = 1.67 \times 10^{-3}$ J

Decrease in energy = $8.88 \times 10^{-3} - 1.67 \times 10^{-3} = 7.2 \times 10^{-3}$ J

**16 A**

Acceleration of SHM given by
$a = -a_0 \sin(\omega t)$

Displacement of SHM given by
$x = x_0 \sin(\omega t)$

Ratio

$$\frac{x_{t=\frac{5T}{8}}}{x_0} = \frac{x_0 \sin(\frac{2\pi}{T} \times \frac{5T}{8})}{x_0}$$

$$= x_0 \sin(\frac{5\pi}{4})$$

$$= -0.71$$

**17 D**

Minimum angle of resolution , $\theta_{\min} = \frac{\lambda}{b}$

Images seen are resolved if the angular separation between the 2 sources are larger than the minimum angle of resolution.

If the aperture size *b* remained unchanged, $\theta_{min}$ will remain unchanged, and so the images will still not be resolved.

Moving the slit further from the 2 sources will decrease the angular separation of the 2 sources, and so the images will still not be resolved.

$\lambda_R > \lambda_G > \lambda_v$ , using violet light will decrease the minimum angle of resolution $\theta_{min}$, and hence allowing the angular separation between the 2 sources to be larger than $\theta_{min}$ for the images to be resolved.

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**18 C** $I = I_0 \cos^2\theta$

$\Rightarrow 2 = 8\cos^2\theta$

$\Rightarrow \theta = 60°$

Using again $I = I_0 \cos^2\theta$

$= 8\cos^2(90+60) = 6$ W

**19 A**

Electric field lines radiate out of positive charges and enters the negative charge.

**20 A**

R of inner core $= \rho l / A$

$= ( 1.7 \times 10^{-8} ) ( 10 ) / [ \pi \times ( 0.0050 / 2 )^2 ]$

$= 0.00866\ \Omega$

R of outer layer $= \rho l / A$

$= ( 2.7 \times 10^{-8} ) ( 10 ) / [ \pi \times ( 0.010 / 2 )^2 - \pi \times ( 0.0050 / 2 )^2 ]$

$= 0.00459\ \Omega$

Since the inner core and the outer layer are in parallel,

$1 / R_{total} = 1 / 0.00866 + 1 / 0.00459$

$R_{total} = 0.0030\ \Omega$

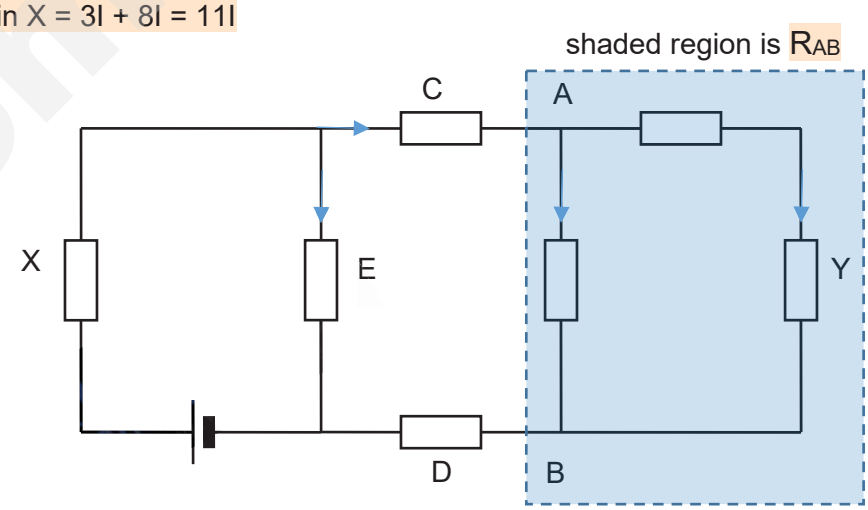
**21. B**

if current in Y is I, then current in F is 2I, so current in C is 3I

$R_{AB} = 2/(1+2) = 2/3$ R, so $R_{C+AB+D} = 1 + 2/3 + 1 = 8/3$ R

since current in $R_{C+AB+D}$ is 3I, then current in E is 8I

so current in X = 3I + 8I = 11I




**22 C** To turn on both diodes $D_1$ and $D_2$ so that they are forward-biased, $V_0$ must be more than (0.3 + 0.7) V = 1.0 V.

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**23 C** Use Fleming Left Hand Rule.

**24 A** The component of velocity perpendicular to the B field causes the electron to move in a circle. Using FLHR, electron turns into the page

The component of velocity parallel to the B field causes the electron to travel upwards.

Hence, a helical path upwards.

Magnetic force provides centripetal force for electron.

$$Bev = \frac{mv^2}{r}$$
$$r = \frac{mv}{Be} = \frac{\sqrt{2mK}}{be}$$
$$r \propto \sqrt{K}$$

**25 B** F = BIL

Gradient of force-current graph = BL = $\frac{10\times10^{-3}}{5} = 2.0 \times 10^{-3}$

$\varepsilon$ = BLv = BL($\omega x_0$) = $2.0 \times 10^{-3}(630)(1.5 \times 10^{-3})$) = $1.86 \times 10^{-3}$ V

**26 D** P = $\frac{V^2}{R} = \frac{1}{R}(\frac{d\Phi}{dt})^2 = \frac{1}{R}(\frac{d}{dt}BA)^2 = \frac{A^2}{R}(\frac{d}{dt}B)^2$ where $\frac{dB}{dt}$ = gradient of *B-t* graph

**27 B**
$$L = \frac{N}{t}\frac{hf}{A}$$

If the frequency is increased to 2*f*, the no. of photons incident per unit time ( *N/t* ) will be halved for the same intensity $L$ and hence the number of photoelectrons emitted per second will decrease. Hence, the maximum photocurrent will be less than $I$.

Using the Einstein photoelectric equation, $hf = eV_s + \phi$ , if the frequency is increased to 2*f*, the photoelectric equation will be $h2f = eV_s^{'} + \phi$ , hence $eV_s^{'} + \phi = 2eV_s + 2\phi$

$$\Rightarrow \quad V_s^{'} = 2V_s + \frac{\phi}{e}$$

**28 B** Frequency of uv > frequency of yellow > frequency of red.

Using $\Delta E = hf$ , uv will have the largest $\Delta$E, followed by yellow and finally red.

**29 A**

Let R be the nucleus formed after the first stage decay.

Option A:

$$^{A}_{\square}\mathrm{P} \rightarrow {}^{A}_{\square+1}\mathrm{R} + {}^{0}_{-1}e$$

$$^{A}_{\square+1}\mathrm{R} \rightarrow {}^{A}_{\square+1}\mathrm{Q} + \gamma$$

Number of neutrons in nucleus Q $= A - (\square + 1) = A - \square - 1$

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**30** **B**

Spontaneous processes tend towards stability or higher binding energy per nucleon

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**2019 Prelim H2 P2 Solutions**

**1.**

**(a)** ***(i)*** $\eta = F / 6\pi rv$

Units of $\eta$ = kg m $s^{-2}$ / m (m $s^{-1}$) = kg $m^{-1}$ $s^{-1}$ [M1], require "unit of" or equivalent

**(ii) 1.**

$F = 6\pi\eta rv$ = 6 (3.142) (0.13) (0.01) (2.7) = 0.06617 N A1

$$\frac{\Delta F}{F} = \frac{\Delta \eta}{\eta} + \frac{\Delta r}{r} + \frac{\Delta v}{v}$$

$$\frac{\Delta F}{0.06617052} = \frac{0.02}{0.13} + \frac{0.1}{2.0} + 0.05$$

00070777

$$\frac{\Delta F}{0.06617052} = 0.154 + 0.050 + 0.050 = 0.254$$

$$\Delta F = 0.02N \ (1 \ sf)$$

M1

A1

F = (0.07 ± 0.02) N

**2.** Measurement of <u>viscosity</u>, $\eta$, should be improved as it has the <u>highest fractional uncertainty</u> A1

**2** **(a)** From Newton's third law, if body A exerts a force on body B, then body B will exert a force of the same type that is <u>equal in magnitude and opposite in direction</u> on body A. M1

Hence, $(ma)_A = -(ma)_B$ , where m represents mass and a represents acceleration

By Newton's second law, $\underline{m_A(v_A-u_A)/t} = -\underline{m_B(v_B-u_B)/t}$

For the <u>same duration of interaction</u>, the <u>gain in momentum by body A is equal to the lost in momentum by body B</u>. M1

This shows principle of conservation of momentum.

<u>Comments</u>:

Stating the definitions of either Newton's second law, third law and Conservation of momentum (COM) without showing how they are inter-related which leads to the deduction of COM will not earn any credit.

Newton's third law is **NOT** stated as "for every action there is an equal and opposite reaction"!

**(b)** **(i)** $mv_0 + 0 = m(0.5\ v_0)$ + momentum of nucleus at $t_1$ B1

momentum of nucleus at $t_1$ = 0.5 $mv_0$

**(ii)** By conservation of momentum, total momentum of the system is conserved since no external force acts on the system. B1

$\therefore$ total initial momentum of the system = total momentum of the system at $t_1$. A1

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Comments:
Students must realise that in order for COM to be applied, the premise is there is no resultant external force acting on the system and this has to be stated clearly for marks to be awarded.

**(iii)** By conservation of momentum,
total initial momentum of system = total momentum of system at $t_2$ B1
$mv_0 = mv + Mv$
$v = \frac{m}{m+M} v_0$ A1

Comments:
Most students are able to get this part correct.

**(c)** Method 1:
By COM,
$4u(0.02c) + 0 = 4uv_a + 14u(0.005c)$ A1
final speed of alpha, $v_a = 0.0025\ c$
Relative velocity of approach = $u_a - u_n = 0.02\ c$ A1
Relative velocity of separation = $v_n - v_a = 0.005\ c - (0.0025\ c) = 0.0025\ c$ A1
Since relative speed of approach is not equal to relative speed of separation, the interaction is not elastic.
OR
Method 2:
By COM,
$4u(0.02c) + 0 = 4uv_a + 14u(0.005c)$
final speed of alpha, $v_a = 0.0025\ c$
Initial ke of alpha particle = $\frac{1}{2}(4u)(0.02c)^2 = 0.0008\ uc^2$
Final ke of nitrogen and alpha particle = $\frac{1}{2}(4u)(0.0025c)^2 + \frac{1}{2}(14u)(0.005c)^2$
$= 0.00019\ uc^2$
Since initial ke ≠ final ke, collision is not elastic

Comments:
There are many errors for this part:

1. Students are expected to deduce the mass of alpha particle and nitrogen from the number of nucleons by using the unified atomic mass.

2. Some students calculated the ke of alpha and nitrogen by substituting values. However, please note 1 u = $1.66 \times 10^{-27}$ kg **NOT** $1.67 \times 10^{-27}$ kg (which is the mass of proton). Marks will be deducted for substituting wrong values.

3. Some students showed that initial momentum of system not equal to final momentum of system, which is wrong concept.

4. When showing initial ke not equal to final ke, many students did not consider the final ke of alpha particle. Hence even if the conclusion is correct, no marks will be awarded as working is not conclusive.

5. Some students found the final velocity of alpha particle using relative velocity of approach = relative velocity of separation, and subsequently substituted the velocity found to find final ke and went on to conclude the collision is inelastic. This is not correct as when one uses relative velocity of approach = relative velocity of separation, one has assumed elastic head-on collision.

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**3** (a) Total distance = area under the graph
= 39 m ( allow ± 2.0 m ) A1

Comments:
This part is generally well done by most of the students.

(b) (i) Change in kinetic energy, $\Delta E_k = \frac{1}{2}m\left(v_f^2 - v_i^2\right) = \frac{1}{2}\times 92\times\left(3^2 - 6^2\right) = -1240$ J A1

Comments:
Quite a lot of students have a misconception that change in ke = ½ m $(\Delta v)^2$, which is very alarming. Besides, also quite a number of students also gives the change in ke as initial ke – final ke which by right should be the reverse.

(ii) Change in gravitational pe, $\Delta E_p = mgh = 92\times 9.81\times 1.3 = 1170$ J A1

Comments:
This part is generally well done by most of the students.

(iii) Useful work done = $P\times t = 75\times 8.0 = 600$ J A1

Comments:
This part is generally well done by most of the students.

(c) (i) Useful work done
= change in ke + change in Gpe + work done overcoming frictional force
$\Rightarrow$ 600 = -1240 + 1170 + work done overcoming frictional force M1
$\Rightarrow$ work done overcoming frictional force = 600 +1240 – 1170 = 670 J A1

Comments:
This part is generally badly done by most of the students. Only the more able students were able to obtain the correct answer based on the correct equation.

(ii) average force = $\frac{670}{39} = 17$ N A1

Comments:
Some of the student use the height of the slope instead of the total distance to calculate the average force.

(d) Total resistive force include both ground friction and air resistance. B1
Air resistance will decrease as the speed decreases, and hence total resistive force would not be constant. B1

Comments:
A lot of the students were not able to state that the total resistive force is a combination of the ground friction and the air resistance. Quite a lot of them still do not have the idea of the dependence of air resistance on the speed of the object which is quite alarming.

**4** **(a)** For a body moving in uniform circular motion, there is a change in velocity as the direction of motion is changing. B1

B1

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The rate of change of velocity gives rise to an acceleration. Since the change in velocity is directed towards the centre of the circular motion, the acceleration is also towards the centre.

Comments:

This part is generally quite badly done by most students. Though they are able to explain why there is an acceleration, they were not able to explain why the acceleration is towards the centre.

**(b) (i)**

$$a = r\omega^2 = (5.0\cos 60^\circ)\left(\frac{2\pi}{3.5}\right)^2$$
$$= 8.06\ m\ s^{-2}$$

M1
A0

Comments:

This part is generally very well done by most students.

**(ii)** $T\cos 60^\circ = ma$

$$T = \frac{0.40\times 8.06}{\cos 60^\circ} = \frac{0.40\times 8.06}{0.5} = 6.45\ \text{N}$$

B1
A1

Comments:

Some of the students resolve the tension T wrongly, hence failing to obtain the marks.

**(iii)** $L = mg + T\sin 60^\circ$

$= (0.40 \times 9.81) + 6.45\sin 60^\circ$

$= 9.51\ \text{N}$

B1
A1

Comments:

Quite a number of students balance the vertical forces wrongly.

**(iv)** The tension in the wire is unchanged, since centripetal force is unchanged. M1

The vertical component of tension together with the new lift force now balance the weight of the toy plane hence new lift force will be lesser than before. A1

Comments:

Many students did not mention the anchor point that tension remains unchanged. Note: Students are not required to know the origin of lift force or how it is related to velocity of air (i.e. Bernoulli effect).

**5(a)** Gravitational force is attractive in nature. Hence, the work done per unit mass, by an external force acting against the gravitational force is negative as the displacement and the external force are opposite in direction.

Or

Since gravitational potential at infinity is defined to be zero, and yet it increases with distance from the mass, its value has to be negative.

[A1] for any acceptable explanation

Comments:

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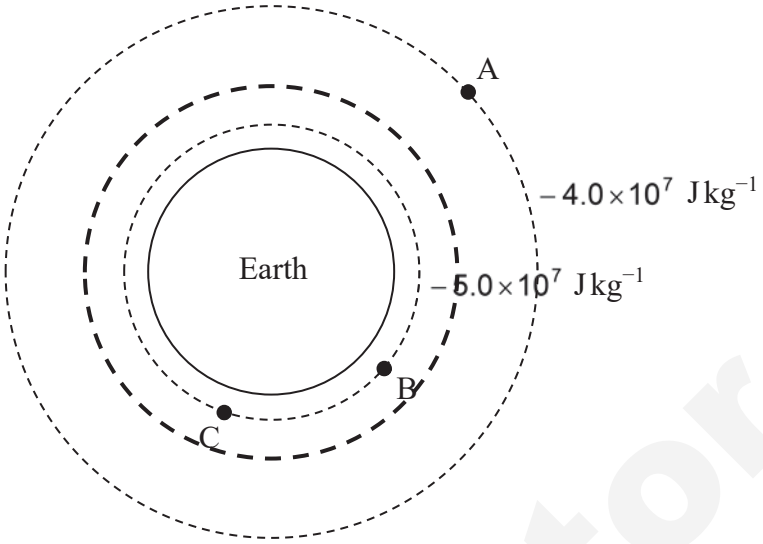
Work done by external force is poorly understood. Some students confuse unit mass with point mass.

**5(b)(i)**




[A1] for line drawn nearer to the $-5.0\times10^{7}$ J kg$^{-1}$ equipotential line

Comments:
Large number of students did not ensure the line drawn is nearer to the -5.0 equipotential line.

**5(b)(ii)** Work done by gravitational field

$= m(\phi_A - \phi_B)$

$= 3000\times(-4.0+5.0)\times10^{7}$

$= 3.0\times10^{10}$ J

[M1] for correct substitution

[A1] for correct answer

Comments:
Many did not realise the question asked for work done by gravitational force, which is negative of the conventional GPE.

**5(b)(iii)** Since the force and displacement vectors are always perpendicular to each other, the work done is therefore zero.

[A1] for correct explanation [zero mark if mention B and C are at same potential]

Comments:
Expectedly, students tend to discuss equipotential values rather than use first principle like definition of work done.

**5 (c) (i)** The gravitational field strength g is not constant [B1]. The student's value would be greater than the actual value [B1] (because the average magnitude of g is less than 9.81 m s$^{-2}$

Comments:
Stating that h is not small alone is not good enough

**(ii)** KE = ½ mv$^2$ where v = 2πr/T [M1]

v = 2 x π x (6800 + 6400) x $10^3$/8.5 x $10^3$ = 9.76 x $10^3$ m s$^{-1}$

KE = ½ x 1500 x (9.76 x $10^3$)$^2$ = 7.1 x $10^{10}$ J [A1]

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(0 marks for method if use $\left(\frac{GMm}{2r}\right)$ as mass of Earth not given)

**(iii)** A geostationary satellite stays above the same point with respect to the earth and as such can be used for radio communications. [B1]
The satellite is not in geostationary orbit because its period is less than 1 day or 8.6 x $10^4$ s. [B1]

Comments:
Many students merely stated what geostationary meant without discussing the advantage. Some students mentioned an advantage eg clearer images without explaining how it is linked to geostationary orbits.
Merely saying the period is different without evidence eg calculation or at least stating which value is larger is insufficient as it constitutes to guesswork.

**6(a) (i)** When the slide contact S is moved all the way up to the top of the 20 kΩ resistance, $V_{xs}$ = 0 V.

When the slide contact S is moved all the way down, $V_{xs}$ can be found using the potential divider principle:

$$V_{xs} = \left(\frac{20}{20+4}\right)12 = 10\text{V}$$ M1

Hence, the voltage range of $V_{XS}$ is 0 V to 10 V. A1

Comments
The key concept is potential divider in accordance to ratio of the resistances. Some candidates could not identify 0V value when there is 0 Ω resistance.

**(ii)** When the slide contact S is moved all the way up to the top of the 20 kΩ resistance,

$V_{sz}$ = 12 – 0 = 12 V

When the slide contact S is moved all the way down,

$V_{sz}$ = 12 – 10 = 2V

Hence the voltage range of $V_{SZ}$ is 2 V to 12 V. A1

Comments
Alternative method. By looking at the answer in part (i). When $V_{XS}$ is 0 V, $V_{SZ}$ is 12 V. When $V_{XS}$ is 10 V, $V_{SZ}$ is 2 V.

**(iii)** When the slide contact is placed at midpoint of the 20 kΩ track, R = 10 kΩ

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$$\frac{1}{R_{S\square}} = \frac{1}{10} + \frac{1}{10}$$ [1]

$$R_{S\square} = 5\ \text{k}\Omega$$

Using potential divider principle,

[1]

$$V_{S\square} = \frac{5}{10+5+4}(12) \approx 3.2\ \text{V}$$

The voltmeter reading = $V_{SY}$
≈ 3.2 V

Comments
Alternative method. By looking at the answer in part (i). When $V_{XS}$ is 0 V, $V_{SZ}$ is 12 V. When $V_{XS}$ is 10 V, $V_{SZ}$ is 2 V.

**(b) (i)** Since the voltmeter reading is 3.0 V when the switch is opened, the e.m.f. of the battery is 3.0 V.

When switch is closed,
p.d. across siren and warning lights = 1.7 V
Total current through siren & warning lights = 1.7 / 1.5 + 1.7 / 2.4 + 1.7/ 2.4
= 2.55 A [C1]

p.d. across internal resistance = 3.0 - 1.7 = 1.3 V
internal resistance = 1.3 / 2.55 [M1]
= 0.51 Ω [A1]

Comments
A common misconception is to consider the internal resistance as parallel to the siren and warning lights. Students should note that the siren and the warning lights are in parallel. The internal resistance is in series with the combined arrangement of siren and warning lights.

**(ii)** 1. The p.d. across the siren (or current through siren) decreases and hence less loud [B1].
2. The p.d across the warning lights (or current through lights) decreases and hence dimmer lights. [B1]

Comment
This part was well-attempted.

**7 (a)** Current *I* pointing downwards. A1

Comments:
Most students obtained the correct answer.

**(b)** The direction of the magnetic field in the tube should be in the negative z direction. A1

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Comments:
Students are required to use Fleming's Left-Hand rule for this part.

**(c)** $F = BIL$

$$B = \frac{F}{IL} = \frac{1.6 \times 10^4}{10.0 \times 0.300}$$ B1

$= 5.33 \times 10^3$ T A1

Comments:
Some students mistook the length as 0.100 m. Others used a product of lengths for area calculations, which is errorneous.

**(d)** - A current of 10A is very large, thus a large power supply is required. Power loss due to this current will also be very high. A1

- The large magnetic field required may interfere with the electronic equipment on the ship. A1

Comments:
This part was poorly attempted.

**8 (a)** Solar power collected = intensity x surface area

= (0.90x x$10^3$) x 7.7 = 6930 W M1

Time taken to travel 200 km journey = distance /speed = 200 km / 67 km $h^{-1}$

= (200/67) h = (200/67)x3600 s

= 1.07x$10^4$ s M1

Total energy collected = power x time = 6930 x (200/67)x3600 = 7.45x$10^7$ J A1

Comments:

Power of ten error in some answers. E.g. Solar power collected = (0.90) x 7.7 = 6.93 W

**(b)** electrical energy transformed = 26% of solar input energy

= (26/100) x 7.45x$10^7$

= 1.94x$10^7$ J M1

= 5.39 kWh A1

Comments:

Some students thought kWh is a unit for power.

Many were unable to convert J to kWh correctly. Equating kWh to kJ is one of the common errors.

**(c)** At average power,

Efficiency = (motor power output / electrical power input) x 100% = 92% C1

Electrical input power by battery = 1.1 / 0.92 M1

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= 1.2 kW A0

**(d)** **(i)** N x area of each cell = total area of the cells

$\Rightarrow$ $N = 7.7 / 6.4 \times 10^{-3} = 1.2 \times 10^{3}$ B1

**(ii)** N x energy collected by each cell = total solar energy collected by all cells

Energy collected by each cell = $7.45 \times 10^{7} / 1.2 \times 10^{3}$ C1

$= 6.2 \times 10^{4}$ J B1

**(e)** Given: $R \propto v^2 \Rightarrow R = kv^2$ where k = constant

At constant speed, net force = 0

$\Rightarrow$ Driving force of motor F = total resistive force R C1

Using $P = Fv = Rv = kv^2 v$

$P = kv^3$ i.e. $\langle P \rangle = k \langle v \rangle^3$ and $P_{peak} = k\ v_{peak}^3$ M1

$\Rightarrow$ $1100 / 4500 = 67^3 / v_{peak}^3$

$\Rightarrow$ $v_{peak} = 107$ km $h^{-1}$ A1

Comments:

Some students realised that at constant velocity, forward force and total resistive force are equal in magnitude. However, many did not go on to work out the correct relationship between power and velocity. A significant number of students wrongly equate $P = v^3$.

**(f)** Using P = IV,

$I = P/V = 1200 / 50 = 24$ A B1

**(g)** Using Q = It,

$t = 60A\ h / 24\ A$ M1

$= 2.5$ h A1

Comments:

Some students have difficulty with interpretation of charge capacity in Ah and calculated 1/t instead, using 24/60.

**(h)** Any two factors:

1. weather conditions of the day – amount of cloud cover

2. Dirt on panel or shade by trees.

3. Angle of incidence of the solar beam on the solar cells B2

Comments:

Answer should focus on specific factors affecting intensity of solar energy received by the solar cells.

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**(i)** 1. Wide to maximize surface area exposed to sunlight.

2. Flat to minimize energy losses due to air resistance. B2

Comments:

Most students know maximizing sunlight exposure is key but attributed it to flatness rather than wide area.

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## Suggested solutions

**1 a) (i)** Explain why the temperature rise is different in the two experiments.
For experiment 1, no work is done by gas, hence all the thermal energy supplied is used to increase the internal energy while for experiment 2, some of the thermal energy supplied is used by the gas to do work in expanding, resulting in less increase in internal energy [B1] [2]

Hence experiment 2 has a smaller increase in internal energy than experiment 1, resulting in smaller temperature rise [B1]

(Alternatively, use first law of thermodynamics to explain)
(Important: Comparisons between both experiments are required)

**(ii)**

| | thermal energy supplied to gas/J | work done on gas /J | increase in internal energy of gas/J |
|---|---|---|---|
| Experiment 1 | +150 | 0 [1 mark] | +150 [1 mark] |
| Experiment 2 | +150 | -57 [1 mark] | + 93 [1 mark] |

- 1 mark for calculating increase in internal energy for experiment 2, with working
$\Delta U_2 = \Delta U_1 (\Delta T_2 / \Delta T_1) = 150 (18 / 29) = 93$ J

- 1 mark for calculating work done on gas in experiment 2, with working
$W = \Delta U - Q = 93 - 150 = -57$ J

**(b) (i)** $KE = \frac{3}{2} kT$ **[M1]**

$= \frac{3}{2}(1.38 \times 10^{-23})(100 + 273)$

$= 7.72 \times 10^{-21}$ J **[A1]**

**(b) (ii)** $m_{Ar}\langle c^2\rangle_{Ar} = 7.72 \times 10^{-21}$

$0.5(1.8)(3.35 \times 10^{-26})\langle c^2\rangle_{Ar} = 7.72 \times 10^{-21}$ **[M1]**

$V_{rms,Ar} = 506$ m s$^{-1}$ **[A1]**

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**2(a)** By Newton's 2nd law,

$T - mg\sin\theta = ma$ M1

At equilibrium,

$T_1 = ke = mg\sin\theta$ M1

$T - T_1 = ma$

$k(x+e) - ke = ma$ A1

Since x is measured downwards from equilibrium,

$$a = -\frac{kx}{m}$$

**(b)** Acceleration is directly proportional to displacement from equilibrium and the acceleration is in the opposition direction to displacement (or directed towards equilibrium). B1 B1

**(c)**

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

$v_o = \omega x_o$

$$\frac{v}{v_o} = \frac{\sqrt{x_o^2 - x^2}}{x_o}$$ M1

$$0.25 = \frac{\sqrt{3^2 - x^2}}{3}$$ A1

$x = 2.9$ cm

**(d)(i)** Resonance is illustrated. The driving frequency of the oscillator is equal to the natural frequency of the mass-spring system, maximum energy is transferred to the system and the mass-spring system oscillates with maximum amplitude. B1 B1

**(d)(ii)** $|a| = \omega^2 x_o = (2\pi f)^2 \; x_o = [2\pi(1.2)]^2 \; (0.06) = 3.4 \text{ ms}^{-2}$ A1

Comments
Most students obtained the correct answers for (d)(i)(ii).

**3(a)(i)** In Fig. 3.1, the electron moves in a projectile motion and trace a parabolic path towards the higher potential plate. B1

There is a resultant force in the vertical direction. There is an acceleration in the vertical direction and a constant velocity in the horizontal direction. B1

Comments
Some students stated that the electron curves or is deflected. This answer is not sufficient. Students need to state parabolic path upwards due to constant acceleration in vertical direction and constant velocity in horizontal direction. The criteria for projectile motion was missing in most scripts.

**(a)(ii)**

$$a = \frac{F}{m} = \frac{qE}{m} = \frac{q\left(\frac{V}{d}\right)}{m}$$

$$= \frac{(1.6\times10^{-19})\left(\frac{50}{5\times10^{-3}}\right)}{9.11\times10^{-31}}$$ M1

$$= 1.8\times10^{15} \text{ ms}^{-1}$$ A1

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**(a)(iii)** Time taken for electron to move between the plates =

$$\frac{s_x}{u_x} = \frac{9\times10^{-3}}{1.5\times10^{7}} = 6.0\times10^{-10}\ s$$ M1

Vertical speed of electron when it emerges from plates,

$v_y = u_y + at$

$v_y = 0 + (1.8\times10^{15})(6\times10^{-10}) = 1.08\times10^{6}\ \text{ms}^{-1}$

M1

$$\tan\theta = \frac{v_y}{v_x} = \frac{1.08\times10^{6}}{1.5\times10^{7}}$$

$\theta = 4.1°$

Comments

(a)(ii) was well-attempted. In a(iii), some students erroneously used the ratio of the displacements to obtain the angle of deflection, which is incorrect. Students should use the ratio of velocities. A1

**(b)(i)** In Fig. 3.2, the electron moves in an oscillatory motion about the line that joins the centre of masses of the positive charges. It moves to and fro along the horizontal line and is always equidistant between the two positive charges.

The resultant force is horizontal and always points towards the centre of masses of the two positive charges. Hence, the acceleration is in the horizontal direction and points towards the centre of masses of the two positive charges.

Comments

This part was poorly attempted. Students were not able to identify an oscillatory motion.

**(b)(ii)**

$$F = \frac{Qq}{4\pi\varepsilon_o r^2} = \frac{\left(1.6\times10^{-19}\right)^2}{4\pi\varepsilon_o\left(\sqrt{(5\times10^{-3})^2 + (2\times10^{-3})^2}\right)^2} = 7.9376\times10^{-24}\ \text{N}$$ M1

Resultant force = $2F\cos\theta$

$$= 2(\ 7.9376\times10^{-24})\ \frac{5\times10^{-3}}{\sqrt{(5\times10^{-3})^2 + (2\times10^{-3})^2}}$$ M1

$$= 1.5\times\ 10^{-23}\ \text{N}$$ A1

Comments

Most students showed understanding that the resultant force is in the horizontal direction.

**4** **(a)** Alternating voltage can be stepped up or down whereas direct voltage cannot be stepped up or down easily. Transmission of power at high voltages minimizes power loss. B2

**(b)** Root-mean-square value of an alternating current is defined as the value of the steady direct current which would dissipate heat at the same rate in a given resistance as the alternating current. B2

Comments:

'Square root of the mean of the square of the instantaneous a.c. current' is not acceptable as explanation for r.m.s. value.

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**(c)** Step-up transformer with turns ratio $\frac{N_s}{N_p} = \frac{240}{120} = 2.0$ B1

Comments:
The transformer is required for stepping up the 120 V provided in USA to the 240 V required by the hair dryer (connected to the secondary coils).

**(d)** Assuming no power losses in the transformer, B1
$120I_p = 1000$ M1
$I_p = 8.33$ A r.m.s.
Peak current = $8.33\sqrt{2} = 11.8$ A A1

Comments:
Do not accept: resistance remains constant, ideal transformer, a.c. vary sinusoidally

**5 (a)** Faraday's law of electromagnetic induction states that the magnitude of the induced emf is directly **proportional** to the rate of change of magnetic flux **linkage** or the rate of cutting of magnetic flux. A1

Comments:
Definitions must be phrased as the way it is. More importantly, e.m.f stands for electromotive force NOT electromagnetic force!!

**(b)** When the card is brought in range of/ near to a card reader, the **varying magnetic field** generated by the card reader results in a **changing magnetic flux linkage** through the loops/coils of printed wire embedded in the card. A1

**By Faraday's law**, there is an **emf induced in the loops**. (The emf is produced in a direction such that is opposes the varying magnetic field.) A1

The **closed circuit** allows the emf to drive a current and thus supplies power to the internal transmitter (which can then send its data to the card reader). A1

Comments:
Students should answer such that the "cause and effect" are clear from the marker's point of view.
Firstly, it is the changing magnetic flux linkage through the 3 loops that causes an emf to be induced.
Secondly, when implying there is induced emf, Faraday's law must be stated since the question said "using Faraday's law".
Thirdly, students have to explain why the transmitter receives electrical power by saying there is an induced current flowing since circuit is closed.

**(c) (i)**
$$\varepsilon = -\frac{d\Phi}{dt} = -\frac{d(NBA\sin 2\pi ft)}{dt}$$
$$= -2\pi fNBA\cos 2\pi ft$$ M1
Magnitude of peak emf = $\varepsilon_0$ when $\cos 2\pi ft = 1$ M1
$\varepsilon_0 = 2\pi fNAB_0$
$= 2\pi(13.6 \times 10^6)(3)(4.0 \times 10^{-3})B_0$ M1
$= 1.02 \times 10^6\, B_0$ A0

**(ii)** $V_{rms} = \frac{V_0}{\sqrt{2}}$ B1

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$10.0 \times 10^{-3} = 1.02 \times 10^{6} \frac{B_0}{\sqrt{2}}$ A1

$B_0 = 1.38 \times 10^{-8}$ T

Comments:
The question asks "to show clearly" hence working must be detailed with good physics shown.

**(d)** The card is designed to operate if a current flows through it, regardless of direction. Since when tapped with either face, the changing magnetic flux linkage through the loops of wire will be able to induce an emf and allow current to flow to power the transmitter. A1

Comments:
A lot of answers are unclear as they stopped short of explaining induced current will flow regardless which face of the card is tapped.

6 (a) (i) the spreading of the waves when it passes through a gap or around an obstacle.
B1

Comments:

This part is generally not well done by most students. Most of them did not use the key word " spreading " when describing the phenomenon, and even if they do, they did not state that the phenomena occurs when passing through a gap or an obstacle.

(ii) wavelength of the electron must be comparable/of the same order of magnitude as the atomic spacing of the graphite. B1

Comments:
This part is badly done by most students. Most of them were not able to state the condition for diffraction to occur which is rather alarming.

(b) (i) Wavelength associated with a particle that is moving. B1

Comments:
This part is also not well done. Most of the students just either quote the equation for de_broglie wavelength without explaining what it is, or give the wrong definition.

(ii) work done by p.d = increase in ke of electron B1

$qV = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ since $p = mv$ B1

Hence, $p = \sqrt{2mqV}$

$p = \sqrt{2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120}$ = 5.91 x $10^{-24}$ kg m $s^{-1}$ C1

$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{5.91 \times 10^{-24}} = 1.12 \times 10^{-10}$ m A1

Comments:
Most students were able to obtain the correct answer. Those weaker students use the speed of light as the speed of the particle which is a misconception.

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(iii) When the p.d $V$ is increased slightly, the momentum of the electron would increase. Hence, the de Broglie wavelength of the electron would decrease.
B1
Using $d \sin\theta = n\lambda$ , the angular separation between successive fringes would decrease,
C1
and therefore diameter of the concentric circles decreases. A1

Comments:
This part is generally not very well done. Some of the weaker students use the young double slit formula in explaining which is not correct, instead the correct formula is the diffraction grating formula.

7 (a) When 2 or more waves of the same kind meet at a point, they superpose to produce a resultant wave whereby there is a change in the total displacement. B1

Comments:
This part is also badly done by most student. Most of them did not use the key phrases such as " of the same kind" or "superpose" in defining the term.

(b) $\lambda = \frac{c}{f} = \frac{3.00\times10^{8}}{1.0\times10^{10}} = 0.030\,\text{m}$ M1

Aerial length = $\frac{\lambda}{2} = \frac{0.030}{2} = 0.015$ m A1

Comments:
This part is generally well done by most students. Only a few of them have problems with the conversion of units from GHz to Hz.

(c) (i) 1. The path difference between the signal changes along OP. B1

When the path difference is equal = nλ, where n is an integer, .
( OR when signals meet in phase at points along OP)

constructive interference takes place, and the resultant amplitude is the sum of the individual amplitudes. B1

When the path difference is equal = (n-1/2)λ, where n is an integer, .( OR when signals meet in anti-phase at points along OP)

destructive interference takes place, and the resultant amplitude is the difference of the 2 amplitudes. B1

Comments:
Most of the students who attempted this were able to quote the conditions for constructive and destructive interference.

7(c)(i) 2. $\Delta x = \lambda\frac{D}{a} = 0.030\times\frac{4.0}{0.20} = 0.60$ m C1

Distance = $\frac{\Delta x}{2} = 0.30$ m A1

Comment:
Students must realise that the distance between max and min is ½ the fringe separation.

(ii) As detector is moved from O to Q, the amplitude of signal from both A and B decreases since amplitude varies inversely with distance B1

Because energy emitted by the transmitters spread out ( so less is collected by the receiver the further away it is ) B1

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**OR**

Since intensity varies inversely with the square of separation, as the detector is moved from O to Q, the intensity from each transmitter A and B decreases.
As intensity is proportional to the square of amplitude, since intensity at Q decreases, the amplitude from both A and B decrease and hence the resultant amplitude at Q decreases.

Comments:
This part of the question is not well explained. Many students used symbols r and A with explaining what they represent.

(iii) 1. When the path difference AO and BO is $\lambda/2$, a minimum occurs due to destructive interference between the signals from A and B. When the path difference AO and BO is $\lambda$, a maximum occurs due to constructive interference between the signals from A and B. B1

2. distance = $\frac{\lambda}{2}$ C1

= $\frac{0.030}{2} = 0.015$ m A1

Comments:
Again this part is not done well due to proper concept.

(d) (i) Intensity increases by a factor of 4 B1
As intensity $\propto$ (amplitude)$^2$ B1

Comments:

$$I \propto A^2$$

$$\frac{I'}{I} = \left(\frac{2A + 2A}{A + A}\right)^2 = 4$$

(ii) Intensity becomes 0 instead of maximum B1
Path difference AO – BO = 0, and so destructive interference occurs at O, and a minima will be at O. B1

Comments:
Waves arriving at O travelled through the same path length.
Since they were anti-phase to each other at A and B, they arrive anti-phase to each other at O.

(iii) Intensity falls to zero B1
Emitted signals is vertically polarized B1
Receiver in position is only able to detect horizontally polarized signal. B1

Comments:
There is no change in the plane of polarization from the 2 sources.
When the detector is rotated $90^0$, the plane of polarization of the resultant wave is $90^0$ to the transmission axis of the detector. Intensity detected becomes $I\ cos^2 90$

**8(a)** Binding energy is the minimum amount of energy required to separate a nucleus into its constituent nucleons such that they are infinitely far apart. B2

Or

Binding energy is the energy released when the nucleus forms from its separate protons and neutrons.

Comments:

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Energy is required to separate a nucleus into its constituent nucleons while energy is released when the nucleus is formed from its separate protons and neutrons.

**(b)(i)** $\text{Mass defect } \Delta m = 88m_p + (226-88)m_n - M_{Ra}$

$= 88(1.00783\text{u}) + 138(1.00867\text{u}) - 226.025\text{u}$

$= 1.8605\text{u}$ M1

$\text{Binding energy per nucleon} = \dfrac{\Delta mc^2}{226}$

$= \dfrac{1.8605(1.66\times10^{-27})(3.00\times10^{8})^2}{226}$ M1

$= 1.2299\times10^{-12}\,\text{J}$

$= 7.68\,\text{MeV}$ A1

Comments:
226.025u is the mass of $^{226}_{88}Ra$ nucleus. Mass defect of $^{226}_{88}Ra$ nucleus is the difference between the mass of the nucleus and the sum of masses of its individual nucleons.

**(b)(ii)** $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$

Energy released

$= m_{reactants}c^2 - m_{products}c^2$

$= (226.025 - 222.018 - 4.00260)(1.66\times10^{-27})(3.00\times10^{8})^2$ M1

$= 6.5736\times10^{-13}$

$= 4.11\,\text{MeV}$ A1

**(c)(i)** Random – do not know when or which particular nucleus will decay. But there is a constant probability of decay (decay constant) B1

Spontaneous – not affected by external factors. B1

Comments:
This part is generally quite badly done. Most of them were not able to define the 2 terms correctly.

**(c)(ii)** The half-life of $^{222}_{86}$Rn is very short (only 3.8 days). It decays very quickly. But $^{222}_{86}$Rn B1

is the product of other radioactive decay ( which probably has a long half-life) and so takes a long time to be produced . Thus they can still be found on Earth. B1

Comments:
This part is generally quite badly done. Most of the students were not able to explain why it is rare.

**(c)(ii)** $A = \lambda N$

$N = \dfrac{200}{2.1\times10^{-6}}$

$= 9.52\times10^{7}$ M1

$N = \dfrac{m}{M_r}N_A$

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$$\text{Mass} = \frac{9.52\times10^{7}}{6.023\times10^{23}}\times222\times10^{-3}$$ M1

$$= 3.5\times10^{-17}\ \text{kg}$$ A1

Or

$$\text{Mass} = 9.52\times10^{7}\times222\times1.66\times10^{-27}$$

$$= 3.5\times10^{-17}\ \text{kg}$$

Comments:
This part is quite well done. The only problem is that some of the students did not convert the unit of grames to kilograms, thus losing 1 mark.

**(d)(i)** $A = A_o e^{-\lambda t}$

$$\frac{8.5}{100}A_o = A_o e^{-\frac{\ln 2}{t_{\frac{1}{2}}}t}$$ M1

$$\ln\left(\frac{8.5}{100}\right) = -\left(\frac{\ln 2}{5700}\right)t$$

$$t = 20300\ \text{years}$$ A1

Comments:
This part was well attempted.

**(d)(ii)** Probability of decay per unit time
= □λ□

$$= \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{5700(365)(24)(60)(60)} = 3.86\times10^{-12}\ \text{s}^{-1}$$ A1

Comments:
Some students do not realise that the probability of decay is the decay constant. And some students forgot to convert year to second. Students are advised to look at the unit requirement show at the answer to be aware.

**(d)(iii)** Carbon-14 cannot be used to determine the age of the stone.
Carbon-14 can only be used for living organism. Once it dies, it ceases to acquire $^{14}C$ (from atmosphere or diet), 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. The change in ratio can be used for carbon dating. A stone does not acquire $^{14}C$. B1 B1

Comments:
This part requires understanding of carbon dating which majority of the candidates who attempted this questions do not have. Hence it was not well answered.

**(d)(iv)** In beta decay, a neutron changes into a proton and electron. The electron is emitted as beta particle. The proton remains in the nucleus. Hence, the neutron number decreases by 1 and the proton number increases by 1. M1

Comments:
The question asks for “state and explain” hence merely stating n -1 and p +1 is insufficient as reason has to be given.

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**Experimental data and suggested solutions for Question 1**

**1(a)**

Zero error = 0.00 mm

$d'_1 = 0.24\,\text{mm}$

$d''_1 = 0.24\,\text{mm}$

$d = 0.24\,\text{mm}$

**1(b)**

$$A_1 = \frac{\pi(0.24)^2}{4} = 0.045\,\text{mm}^2$$

**1(c)**

Zero error = 0.00 mm

$d'_2 = 0.52\,\text{mm}$

$d''_2 = 0.52\,\text{mm}$

$d_2 = 0.52\,\text{mm}$

$$A_2 = \frac{\pi(0.52)^2}{4} = 0.21\,\text{mm}^2$$

**1(e)**

$I =$ 74.8 mA

$V_1 =$ 0.401V

$V_2 =$ 89.5mV

**1(f)**

| $I$/ mA | $V_1$ / V | $V_2$ / mV | $V_1 + V_2$ / V |
|---|---|---|---|
| 74.8 | 0.401 | 89.5 | 0.491 |
| 91.9 | 0.493 | 110.4 | 0.603 |
| 114.5 | 0.613 | 137.3 | 0.750 |
| 135.3 | 0.723 | 161.7 | 0.885 |
| 175.5 | 0.944 | 213.0 | 1.157 |
| 218.4 | 1.178 | 263.5 | 1.442 |

**1(g)**

Gradient of graph = $\dfrac{1.370 - 0.520}{(210.0 - 80.0)\times 10^{-3}} = 6.538$

Gradient of graph = $\rho L\left(\dfrac{1}{A_1} + \dfrac{1}{A_2}\right)$

$$\rho(35\times 10^{-2})\left(\frac{1}{0.045\times 10^{-6}} + \frac{1}{0.21\times 10^{-6}}\right) = 6.538$$

$\rho = 6.92 \times 10^{-7}\ \Omega\,\text{m}$

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| | |
|---|---|
| **1(h)** | Take the ratio of voltages across the wire.<br>The ratio $\frac{V_1}{V_2}$ gives the ratio of the cross-sectional areas $\frac{A_2}{A_1}$. Since current is constant, $V = IR = I\frac{\rho L}{A}$. The voltage across wire $V$ is inversely proportional to cross-sectional area. Hence the ratio of cross-sectional area can be obtained from voltmeter readings. |
| **1(i)** | Graph remains the same. Same gradient.<br>The resistances of the wires remain unchanged. Hence the $V_1$ and $V_2$ values should remain the same for each $I$ value. |

**Marking Scheme for Question 1**

| No | Mark Scheme | Mark | Score |
|---|---|---|---|
| 1(a) | $d$ measured to the nearest 0.01 mm with consistent unit<br>Evidence of repeated measurements of $d$ | 1 | |
| (b) | $A$ calculated correctly to correct s.f | 1 | |
| (e) | $I$ recorded to the nearest 0.1 mA with consistent unit.<br><br>$V_1$ recorded to the nearest 0.001 V and $V_2$ recorded to the nearest 0.1 mV | 1<br><br>1 | |
| (f) | Tabulate at least 6 sets of readings with correct d.p for $I$, $V_1$ and $V_2$.<br>Award 0 marks if $\leq$ 5 readings are taken.<br>Award 0 marks if assistance is provided in circuit setup.<br><br>Correct d.p for $V_1$ + $V_2$<br><br>Correct column headings with units<br><br>Note: − 2 marks for table if unable to obtain varying $I$, $V_1$ and $V_2$ values. | 1<br><br><br><br>1<br><br>1 | |
| (g) | Graph<br>Correct linearization equation. Note: ($V_1$ + $V_2$) against $I$<br>Correct label of axes and graph should occupy at least half of graph paper.<br>Correct plotted points<br><br>Gradient coordinates read correctly and correct calculation of gradient.<br>Correct calculation of $\rho$ with units. | <br>1<br>1<br>1<br><br><br>1<br>1 | |
| (i) | Sensible method to obtain ratio of cross-sectional areas. e.g. ratio of $\frac{V_1}{V_2}$. Correct explanation or elaboration | 1<br><br>1 | |
| (h) | Correct graph Z (labelled) | 1 | |
| | **Total** | 15 | |

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**Experimental data and suggested solutions for Question 2**

2(a)(ii) $L$ = 182 mm

(b)(ii) $d$ = 100 mm

(iii) $c = \frac{d}{L} = \frac{100}{182} = 0.549$

(iv) $q = \frac{\frac{c^2}{3} - c + 1}{1 - \frac{c}{2}} = \frac{\frac{0.549^2}{3} - 0.549 + 1}{1 - \frac{0.549}{2}} = \frac{0.551}{0.726} = 0.759$

(c) (ii) $t_1$ = 7.8 s
$t_2$ = 7.6 s

$\langle t \rangle = \frac{7.6 + 7.8}{2} = 7.7$ s

(iii) $\Delta t$ = 0.2 s

$\%\frac{\Delta t}{t} = \frac{0.2}{7.7} \times 100\% = 2.6\%$

(d) (ii) $d$ = 130 mm

$c = \frac{130}{182} = 0.714$

$q = \frac{\frac{0.714^2}{3} - 0.714 + 1}{1 - \frac{0.714}{2}} = \frac{0.456}{0.643} = 0.709$

$t_1$ = 7.2 s , $t_2$ = 7.4 s , $\langle t \rangle$ = 7.3 s

(e) (i) $k_1 = \frac{7.7^2}{0.759} = 78$

$k_2 = \frac{7.3^2}{0.709} = 75$

(ii) percentage difference from smaller $k$ = $\frac{78 - 75}{75} \times 100\% = 4.0\%$

Since the percentage difference in $k$ > percentage uncertainty in $t$, the relationship is not valid.

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**Name:**_____ **CG:**_____ **Date:** _____

**Marking Scheme for Question 2**

| No | Marking Instructions | Mark | Score |
|---|---|---|---|
| (b)(ii) | Value of d = 0.5L ± 20 mm, recorded to nearest mm or 1 dp in cm or 3 dp in m. | 1 | |
| (b)(iii) | Correct calculation of c | | |
| (b) (iv) | Correct calculation of q | 1 | |
| (d)(ii) | Value of raw *t* to 0.1 s, with units, in range 6 s ≤ t ≤ 20 s | 1 | |
| | Evidence of repeat measurements of *t* | | |
| (c)(iii) | Absolute uncertainty in *t* in range 0.2 s to 0.5 s | 1 | |
| | Correct calculation of percentage uncertainty in 1 or 2 s.f. only | | |
| (d)(ii) | *d* recorded to the nearest mm or 1 dp in cm or 3 dp in m. | | |
| | Correct calculation of c and q, with substitution in working | | |
| | t recorded to 0.1 s or better with units and working for avg. | 1 | |
| | Correct trend for t with respect to d ( t decreases as d increases ) | 1 | |
| (e)(i) | Correct calculation of the 2 k values, wrong s.f. ignored | 1 | |
| (e)(ii) | Valid comment consistent with calculated values of k, testing against a stated criterion e.g. " The calculated percentage difference between k values is less than the percentage uncertainty found in d (iii), so the relationship is probably valid."<br><br>Comment: accept comparison with $t^2$ instead but not recommended, wrong s.f. of percentage uncertainty ignored | 1 | |
| | **Total** | 8 | |

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**Experimental data and suggested solutions for Question 3**

**3 c**

$\alpha$ = 34°
$\beta$ = 68°

**d**

$$\frac{\Delta\alpha}{\alpha}\times 100\% = \frac{2}{34}\times 100\% = 5.9\%$$

**e**

- Friction at the axle of pulleys.
- Difficult to ensure that CD is horizontal.
- Difficult to measure angles $\alpha$ and $\beta$ due to absence of reference vertical line.
- Difficult to measure the angles accurately because it is difficult to hold the protractor still and in position as the hands may be unsteady.

**f**

- Lubricate the (axle of) the pulley.
- Use spirit level to check that CD is horizontal.
- Set up a plumbline and use it to align the protractor.
- Clamp the protractor using a retort stand instead, to measure the θ.

**g**

| $\alpha$ / ° | $\beta$ / ° | cos ($\alpha$ / °) | cos ($\beta$ / °) | $k = \frac{\cos(\alpha/°)}{\cos(\beta/°)}$ |
|---|---|---|---|---|
| 34 | 68 | 0.83 | 0.37 | 2.2 |
| 35 | 70 | 0.82 | 0.34 | 2.4 |

Percentage difference in values of k = $\frac{2.4-2.2}{2.2} x100\% = 9.1\%$

$$\frac{\Delta\cos\alpha}{\cos\alpha} + \frac{\Delta\cos\beta}{\cos\beta}$$

$$= \frac{(\cos 32 - \cos 36)/2}{\cos 34} + \frac{(\cos 66 - \cos 70)/2}{\cos 68}$$

$$= \frac{0.0195}{0.829} + \frac{0.0324}{0.375}$$

$$= 0.110 = 11.0\%$$

Since percentage difference in values of k < 11.0 %, suggestion is agreed.

**h**

- Keeping the mass hung at end B constant at 50 g, increase the mass hung at end A by adding slotted mass.
- Use a spirit level to check that string CD is kept horizontal.
- Measure angles $\alpha$ and $\beta$ using a protractor.
- Plot a graph of $\frac{m_A}{m_B}$ vs $\frac{\cos\alpha}{\cos\beta}$
- If the graph is a straight line passing through the origin, $\cos\alpha$ increases proportionally to $\cos\beta$

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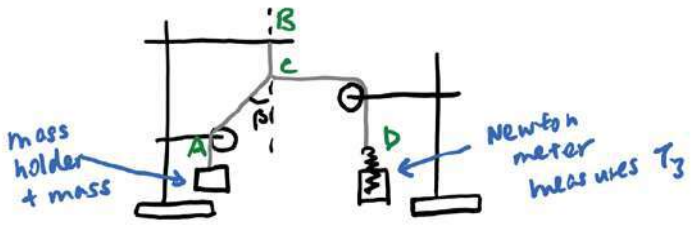
| | | |
|---|---|---|
| | i |  <br>1) Modified set up as shown. BC attached to boss, plumbline in background to ensure vertical<br><br>or One end of thread BC (point B) should now be tied in fixed position to a boss, with plumbline in background to ensure vertical. The other end CA that passes over pulley maintained at fixed angle β to vertical at point C. β maintained with reference to fixed protractor clamped to retort stand. [1]<br>2) CD now wound over pulley and attached to Newton meter vertically at point D, reads $T_3$ . Point C tied to thread BA at point C and maintained horizontal by referencing to spirit level and adjusting the force exerted by the Newton meter. [1]<br>3) Tension $T_1$ increased by adding masses to mass holder, for total of 6 values. [1]<br>4) To verify equation: $T_3 = k\ T_1$ . Plot $T_3$ /N vs $T_1$/N. [1]<br>5) If plotted data fits a straight line with constant gradient k and vert-int c = 0, suggested equation/relationship is probably valid. [1] |

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**Name:**_____ **CG:**_____ **Date:** _____

**Marking Scheme for Question 3**

| | | | Mark | Score |
|---|---|---|---|---|
| **3** | **c** | $\alpha$ and $\beta$ recorded to the correct d.p. with unit<br>Unit: ° (zero d.p.) | 1 | |
| | | $\alpha < \beta$<br>$\alpha$ and $\beta$ are less than 90° | 1 | |
| | **d** | Percentage uncertainty calculated correctly to appropriate s.f.<br>($2° \leq \Delta\alpha \leq 5°$) | 2 | |
| | **e** | • Friction at the axle of pulleys.<br>• Difficult to ensure that CD is horizontal.<br>• Difficult to measure angles $\alpha$ and $\beta$ due to absence of reference vertical line.<br>• Difficult to measure the angles accurately because it is difficult to hold the protractor still and in position as the hands may be unsteady. | 1 | |
| | **f** | • Lubricate the (axle of) the pulley.<br>• Use spirit level to check that CD is horizontal.<br>• Set up a plumbline and use it to align the protractor.<br>• Clamp the protractor using a retort stand instead, to measure the θ. | 1 | |
| | **g** | $\alpha$ and $\beta$ recorded to the correct d.p. with unit | 1 | |
| | | cos $\alpha$ and cos $\beta$ calculated correctly | 1 | |
| | | constant of proportionality *k* calculated correctly to correct s.f. | 1 | |
| | | % difference in values of *k* calculated correctly | 1 | |
| | | Draw sensible conclusion based on results in (d) | 2 | |
| | **h** | Method to increase the ratio of mass at A to mass at B (e.g. increase the mass at end A while keeping the mass at end B the same) | 1 | |
| | | Method to keep CD horizontal. | 1 | |
| | | Suggest an appropriate graph to plot and draw sensible conclusion from the graph. | 1 | |
| | **i** | Description or diagram showing –<br><br>how BC kept vertical, eg. end of thread attached to ring slotted into boss<br>how $T_3$ kept horizontal and measured, eg thread CD over pulley and vertical portion attached to Newton-meter<br>Method to increase $T_1$ without changing $\beta$<br>Suggest an appropriate graph to plot using eqn from (h)<br>draw sensible conclusion from the graph. | <br><br>1<br>1<br><br>1<br>1<br>1 | |
| | | **Total** | 20 | |

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**Suggested solution for Question 4:**

**4**

**Diagram**

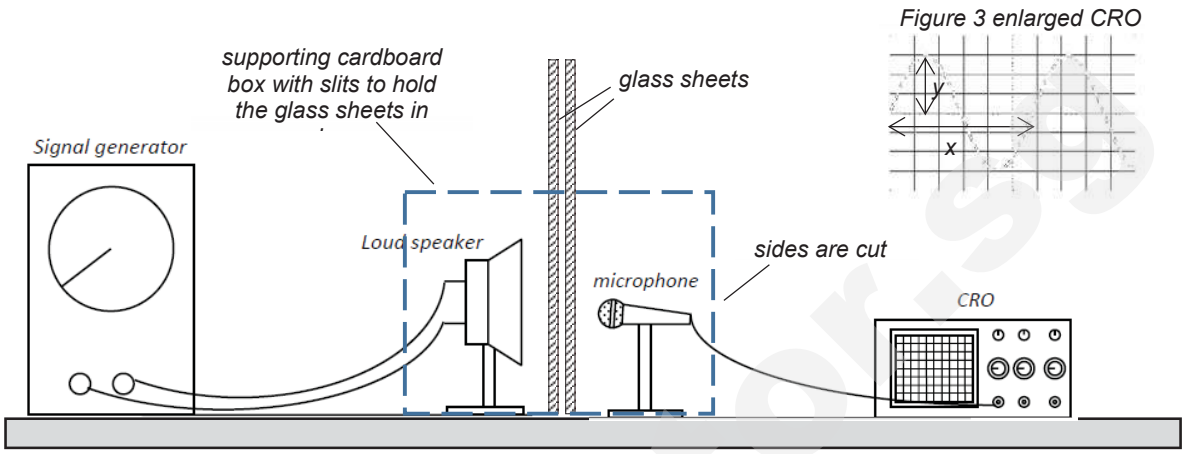


*Figure 1*

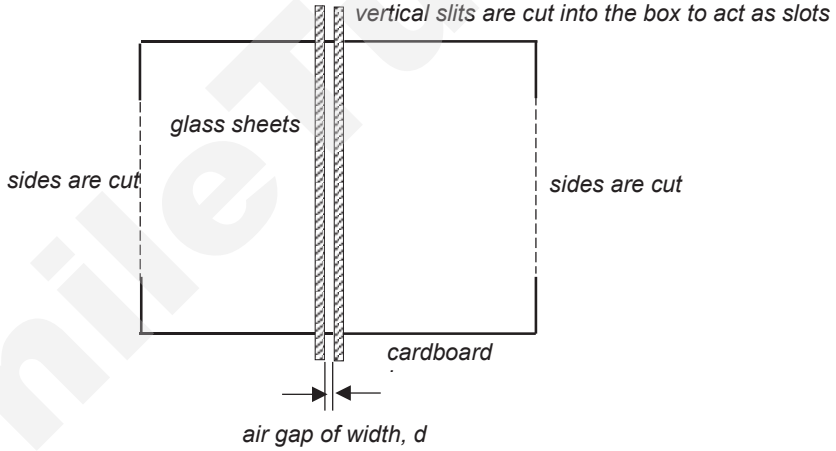


*Figure 2 Top view of cardboard box with glass sheets inserted*

**Defining the problem**

Independent variable is width of air gap *d* between the 2 glass panes or frequency *f* of sound
Dependent variable is amplitude of transmitted sound *A*
Control of variables:

1. Distance between loudspeaker and glass sheets, and distance between microphone and glass sheets are kept fixed
2. Amplitude of incident sound, $A_o$ is kept fixed
3. Ambient temperature and pressure are kept constant

**Procedure**

Expt A: Keep *f* constant. Vary *d* to measure *A*

1. Cut two vertical slits about 1 cm apart on a large sturdy cardboard box. Insert the 2 sheets of glass into the slots. Measure the width of the air gap between the two glass sheets using the internal calipers of a Vernier calipers. Record the width of air gap as *d* (see Figure 2).

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2. Set up the rest of the apparatus as shown in Figure 1. Both the loud speaker and microphone should be facing perpendicularly into the glass sheets. They should also be as close to the glass sheets as possible without touching them.
3. Adjust the frequency of the signal generator to produce a sound in the audible range (20 H to 20 kHz), eg 1 kHz.
4. Do not change the amplitude and the frequency of the incident sound throughout the whole experiment.
5. Adjust the Y-scale to maximize the waveform on the CRO display. Measure the amplitude y (see Figure 3). Calculate the amplitude of the transmitted sound *A* in volts, where *A* is the product of *y* and the vertical sensitivity.
6. Make another two more vertical slits in the cardboard box and increase the width of the air gap *d*. Shift the loud speaker and microphone to maintain a constant distance with the sheets of glass similar to step 2.
7. Repeat steps 1 to 6 until 6 sets of readings for *A* and *d* are collected.

<u>Expt B: Keep *d* constant. Vary *f* to measure *A*</u>

8. Using a fixed air gap, d, repeat step 2.
9. Adjust the frequency of the signal generator to produce a sound in the audible range (20 H to 20 kHz).
10. Do not change the amplitude of the incident sound throughout the whole experiment.
11. Adjust the Y-scale to maximize the waveform on the CRO display. Measure the amplitude y (see Figure 3). Calculate the amplitude of the transmitted sound *A* in volts, where *A* is the product of *y* and the vertical sensitivity.
12. Adjust the time-base (X-scale) of the CRO to get a stable waveform of one or two cycles. Measure x, time for 1 complete waveform. Calculate the period, *T* in seconds, where *T* is the product of *x* and time-base (see Figure 3).
13. Calculate the frequency of the sound using $f = \frac{1}{T}$ .
14. Repeat steps 9 to 13 until 6 sets of readings for *A* and *f* are obtained.

**Analysis:**

Given $A = A_o\, d^m\, f^n$

Expt A : For constant *f*, $A = A_o\, d^m\, f^n \Rightarrow \quad lgA = \lg(A_o f^n) + mlgd$
Plot lg A versus lg d , gradient = m and y-intercept = lg ($A_o$ $f^n$)

Expt B : For constant *d*, $A = A_o\, d^m\, f^n \Rightarrow \quad lgA = \lg(A_o d^m) + nlgf$
Plot lg A versus lg f , gradient = n and y-intercept = lg ($A_o$ $d^m$)

**Other reliability measures/Additional details**

1. The experiment should be conducted in a quiet room or sound proof box to reduce background noise.
2. Do a pre-experiment to select an appropriate volume of sound that will be comfortably detected by the CRO for the range of air gaps used.
3. Glass sheets used to be reasonably large (eg 1 m x 1 m) so that the direct detection of the sound produced from the loudspeaker by the microphone can be minimized.
4. Repeat measurement at different positions of glass panes and find the average width of air gap.
5. Keep distance between loudspeaker and glass sheet constant, and distance between microphone and glass sheet constant and measure them regularly using metre rule to ensure they are constant.
6. Keep amplitude of incident sound constant by not changing the setting on the signal generator and to ensure it is constant by measuring it using a sound intensity meter regularly.
7. Face the loudspeaker and microphone towards each other and ensure they lie along the same horizontal axis by ensuring the height of the loudspeaker and microphone from the table top are equal.

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| | |
|---|---|
| | **Safety precaution**<br>1. Wear thick gloves when handling the glass sheets to provide additional grip/ cushion the fall of glass sheet to prevent accident cut/ place heavy weights in retort stands (if retort stands are used) to prevent the glass sheets from falling.<br>2. Wear ear plugs/ noise cancelling microphone in case the frequency of sound is too high such that it may damage the ear. |

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**Marking Scheme for Question 4**

| | | |
|---|---|---|
| | | **Design [2]** |
| | A1 | Diagram with method to produce sound (using **loudspeaker connected to signal generator**) |
| | A2 | Measure frequency and amplitude of transmitted sound (using time-base and vertical sensitivity of CRO respectively). |
| | | **Procedure [5]** |
| | B1 | Method of measuring the width of air gap (Vernier caliper) |
| | B2 | Method of measuring and determining the amplitude of transmitted sound (vertical sensitivity on CRO) |
| | B3 | Method of measuring the frequency of transmitted sound (time-base on CRO) |
| | B4 | Method to vary the width of air gap (shifting glass panes by sensible means) |
| | B5 | Method to vary the frequency of sound (by varying frequency on signal generator) |
| | | **Safety and analysis [3]** |
| | C1 | Expt A : For constant *f*, Plot lg A versus lg d , gradient = m and y-intercept = lg ($A_o f^n$) |
| | C2 | Expt B : For constant *d*, Plot lg A versus lg f , gradient = n and y-intercept = lg ($A_o d^m$) |
| | C3 | Wear thick gloves when handling the glass sheets to provide additional grip/ cushion the fall of glass sheet to prevent accident cut/ place heavy weights in retort stands (if retort stands are used) to prevent the glass sheets from falling/ wear ear plugs/ noise cancelling microphone in case the frequency of sound is too high such that it may damage the ear. |
| | | **Detail [Maximum 2 marks]** |
| | D1 | The experiment should be conducted in a quiet room or sound proof box to reduce background noise. |
| | D2 | Do a pre-experiment to select an appropriate volume of sound that will be comfortably detected/measurable by the CRO for the range of air gaps used. |
| | D3 | Glass sheets used to be reasonably large (eg 1 m x 1 m) so that the direct detection of the sound produced from the loudspeaker by the microphone can be minimized. |
| | D4 | Repeat measurement at different positions of glass panes and find the average width of air gap. |
| | D5 | Keep distance between loudspeaker and glass sheet constant, and distance between microphone and glass sheet constant and measure regularly, using a metre ruler to ensure they are always constant. |
| | D6 | Keep amplitude of incident sound constant by not changing the setting on the signal generator and to ensure it is constant by measuring it using a sound intensity meter/checking the amplitude using the vertical displacement on the CRO regularly. |
| | D7 | Other possible good physics suggestions |
| | 12 | |

If method is unworkable:
-no mark for diagram, A zero, D zero
Only award - B [maximum 4 marks]
-C1, C2, C3 [1 mark each]

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**VICTORIA JUNIOR COLLEGE**
**2019 JC2 PRELIMINARY EXAMINATIONS**
**Higher 2**

Name : _____ CT group : _____

**PHYSICS** **9749 / 01**

Paper 1 Multiple Choice **25 September 2019**

**WEDNESDAY**

Additional Materials: Multiple Choice Answer Sheet **8 – 9 am (1 Hour)**

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, CT group and shade your index number on the Answer Sheet provided.

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

**Read the instructions on the Answer Sheet very carefully.**

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

*This document consists of **15** printed pages and **1** blank page.*


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**Data**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion, | $s = ut + (½)\,at^2$<br>$v^2 = u^2 + 2as$ |
| work done on/by a gas, | $W = p\Delta V$ |
| hydrostatic pressure, | $p = \rho gh$ |
| gravitational potential, | $\phi = -\frac{GM}{r}$ |
| temperature | $T / K = T / °C + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m., | $x = x_o \sin \omega t$ |
| velocity of particle in s.h.m., | $v = v_o \cos \omega t$<br>$= \pm\omega\sqrt{(x_o^2 - x^2)}$ |
| electric current | $I = Anvq$ |
| resistors in series, | $R = R_1 + R_2 + ...$ |
| resistors in parallel, | $1/R = 1/R_1 + 1/R_2 + ...$ |
| electric potential, | $V = Q/4\pi\varepsilon_o r$ |
| alternating current/voltage, | $x = x_o \sin \omega t$ |
| Magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| Magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| Magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay, | $x = x_o \exp(-\lambda t)$ |
| decay constant, | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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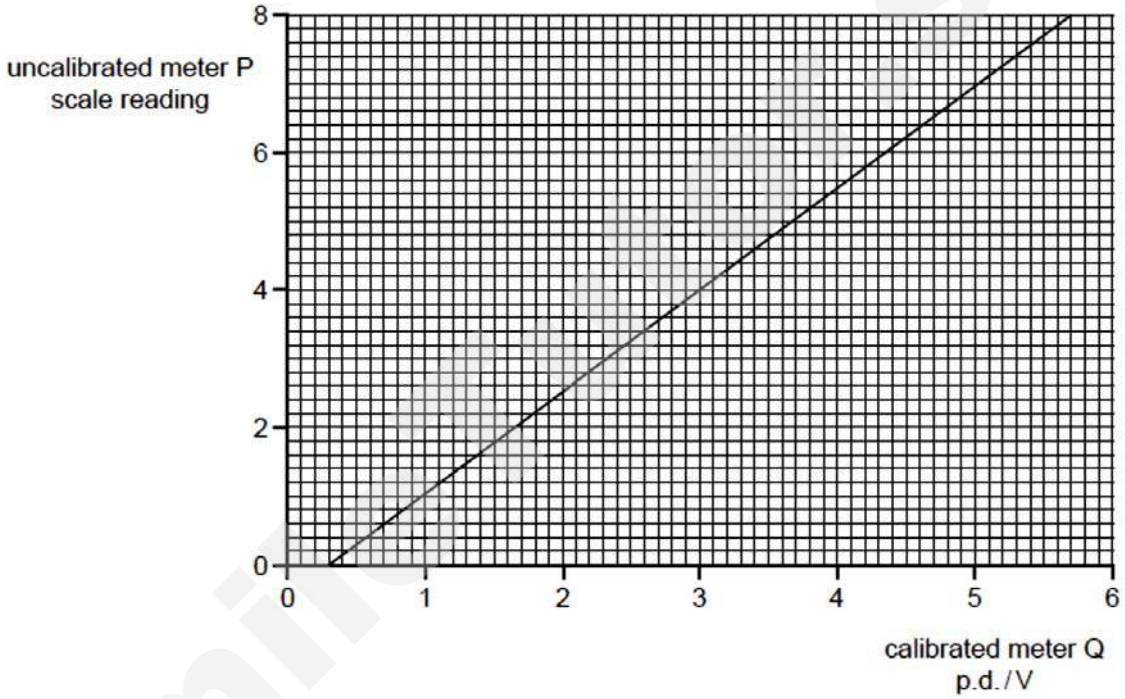
**1** Estimate the average number of hairs on a healthy person's head, assuming 2 strands of hair in an area of 1 $mm^2$ on the scalp.

**A** 5000 **B** 25 000 **C** 50 000 **D** 100 000

**2** An un-calibrated analogue voltmeter P is connected in parallel with another voltmeter Q which is known to be accurately calibrated. For a range of values of potential difference (p.d.), readings are taken from the two meters.

The diagram shows the calibration graph obtained.




The graph shows that meter P has a zero error. This meter is now adjusted to remove this zero error. When the meter is re-calibrated, the gradient of the calibration graph is found to be unchanged.

What is the new scale reading on meter P when it is used to measure a p.d. of 5.0 V?

**A** 6.6 **B** 6.7 **C** 7.2 **D** 7.4

**3** A racing car accelerates uniformly through three gear changes with the following average speeds:

20 m $s^{-1}$ for 2.0 s
40 m $s^{-1}$ for 2.0 s
60 m $s^{-1}$ for 6.0 s

What is the overall average speed of the car?

**A** 12 m $s^{-1}$ **B** 40 m $s^{-1}$
**C** 13.3 m $s^{-1}$ **D** 48 m $s^{-1}$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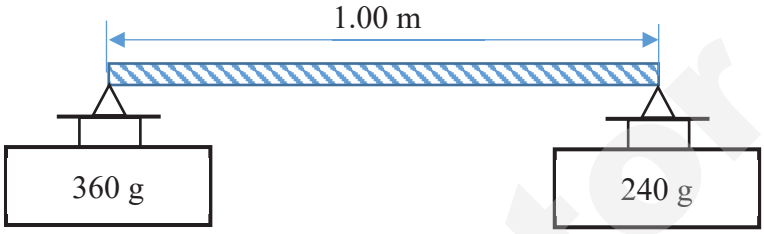
**4** In a popular movie, a man wearing a metallic robotic suit is able to fly by ion thrusters which expel ions downward from the suit's feet. If the total mass of the robotic suit with the man inside is 250 kg and the speed of the ion stream exiting the suit is 30,000 m $s^{-1}$, determine the mass of the ions that must leave the suit per unit time for it to hover above ground.

**A** 0.0010 kg $s^{-1}$ **B** 0.082 kg $s^{-1}$ **C** 1.3 kg $s^{-1}$ **D** 24.5 kg $s^{-1}$

**5** A rod of length 1.00 m has non-uniform composition, so that the centre of gravity is not at its geometrical centre. The rod is laid on supports across two mass balances as shown in the diagram. The balances give readings of 360 g and 240 g.



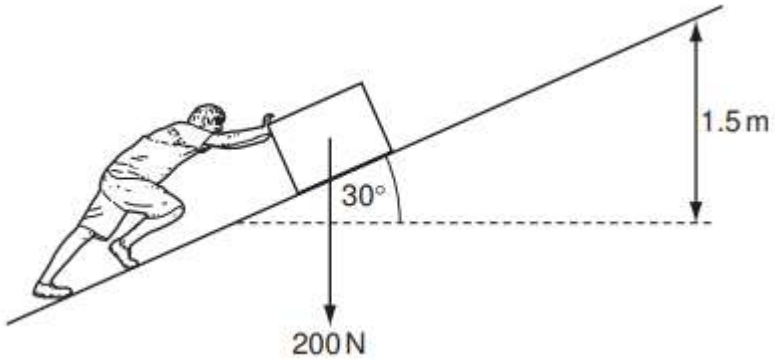

Where is the centre of gravity of the rod relative to its geometrical centre?

**A** 10 cm to the left **B** 10 cm to the right
**C** 17 cm to the left **D** 20 cm to the left

**6** A car of mass $1.2 \times 10^3$ kg travels along a horizontal road at a speed of 10 m $s^{-1}$. It then accelerates at 0.20 m $s^{-2}$. At the instant it begins to accelerate, the total resistive force acting on the car is 160 N.
What total output power is developed by the car as it begins the acceleration?

**A** 0.80 kW **B** 1.6 kW **C** 2.4 kW **D** 4.0 kW

**7** A box of weight 200 N is pushed so that it moves at a steady speed along a ramp, through a height of 1.5 m. The ramp makes an angle 30° with the ground. The frictional force on the box is 150 N while the box is moving.




What is the work done by the person?

**A** 150 J **B** 300 J **C** 450 J **D** 750 J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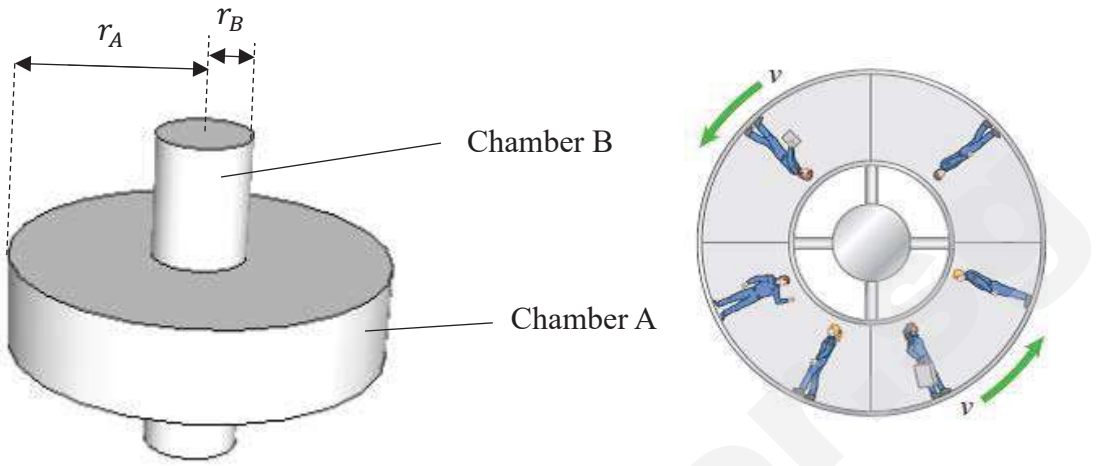
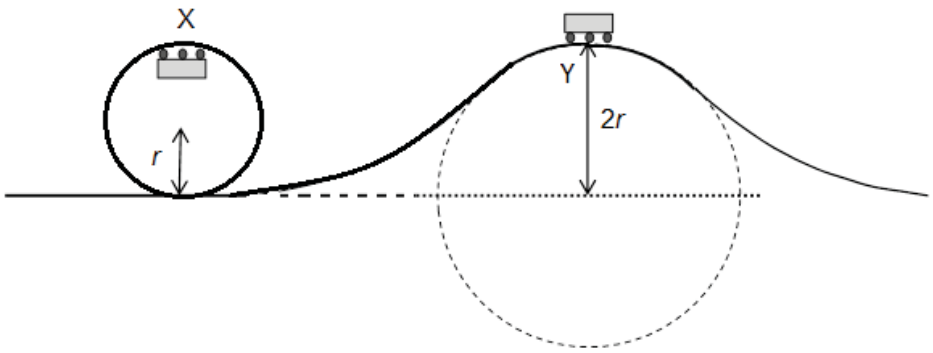
**8** To create artificial gravity, the space station shown in the figure below is rotating at a rate of 1.0 revolution per minute. This allows the astronauts to experience the illusion of gravity and walk on the inner walls as shown below.




The radii of the cylindrically-shaped chambers A and B are $r_A$ and $r_B$ respectively. The ratio of the radii is $r_A/r_B$ = 4.0. Chamber A simulates acceleration due to gravity of 10.0 m s$^{-2}$. What is the tangential velocity of chamber B and its acceleration due to gravity that is simulated in it?

| | Tangential velocity of Chamber **B** /m s$^{-1}$ | Acceleration in Chamber **B** /ms$^{-2}$ |
|---|---|---|
| **A** | 12 | 2.5 |
| **B** | 24 | 2.5 |
| **C** | 48 | 5.0 |
| **D** | 64 | 5.0 |

**9** In a roller coaster ride, a cart of mass *m* loops a loop of radius *r* before racing over a hump of radius of curvature 2*r* as shown in the diagram.
If the cart just remains in contact with the track at the top of the loop at point X, what is the force the cart exerts on the track at the top of the hump at point Y? Assume that resistive forces are negligible, and ignore the dimensions of the cart.




**A** 0 **B** $\frac{mg}{2}$ **C** $mg$ **D** $\frac{3mg}{2}$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**10** A sound wave of frequency 400 Hz is travelling in air at a speed of 320 m $s^{-1}$. What is the difference in phase between two points on the wave 0.20 m apart in the direction of travel?

**A** $\frac{\pi}{5}$ **B** $\frac{\pi}{4}$ **C** $\frac{\pi}{2}$ **D** $\frac{4\pi}{5}$

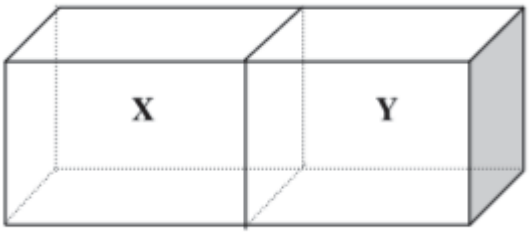
**11** Transverse progressive sinusoidal waves of wavelength $\lambda$ are passing vertically along a horizontal rope. P and Q are $5\lambda/4$ apart and the waves are travelling from P to Q. Which one of the following correctly describes Q at an instant when P is displaced upwards but is moving downwards?

| | **Displacement of Q** | **Movement of Q** |
|---|---|---|
| **A** | Upwards | Downwards |
| **B** | Upwards | Upwards |
| **C** | Downwards | Upwards |
| **D** | downwards | Downwards |

**12** An object moves vertically with simple harmonic motion just behind a garden fence. From the other side of the fence, the object is visible for 2.0 s in each cycle. It is hidden behind the fence for 6.0 s. The angular frequency of the object is

**A** 0.79 rad $s^{-1}$ **B** 1.0 rad $s^{-1}$ **C** 3.1 rad $s^{-1}$ **D** 1.6 rad $s^{-1}$

**13** A container of helium gas shown below has two identical sections with a common wall between them which does not allow gas to leak through. The two sections contain helium gas of mass 2.0 g in compartment X and 1.0 g in compartment Y. The two halves of the container are at the same temperature. Which of the following is the same for the gas in the two sections X and Y?




**A** The number of collisions per second on the common wall
**B** The root mean square speed of the atoms
**C** The density of the helium
**D** The pressure exerted by the helium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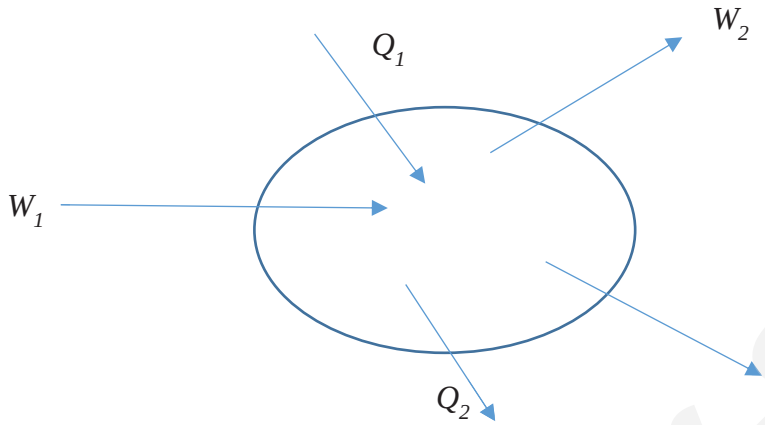
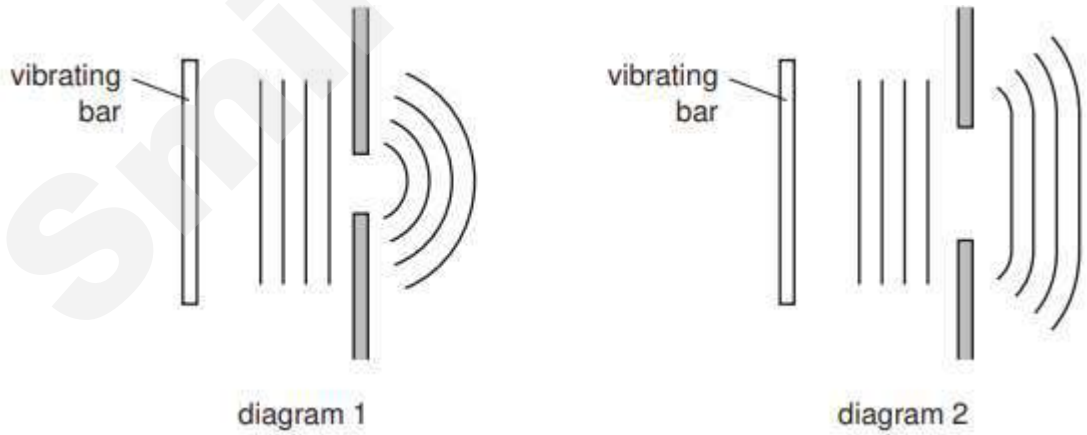
**14** Consider the following diagram involving heat transfer $Q$ and work $W$ done for a system.




If $\Delta U$ is the change in the internal energy of the system, which of the following equations is correct?

**A** $\Delta U = (Q_1 - Q_2) + (W_2 + W_3 - W_1)$
**B** $\Delta U = (Q_1 - Q_2) + (W_1 - W_2 - W_3)$
**C** $\Delta U = (Q_1 + Q_2) + (W_2 + W_3 - W_1)$
**D** $\Delta U = (Q_1 + Q_2) + (W_1 - W_2 - W_3)$

**15** Diagram 1 shows a ripple tank experiment in which plane waves are diffracted through a narrow slit in a metal sheet. Diagram 2 shows the same tank with a slit of greater width. In each case, the pattern of the waves incident on the slit and the emergent pattern are shown.




Which action would cause the waves in diagram 1 to be diffracted less and so produce an emergent pattern closer to that shown in diagram 2?

**A** increasing the frequency of the vibration of the bar with the wave velocity constant.
**B** increasing the speed of the waves by making the water in the tank deeper
**C** reducing the amplitude of vibration of the bar
**D** reducing the length of the vibrating bar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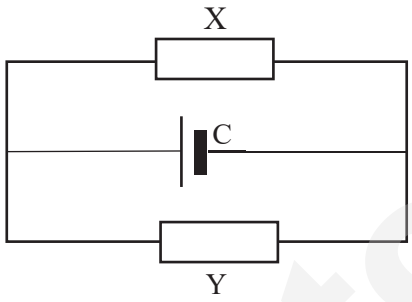
**16** A metal wire of cross sectional area 1.0 $mm^2$ has a conducting electron density of $6.0 \times 10^{28}$ $m^{-3.}$ If the wire is carrying 1.0 A of current, what is the approximate average drift speed of the conducting electrons along the wire?

**A** 1.0 cm $s^{-1}$ **B** 1.0 mm $s^{-1}$ **C** 0.10 mm $s^{-1}$ **D** 0.010 mm $s^{-1}$

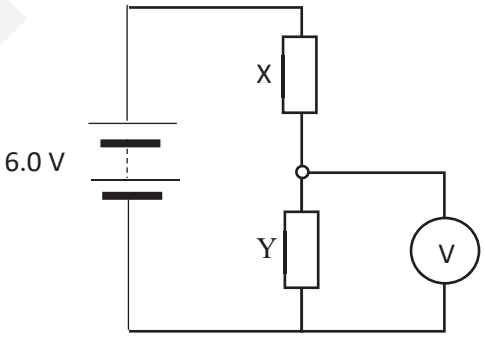
**17** In the circuit shown, each of the resistors X and Y has resistance 6.0 Ω. The cell C has e.m.f. 12 V and internal resistance 3.0 Ω.




What is the current in Y?

**A** 0.50 A **B** 1.0 A **C** 2.0 A **D** 4.0 A

**18** In the circuit shown, resistors X and Y, each of resistance *R*, are connected to a 6.0 V battery of negligible internal resistance. A voltmeter, also of resistance *R*, is connected across Y.




What is the reading of the voltmeter?

**A** 1.0 V **B** 2.0 V **C** 3.0 V **D** 4.0 V

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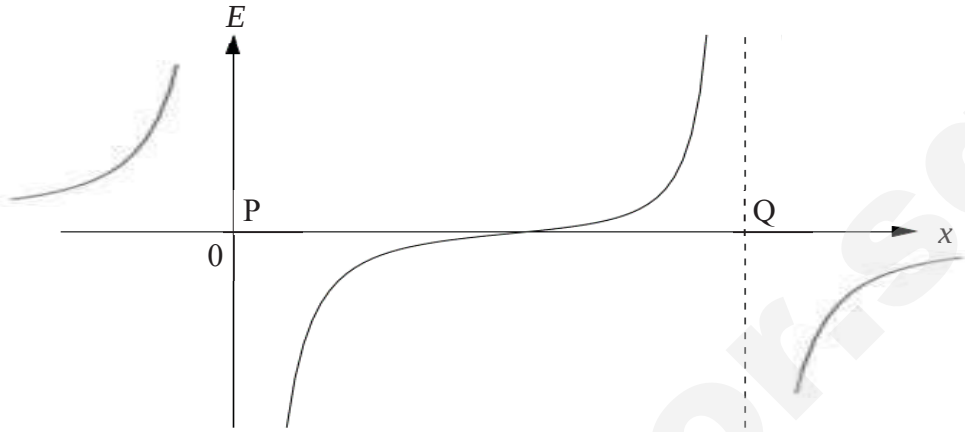
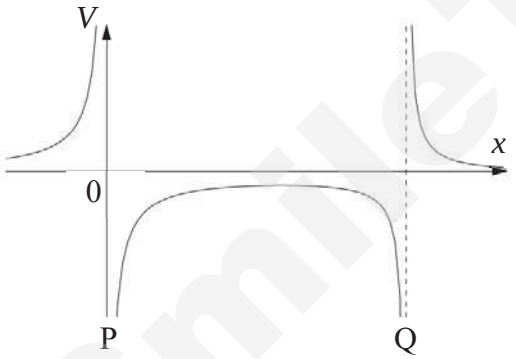
**19** Two negative electric charges are located a distance apart at points P and Q. The graph below shows the variation with distance $x$ of the electric field at all points along the line that joins the two charges. The distance $x$ is measured from the centre of the first charge at P in the direction toward Q. For the sign convention, take the rightward direction as the positive direction.

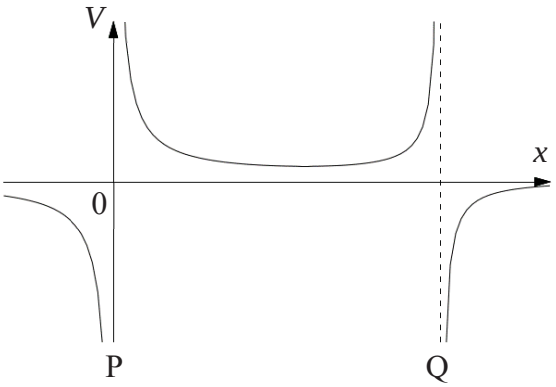



Which of the following graphs correctly shows the variation of the electric potential $V$ with distance $x$ ?

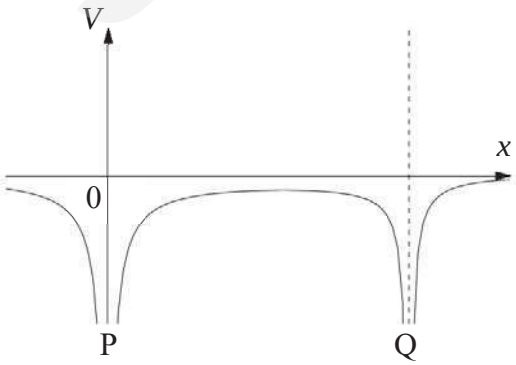
**A**



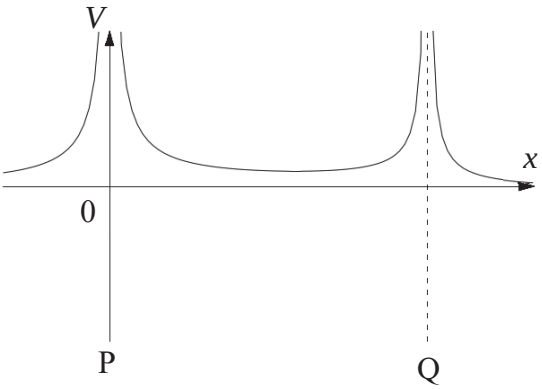

**B**




**C**




**D**

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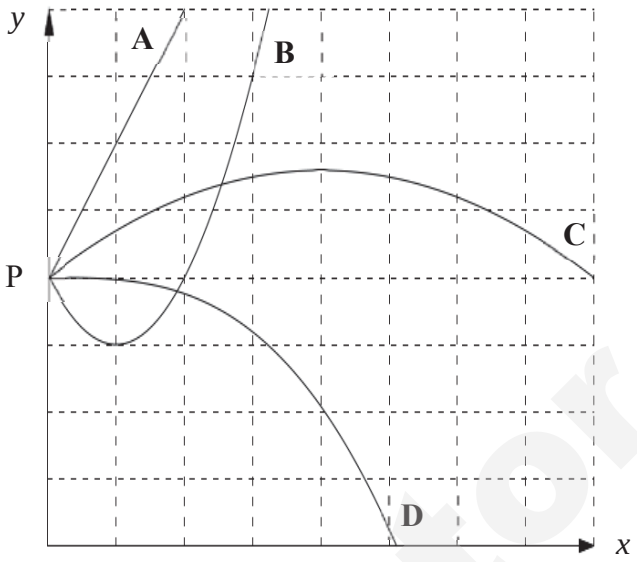
**20** A moving negatively-charged particle enters a uniform electric field at point P. If the electric field acts in the negative *y*-direction, which of the following trajectories will be followed by the particle?

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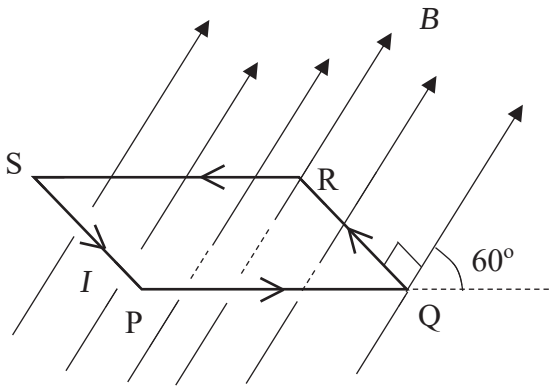
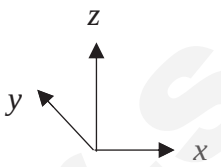
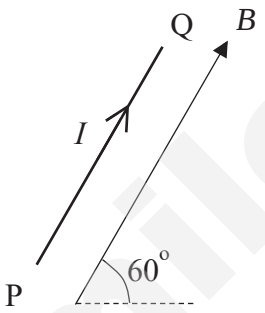
**21** In a weightless environment (such as on board a spacecraft orbiting the Earth), a square coil is placed in a uniform magnetic field with its plane horizontal, so that the field lines make an angle of 60° with its sides PQ and RS while being perpendicular to sides QR and SP, as shown below. A current flows through the coil in the direction PQRS.



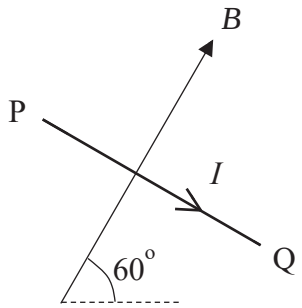




Which of the following diagrams shows the correct final orientation of the coil as seen along the *y*-axis? Assume that resistive forces (e.g., air resistance) are present to damp any oscillation.

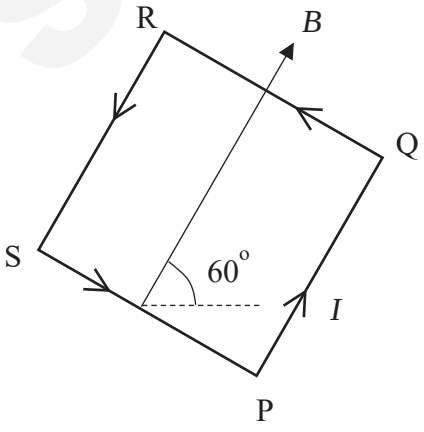
**A**



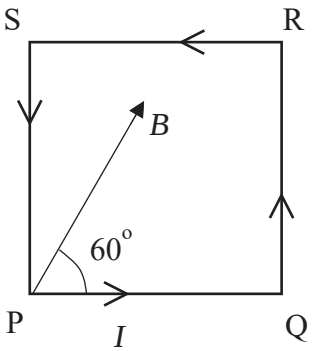

**B**




**C**




**D**

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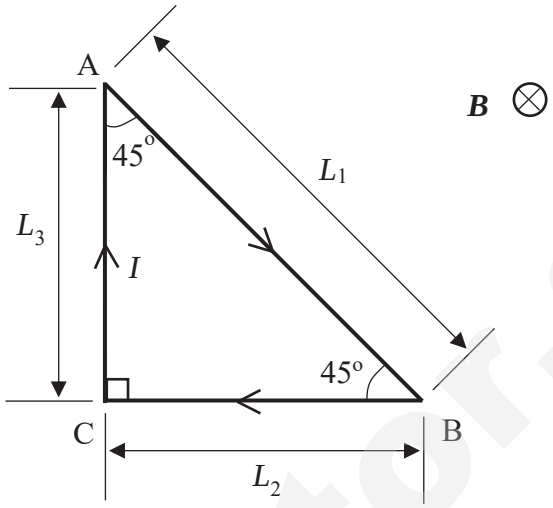
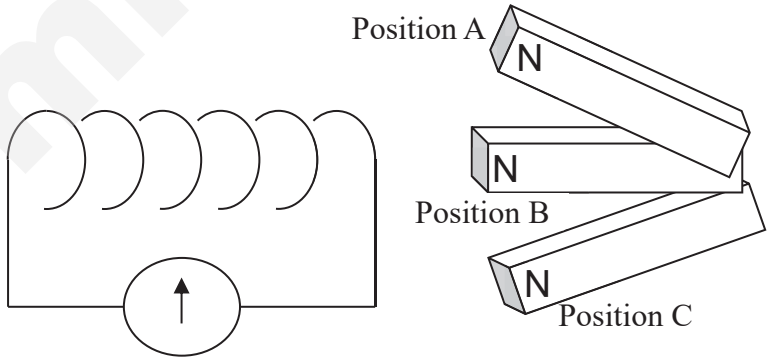
**22** A triangular coil ABC is placed in a uniform magnetic field of flux density $B$ = 1.8 T directed into the page. The coil carries a current $I$ = 0.14 A. The lengths of sides AB, BC and CA are $L_1$ , $L_2$ and $L_3$ respectively, where $L_1$ = 2.0 m. BC is horizontal while CA is vertical. AB is inclined at 45° to the vertical.




Determine the magnitude of the resultant magnetic force experienced by the coil.

**A** 1.19 N **B** 0.18 N **C** 0.94 N **D** zero

**23** The North pole of a bar magnet is rotated across one end of a coil of wire from position A to B to C as shown in the diagram below, at a rate of rotation $\omega$. The maximum movement of the galvanometer needle is 10 units to the left.




The North pole of a bar magnet is then rotated across the same end of the coil of wire from the reverse direction from positions C to B to A, at twice the rate of rotation. 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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**24** An ammeter uses the heating effect of a current to produce the deflection of the pointer. The reading, which is proportional to the heating, is $X$ when a direct circuit $I$ flows through the meter. When inserted in a circuit, in which an alternating circuit of r.m.s value $I$ flows, the reading is

**A** $X$, because it measures the r.m.s current which gives the same deflection on the scale as the direct current.

**B** $X/\sqrt{2}$, because it measures r.m.s current which is obtained by recalibrating the scale for a.c. use by dividing all scale readings by $\sqrt{2}$.

**C** $X / 2$, because the constantly changing current produces a constantly changing heating effect which averages to one half that of the direct current.

**D** zero, because the needle cannot follow the fast oscillations of the alternating current and hence registers zero on the scale.

**25** In a photoelectric experiment, photons of energy $4.7 \times 10^{-19}$ J fall onto a metal plate in a vacuum tube and electrons are emitted. The electrons are collected by an electrode and a current is detected. When the potential of the metal is made 0.50 V more positive than the electrode, the current reduces to zero. What is the work function energy of the metal?

**A** $3.1 \times 10^{-19}$ J

**B** $3.5 \times 10^{-19}$ J

**C** $3.9 \times 10^{-19}$ J

**D** $4.2 \times 10^{-19}$ J

**26** When a clean metal surface is irradiated with ultraviolet light of intensity $I$, electrons are emitted. When the intensity of the ultraviolet light is halved, which of the following happens?

**A** Electrons are no longer emitted

**B** Smaller number of electrons are emitted per second, with a lower maximum kinetic energy than before.

**C** Smaller number of electrons are emitted per second, each with the same maximum kinetic energy as before.

**D** Same number of electrons are emitted per second, each with the same maximum kinetic energy as before.

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**27** The ground state and the first excited state of a hydrogen atom is 0 and 10.2 eV respectively. The ionisation energy is 13.6 eV. An electron of energy 20.0 eV interacts with the atom. Which of the following processes is **not** possible?

**A** the hydrogen atom remains in the ground state
**B** the hydrogen atom is excited to the first excited state and the bombarding electron carries away 3.4 eV of kinetic energy
**C** the hydrogen atom is ionised, with excess kinetic energy carried away by the the bombarding electron and the electron ejected from the atom
**D** the hydrogen atom is excited to the fifth excited state. The bombarding electron carries away 20.0 eV less the fifth excitation energy

**28** An electron has a velocity of magnitude 500 m $s^{-1}$, accurate to within 0.010 %. Within what lower limit could we determine the position of it along the direction of the velocity?

**A** $1.5 \times 10^{-6}$ m **B** $1.5 \times 10^{-4}$ m **C** 0.015 m **D** 1.5 m

**29** Two deuterium $\left({}^{2}_{1}\mathrm{H}\right)$ nuclei fuse together to form a helium-3 $\left({}^{3}_{2}\mathrm{He}\right)$ nucleus with the release of a neutron:

$$ {}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} $$

The binding energies per nucleon for:

${}^{2}_{1}\mathrm{H}$ is 1.09 MeV,
${}^{3}_{2}\mathrm{He}$ is 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

**30** A detector is used for monitoring an α-source and a reading of 300 counts is observed. After a time equal to the half-life of the α-source, the reading has fallen to 155 counts. If a 5 mm thick lead sheet is inserted between the α-source and the detector, the reading would probably be

**A** 0 counts **B** 5 counts **C** 10 counts **D** 20 counts

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**VICTORIA JUNIOR COLLEGE**
**2019 JC2 PRELIMINARY EXAMINATIONS**
**Higher 2**

Name : _____ CT group : _____

**PHYSICS** **9749 / 02**

Paper 2 Structured Questions **18 September 2019**

**WEDNESDAY**

Candidates answer on the Question Paper. **8 – 10 am**

No Additional Materials are required. **2 Hours**

**READ THESE INSTRUCTIONS FIRST**

Write your name and CT group at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

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

Answer **all** questions.

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

| For Examiner's Use | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| Total (max. 80) | |

This question set consists of a total of **22** printed pages.



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**Data**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion, | $s = ut + (½)\,at^2$<br>$v^2 = u^2 + 2as$ |
| work done on/by a gas, | $W = p\Delta V$ |
| hydrostatic pressure, | $p = \rho gh$ |
| gravitational potential, | $\phi = -\frac{GM}{r}$ |
| temperature | $T/K = T/°C + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m., | $x = x_o \sin \omega t$ |
| velocity of particle in s.h.m., | $v = v_o \cos \omega t$<br>$= \pm\omega\sqrt{(x_o^2 - x^2)}$ |
| electric current | $I = Anvq$ |
| resistors in series, | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel, | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential, | $V = Q/4\pi\varepsilon_o r$ |
| alternating current/voltage, | $x = x_o \sin \omega t$ |
| Magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| Magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| Magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay, | $x = x_o \exp(-\lambda t)$ |
| decay constant, | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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**1** A motorist travelling at 13 m $s^{-1}$ approaches traffic lights, which turn red when he is 25 m away from the stop line. His reaction time (i.e. the interval between seeing the red light and applying the brakes) is 0.70 s. The condition of the road and his tyres is such that the car cannot slow down at a rate of more than 4.5 m $s^{-2}$.

**(a)** Calculate the time it takes for the car to come to a complete stop from the moment the motorist steps on the brakes.

Time taken = …….. s [1]

**(b)** Sketch a labelled velocity-time graph for the motion of the motorist, starting from the time when he first sees the traffic lights turn red, till the time his car comes to a complete stop.

[3]

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**(c)** Calculate the distance from the stop line when the car comes to a stop.

Distance = ……. m [2]

**(d)** A bird is flying horizontally in a straight line at a constant height of 50 m above the car with a speed of 6.0 m $s^{-1}$. It drops a twig at the same time that the motorist sights the red light when the bird is directly above the car. Deduce whether the twig will hit the car, showing the necessary calculations.

……..…….. [4]

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**2** **(a)** Define power.

……..……..

……..…….. [1]

**(b)** An aircraft of mass 1200 kg climbs upwards with a constant velocity of 45 m $s^{-1}$, as shown in **Fig. 2**.

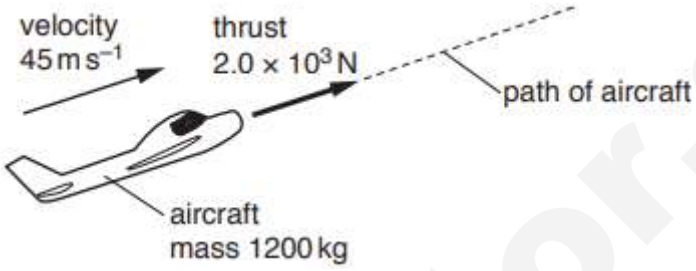


**Fig. 2**

The aircraft's engine produces a thrust of $2.0 \times 10^3$ N to move the aircraft through the air. The rate of increase in height is 3.3 m $s^{-1}$.

**(i)** Calculate the power produced by the thrust.

Power = ……. W [2]

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**(ii)** Determine, for a time interval of 3.0 minutes,

**1.** the work done by the thrust to move the aircraft,

Work done = …….. J [1]

**2.** the increase in gravitational potential energy of the aircraft,

Increase in GPE = …… J [2]

**3.** the work done against air resistance. Explain your working.

……

……

Work done = …….. J [2]

**(iii)** Use your answer in **(b)(ii) 3** to calculate the force due to air resistance acting on the aircraft.

Force due to air resistance = ……. N [1]



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**3** A sealed steel canister is being used to store neon gas (atomic mass = 20.2 u). The mass of the steel canister alone is 12.0 kg, and it has an interior volume of 8.0 litres ($8.0 \times 10^{-3}$ m$^3$). There are 4.50 moles of neon gas in the canister, and the temperature of the entire system is 300 K.

Reference information:
Specific heat capacity of steel $c_s = 448$ J kg$^{-1}$ K$^{-1}$
Molar heat capacity of neon = $C_n$ = 12.5 J mol$^{-1}$ K$^{-1}$
Specific heat capacity of water $c_w = 4186$ J kg$^{-1}$ K$^{-1}$
Specific latent heat of fusion of water $l_f$ = 3.33 x $10^5$ J kg$^{-1}$
Density of water $\rho_w$ = 1.00 x $10^3$ kg m$^{-3}$
Density of ice $\rho_i$ = 917 kg m$^{-3}$

**(a)** Determine the pressure within the canister.

Pressure = …… N m$^{-2}$ [3]

The sealed canister is now placed in a large tank containing a mixture of ice and water at 273 K. You may neglect any change in the volume of the canister.

**(b)** Determine the pressure of the neon gas after the cylinder and its contents have reached thermal equilibrium with the ice-water mixture.

$P$ = …… N m$^{-2}$ [3]


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**(c)** Determine the mass of ice that melts during the equilibration of the canister. Explain clearly how you arrived at your answer.

$M$ = …… kg [4]

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**4** **(a)** A diffraction grating is used to determine the wavelength of light.

**(i)** Explain what is meant by the diffraction of light.

……..

……..…….. [2]

**(ii)** Given that the diffraction grating has $N$ *l*ines per meter and the wavelength of light is $\lambda$, explain using equations how the maximum order of lines can be deduced.

……..

……..……

……..

……..……

……..

……..…….. [2]

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**(b)** A diffraction grating is used with different wavelengths of light. The angle $\theta$ of the second order maximum is measured for each wavelength. The variation with wavelength $\lambda$ of $\sin\theta$ is shown in **Fig. 4**.

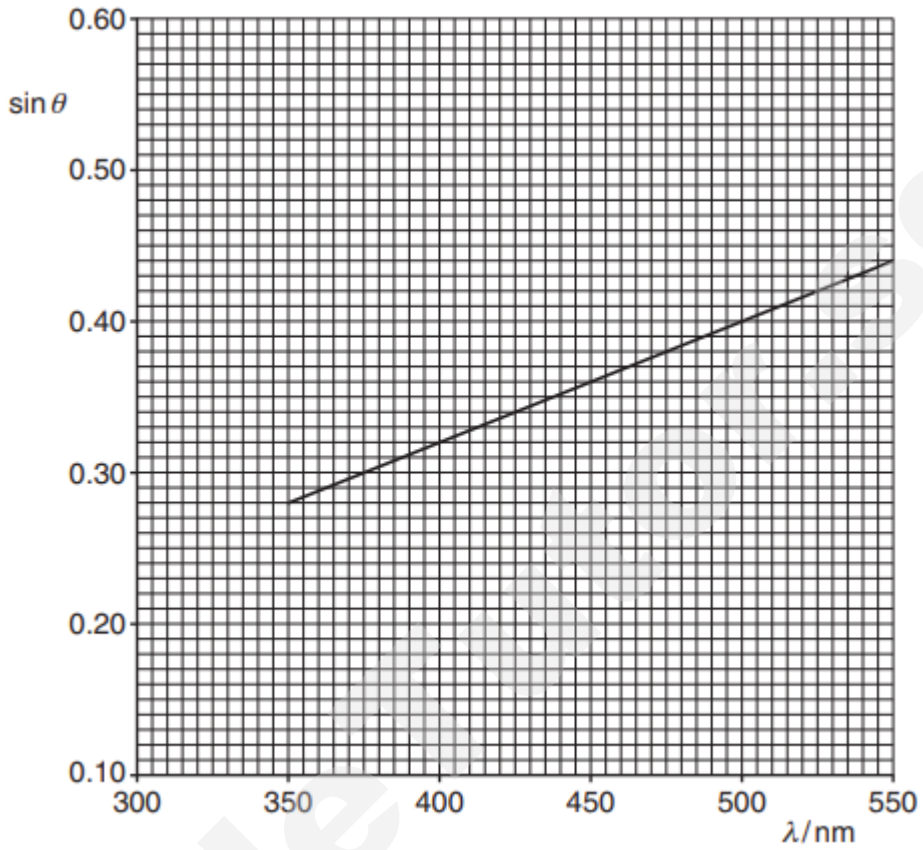


**Fig. 4**

**(i)** Determine the gradient of the line shown in **Fig. 4**.

Gradient = …… [2]



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**(ii)** Use the gradient in **(i)** to calculate the slit separation $d$ of the diffraction grating.

$d$ = …….. m [2]

**(iii)** Explain how the line in **Fig. 4** will change for the 1st order maximum with respect to its gradient and vertical intercept.

……..

……..

……..

……..…….. [2]

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**5** A mass spectrometer is a device used to analyse compounds and measure the charge-to-mass ratio of their constituent ions. In one such device shown in **Fig. 5.1**, a compound comprising two different elements is first vaporised and then ionised. The singly-charged ions of the two constituent elements are then accelerated, focused into a narrow beam, and then passed through a velocity selector, before they enter a magnetic field.

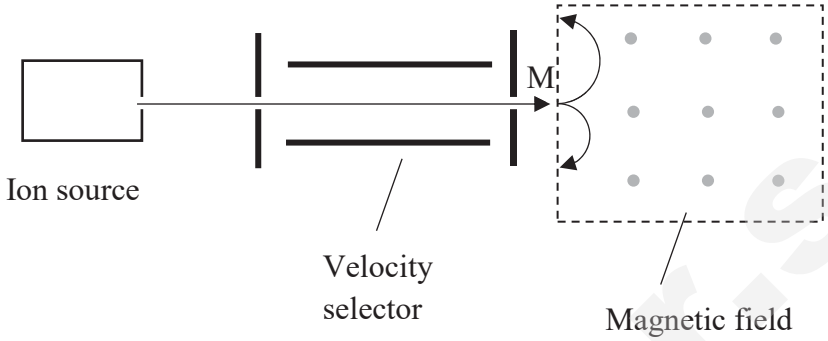


**Fig. 5.1**

**(a)** The electric field applied vertically downwards in the velocity selector has a strength of $1.21 \times 10^3$ V $m^{-1}$, while the magnetic field applied horizontally in the same space has a flux density of 0.015 T. This is shown in **Fig. 5.2**.

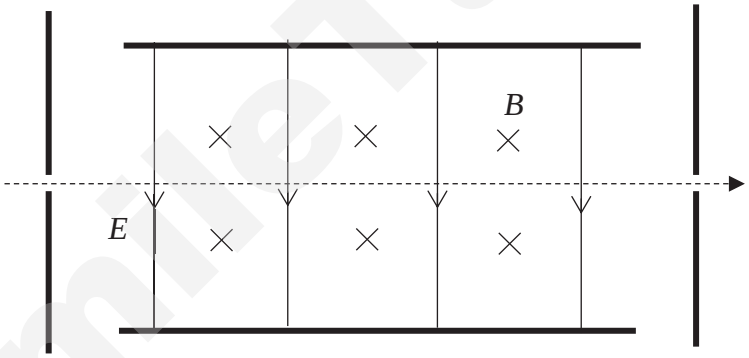


**Fig. 5.2**

**(i)** Calculate the speed that the ions must have for them to travel through the velocity selector in a straight path.

Speed = …….. m $s^{-1}$ [2]



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**(ii)** On **Fig. 5.2**, sketch the paths followed by the positive and negative ions that have speeds greater than that obtained in **(a)(i)**. Label the two paths **P** and **N** respectively. [1]

**(b)** After passing through the velocity selector, the singly-ionised ions enter a uniform magnetic field of flux density 1.6 T directed vertically out of the page at point M. They then follow the circular trajectories shown in **Fig. 5.3**.

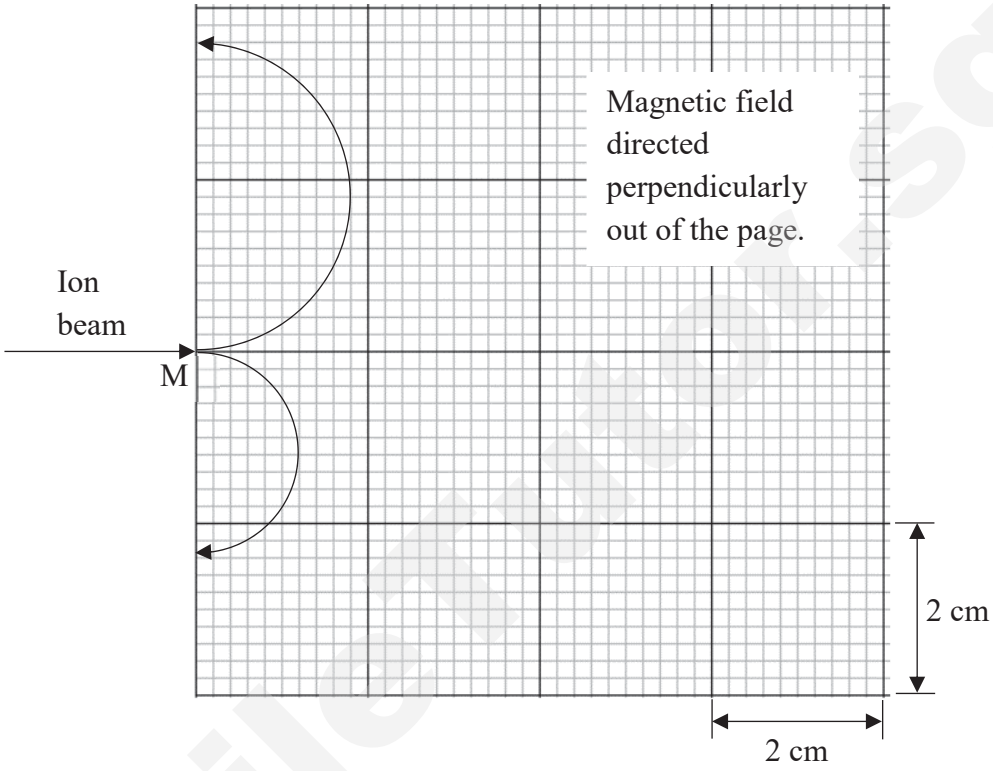


**Fig. 5.3**

**(i)** Use **Fig. 5.3** to determine the charge-to-mass ratios of the positive and negative ions in the compound.

Charge-to-mass ratio of positive ion = …….. C $kg^{-1}$

Charge-to-mass ratio of negative ion = …….. C $kg^{-1}$ [4]



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**Fig. 5.4** shows the first three rows of the Periodic Table and provides information on the eighteen lightest elements.

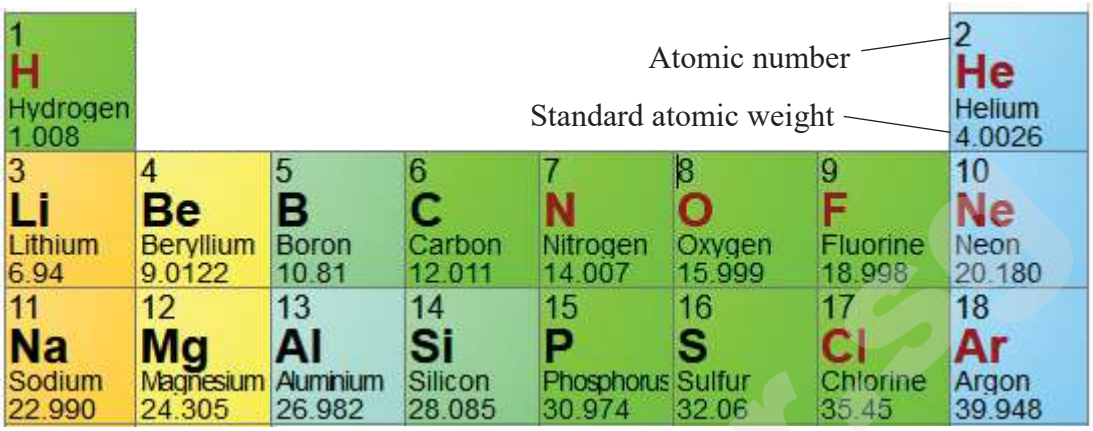


**Fig. 5.4**

**(ii)** Use your answer from **(b)(i)** to identify the compound used to produce the beam of positive and negative ions.

Identity of compound: …… [3]

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**6** The isotope Radium-224 undergoes spontaneous decay and as a result, ionising radiation is produced. A stationary Radium- 224 nucleus decays to a Radon (Rn) nucleus by emitting an α-particle with no gamma emission as shown in the equation below. The daughter nucleus is an isotope of Radon (Rn).

$$^{224}_{88}\text{Ra} \rightarrow {}^{A}_{\square}\text{Rn} + \alpha$$

**(a)** A deuterium nucleus has half the mass number and charge of the α-particle. Explain why a helium nucleus is more likely to be produced in the decay rather than two deuterium nuclei.

……..……

……..…….. [1]

**(b)** Determine the number of neutrons and protons in a nucleus of Rn.

Number of neutrons = ……..……..

Number of protons = …….. [1]

**(c)** The mass of the Radium nucleus is greater than the combined mass of the nuclei of Radon and the α-particle. Use a conservation law to explain how this decay is possible.

……..……

……..…….. [1]

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**(d)** The kinetic energy of the Rn nucleus is 0.1037 MeV. Determine the energy of the α-particle given the following information:

rest mass of $^{224}_{88}Ra$ = 224.0202 u

rest mass of Rn = 220.0114 u

rest mass of α-particle = 4.0026 u

Energy of α-particle = …… MeV [4]

**(e)** As the α-particle travels in air, ionisation of air occurs. A neutral molecule becomes an ion-electron pair. The energy required to produce an ion-electron pair from a neutral molecule at atmospheric pressure is 31 eV.

By estimating the range of an α-particle in air, calculate to two significant figures, the number of ion-electron pairs produced per unit length as the α-particle is stopped in air at atmospheric pressure.

Number of ion-electron pairs produced per unit length = ……. $m^{-1}$ [3]



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**7** **Read the passage below and answer the questions that follow.**

A piece of material is made in the form of a slab of material of thickness $\Delta x$ and of area $A$. One face is maintained at a temperature $\theta$ and the other at $\theta+\Delta\theta$. The heat $Q$ that flows perpendicular to the faces for a time $t$ is measured. The experiment is repeated with other slabs of the same material but with different values of $\Delta x$ and $A$. The results of such experiments show that, for a given value of $\Delta\theta$, $Q$ is proportional to the time $t$ and the area $A$. Also, for a given time and area, $Q$ is proportional to the ratio $\frac{\Delta\theta}{\Delta x}$. These results may be written as

$$\frac{Q}{t} \propto A\frac{\Delta\theta}{\Delta x} \text{ where } \Delta\theta = \theta_1 - \theta_2 \text{ and } \theta_1 > \theta_2,$$

The equation above can be written as

$$\frac{Q}{t} = kA\frac{\theta_1 - \theta_2}{\Delta x} \ldots\ldots (1)$$

where $k$ is known as the thermal conductivity.

Equation (1) is only approximately true. A more accurate version of the equation can be written as

$$\frac{dQ}{dt} = -kA\frac{d\theta}{dx} \ldots\ldots (2)$$

Suppose the conducting material lies between an inner cylinder of radius $r_1$ and an outer cylinder of radius $r_2$ both of length $L$. If the inner cylinder is maintained at a constant temperature $\theta_1$ and the outer at $\theta_2$, there will be a steady radial flow of heat at a constant rate $\frac{dQ}{dt}$. It can then be shown that

$$\frac{dQ}{dt} = \frac{k2\pi L(\theta_1 - \theta_2)}{ln\left(\frac{r_2}{r_1}\right)} \ldots\ldots (3)$$

Equation (3) refers only to heat flowing through the walls of the cylinder.

**(a)** By referring to equation (1), deduce the base units of $k$.

base units of $k$ : …….. [2]



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**(b)** In equation (2), suggest a reason for the negative sign.

……

……. [1]

**(c)** Jane is a connoisseur of fine teas. She is preparing her new tea with boiling water in her cylindrical mug with inner radius $r_1$ = 4.0 cm and length $L$ = 10.0 cm not including the thickness of the base. The thickness of the mug walls as well as of the base is $\Delta x$ = 5.0 mm. The mug has a lid for better insulation. The lid is also made of the same material as that of the mug. Assume it is flat and has the same thickness as the mug walls.

Jane pours her tea, filling her mug completely, and immediately places the lid on her mug.

As heat flows from the tea, the change in its temperature $\Delta T$ given by

$$Q = Mc\Delta T \ldots\ldots(4)$$

where $M$ is the mass of the tea water.

The following data are available:

Temperature of boiling water: $\theta_{boil}$ = 100 ºC.

Thermal conductivity of mug: $k$ = 1.0 in S.I. base units.

Room temperature: $\theta_{room}$ = 25 ºC.

Density of tea-water: $\rho$ = 1000 kg m$^{-3}$.

Specific heat capacity of tea-water: $c$ = 4180 J kg$^{-1}$ K$^{-1}$.

**(i)** Calculate the mass $M$ of the water in the mug.

$M$ = …… kg [2]



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**(ii)** Calculate a value for the *total* internal surface area $A$ of the mug with the lid on.

$A$ = …… m$^2$ [2]

**(iii)** Show that $\Delta T = (0.10)(\theta_{tea} - \theta_{room})$ after 30 s have elapsed, assuming equation (1) holds.

[2]

**(d)** The formula in **(c)(iii)** is used to evaluate the temperatures required to fill in the table shown in **Fig. 7.1**.

| **Time after pouring $t$/s** | **Initial $\theta_{tea}$/°C** | **Temperature change in 30 s $\Delta T$/ °C** | **Final $\theta_{tea}$/°C** |
|---|---|---|---|
| 0 | 100 | 7.5 | 92.5 |
| 30 | 92.5 | 6.8 | 85.7 |
| 60 | 85.7 | 6.1 | 79.6 |
| 90 | | | |
| 120 | 74.1 | 4.9 | 69.2 |
| 150 | 69.2 | 4.4 | 64.8 |
| 180 | 64.8 | 4.0 | 60.8 |
| 210 | 60.8 | 3.6 | 57.2 |
| 240 | 57.2 | 3.2 | 54.0 |
| 270 | 54.0 | 2.9 | 51.1 |

**Fig. 7.1**



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**(i)** Fill in the missing values in **Fig. 7.1** for $t = 90$ s. [2]

A graph to show the variation with time of the temperature of the tea is now drawn and shown in **Fig. 7.2**.

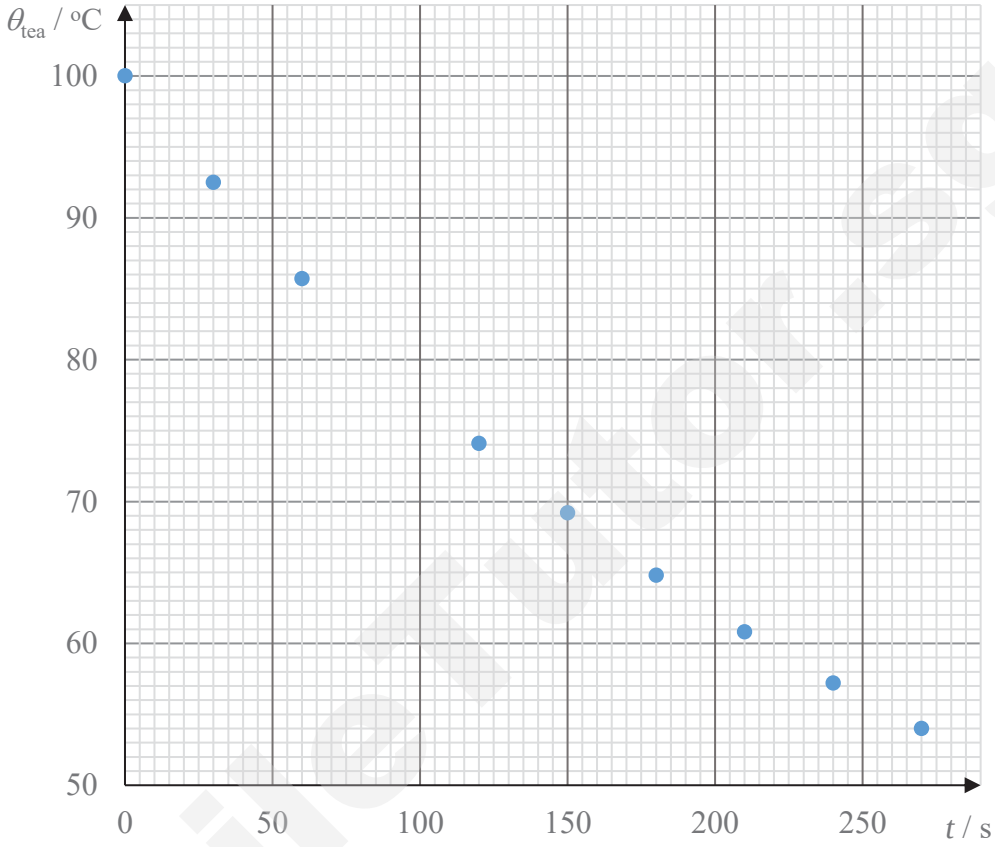


**Fig. 7.2**

**(ii)** Plot in the point corresponding to $t = 90$ s in **Fig. 7.1** and draw the best fit to the curve in **Fig. 7.2**. [2]

**(iii)** Determine the time taken for Jane's tea to drop from 100 °C to 55 °C.

$t$ = …….. s [1]



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**(e)** **(i)** Calculate the rate of heat loss when the tea temperature is 90 °C using equation (1) *only for heat flowing through the walls of the container*.

Rate of heat loss = …….. W [2]

**(ii)** Calculate the rate of heat loss when the tea temperature is 90 °C using equation (3) *only for heat flowing through the walls of the container*.

Rate of heat loss = …….. W [1]

**(iii)** Hence calculate the percentage error incurred in using equation (1).

Percentage error = …….. [1]

**(f)** Jane decides to reheat her tea from 55 °C to 70 °C with a small 1.1 kW heater she places into the tea. She wraps the whole mug with insulating material to prevent heat from escaping from the tea. Determine the time it takes for the tea to reach 70 °C. Assume all the energy supplied by the heater is absorbed by the water.

$t$ = …… s [2]

********* END *********



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**VICTORIA JUNIOR COLLEGE**
**2019 JC2 PRELIMINARY EXAMINATIONS**
**Higher 2**

Name : _____ CT group : _____

**PHYSICS** **9749 / 03**

Paper 3 Longer Structured Questions **24 September 2019**

**WEDNESDAY**

Candidates answer on the Question Paper. **2 – 4 pm**

No Additional Materials are required. **2 Hours**

**READ THESE INSTRUCTIONS FIRST**

Write your name and CT group at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

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

**Section A**
Answer **all** questions.

**Section B**
Answer **one** question only.

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

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

| For Examiner's Use | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| Total (max. 80) | |

This document consists of **25** printed pages and **1** blank page.



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**Data**

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

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**Formulae**

| | |
|---|---|
| uniformly accelerated motion, | $s = ut + (½)\,at^2$<br>$v^2 = u^2 + 2as$ |
| work done on/by a gas, | $W = p\Delta V$ |
| hydrostatic pressure, | $p = \rho gh$ |
| gravitational potential, | $\phi = -\frac{GM}{r}$ |
| temperature | $T/K = T/°C + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m., | $x = x_o \sin \omega t$ |
| velocity of particle in s.h.m., | $v = v_o \cos \omega t$<br>$= \pm\omega\sqrt{(x_o^2 - x^2)}$ |
| electric current | $I = Anvq$ |
| resistors in series, | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel, | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential, | $V = Q/4\pi\varepsilon_o r$ |
| alternating current/voltage, | $x = x_o \sin \omega t$ |
| Magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| Magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| Magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay, | $x = x_o \exp(-\lambda t)$ |
| decay constant, | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

**1** **(a)** Explain the meaning of the term *base quantity*. Give an example of a base quantity.

……..

……..

……..….

…….. [2]

**(b)** The volume $V$ of a liquid flowing through a pipe in time $t$ is given by the equation

$$\frac{V}{t} = \frac{\pi p r^4}{8CL},$$

where $p$ is the pressure difference between the ends of the pipe of radius $r$ and length $L$. The constant $C$ depends on the viscous force acting on the liquid.

In an experiment to determine the numerical value of $C$ for water, a student estimates the percentage uncertainties in his measurements as follows:

| Quantity | Percentage uncertainty |
|---|---|
| $V/t$ | 3 % |
| $p$ | 2 % |
| $L$ | 0.5 % |
| $r$ | 1 % |

Based on the data given, state and explain which is the most significant uncertainty.

……..

……..

……..….

…….. [2]



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**(c)** A body 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 force of 0.20 N acting in a westerly direction is applied to the body for 10 s.

**(i)** Calculate the acceleration of the body due to the applied force.

Magnitude = …….. m $s^{-2}$ [1]

Direction : …….. [1]

**(ii)** velocity of the body at the end of 10 s.

Magnitude = …….. m $s^{-1}$ [3]

Direction : ……... [1]



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**2** A man stands inside a lift that was initially moving at constant speed before it starts to **decelerate** at $t = 2.0$ s. It comes to rest at $t = 6.0$ s. The reaction force $R$ between his feet and the floor varies with time as shown in **Fig. 2.1**. For the sign convention, take the upward direction as positive.

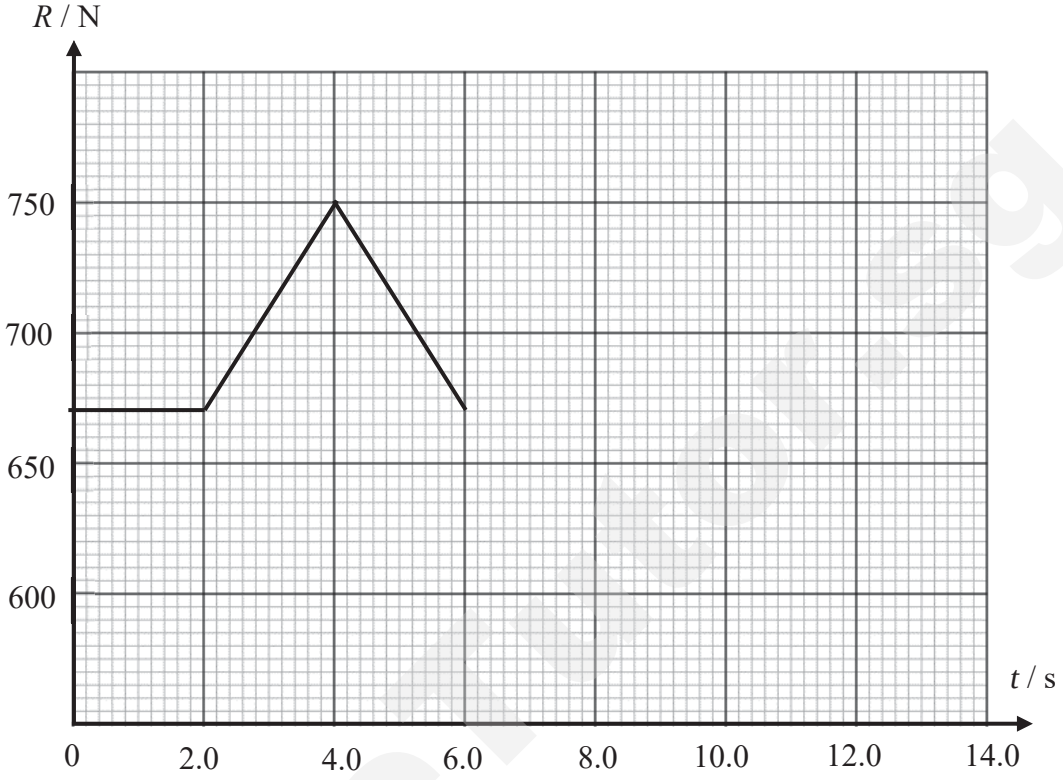


**Fig. 2.1**

**(a)** Determine the mass of the man.

Mass = …… kg [2]

**(b)** State and explain the direction of the motion of the man between $t = 2.0$ s and $t = 6.0$ s using Newton's 2nd Law.

……..

……..

……..

…… [2]



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**(c)** Using **Fig. 2.1**, show that the initial speed of the lift is 2.34 m $s^{-1}$.

Initial speed = …… m $s^{-1}$ [2]

At 10 s, the lift starts moving again, in the **same** direction.

**(d)** If the acceleration profile is the same as that of the deceleration between $t$ = 2.0 s and $t$ = 6.0 s, complete the graph on **Fig. 2.1** to show how the reaction force experienced by the man varies with time between $t$ = 6.0 s and $t$ = 14.0 s. [1]

The lift car has a mass of 1200 kg and is balanced by a counter-weight of mass 1320 kg, as shown in **Fig. 2.2**. Assume that no resistive forces are present to oppose the motion of the lift.

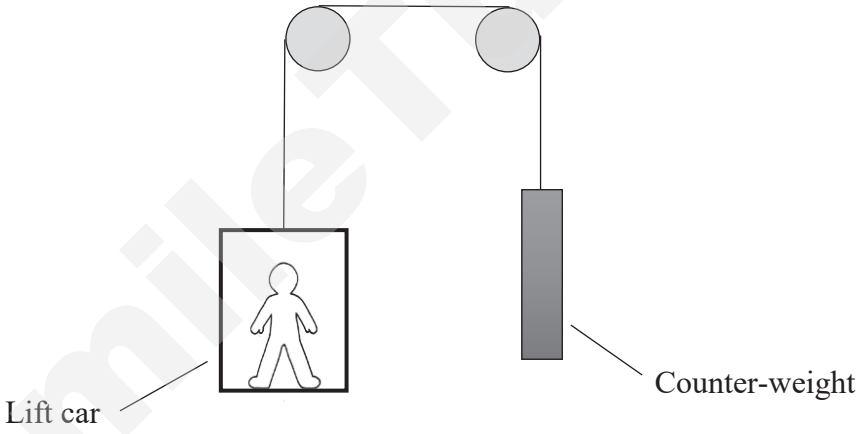


**Fig. 2.2**

**(e)** If the total mass of passsengers in the lift car is 420 kg and it is currently moving downwards with the constant speed calculated in **(c)**, calculate the power exerted by the lift motor.

Power = ……. W [3]



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**3** The masses of the Earth and the Moon each produce a gravitational field. The gravitational potentials at the Earth's and Moon's surfaces are $-62.3 \times 10^6$ J kg$^{-1}$ and $-3.9 \times 10^6$ J kg$^{-1}$ respectively. The mass of the Earth is $M_E$ and the mass of the Moon is $M_m$. The distance between the centres of the Earth and Moon is $D$.

**(a)** Sketch a graph to show the variation with distance of the net gravitational potential for the region between the surfaces of the Earth and the Moon in **Fig. 3.1**. Label the vertical axis with the relevant quantities, units and numerical values.

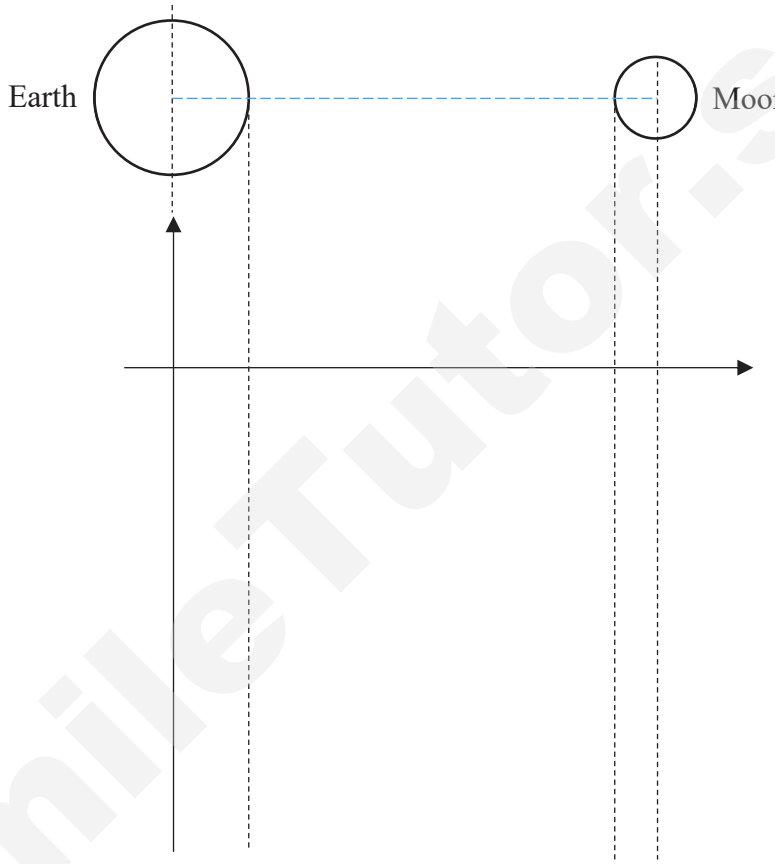


**Fig. 3.1**

[2]

**(b)** A 1000 kg satellite is launched from the Earth to the neutral point between the Earth and the Moon. It requires 6.1 x $10^{10}$ J in order to reach the neutral point.

**(i)** Explain what is meant by the neutral point. Indicate the position of the neutral point on **Fig. 3.1** with an "X".

……

……

……

…… [2]

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**(ii)** Determine the gravitational potential at the neutral point.

Gravitational potential = …….. J $kg^{-1}$ [2]

**(b)** Another 1000 kg satellite is launched from the Earth and has an orbital period $T$ of 27.3 days about the Earth, the same as the orbital period of the Moon. This means that the Earth, satellite and Moon remain in a straight line always, with the satellite between the Earth and Moon.

**(i)** With respect to **Fig. 3.1**, explain whether this satellite is located on the left or right of the neutral point.

……

……

……

…… [2]

**(ii)** The mass of the satellite is $m$. Write down an equation for the circular motion of the satellite about the Earth. The equation must include the masses of the satellite, the Earth and the Moon, the distances $D$ and $r$ where $r$ is the distance from the centre of the Earth to the satellite, and the angular velocity $\omega$ of the satellite.

[2]



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**4** A resistor of resistance of 8.2 kΩ and a LDR (light dependent resistor) are connected in series, as shown in **Fig 4.1**. The resistance of the LDR when light is shone on it is 420 Ω and when dark is 134 kΩ.

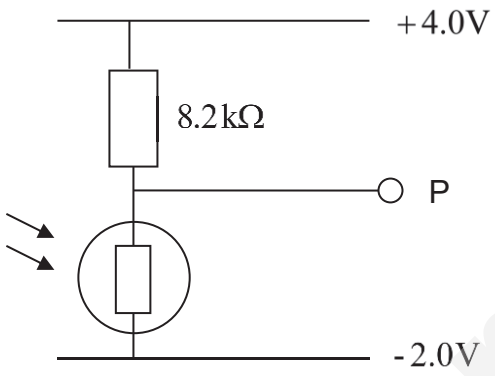


**Fig. 4.1**

**(a)** Calculate the potential at point P when

**(i)** light is shone on the LDR,

Potential = …… V [2]

**(ii)** no light is shone on the LDR (dark).

Potential = …… V [1]

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An alarm is now connected in parallel with the LDR in **Fig. 4.1** and a laser beam is directed at the LDR in a simple burglar alarm system. When a burglar blocks the laser that is shining continuously on the LDR, the alarm is triggered. Assume that the resistance of the alarm is very large.

**(iii)** Explain clearly how the LDR is used to turn on/off the alarm in such a system.

……

……

……

…… [2]

**(b)** A circuit is set up as shown in **Fig. 4.2** below. The potentiometer wire has a resistance of 1.5 Ω and is 1.00 m long. The movable contact J can be connected to any point along wire XY.

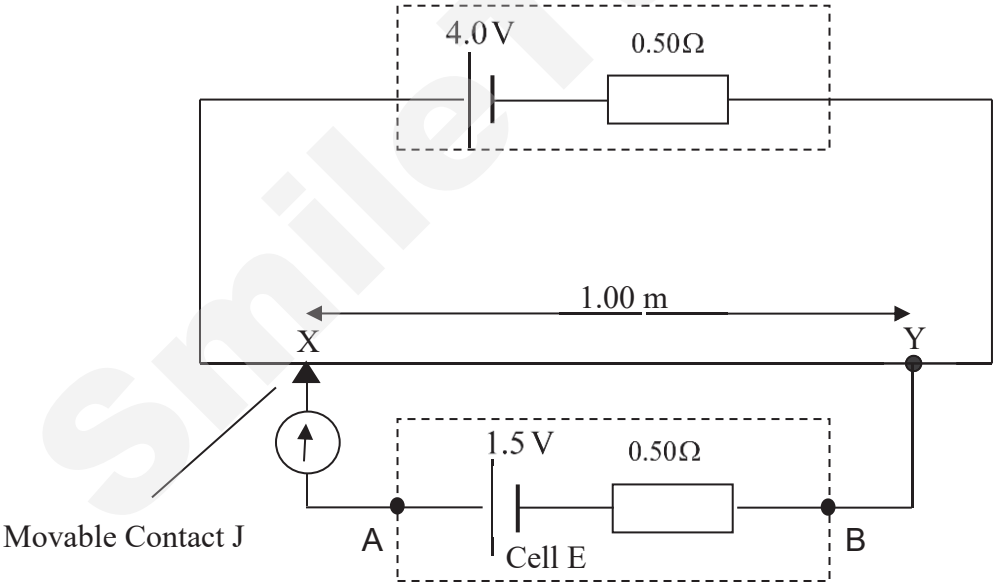


**Fig. 4.2**

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**(i)** Determine the distance of the contact J from X, such that there is no deflection in the galvanometer.

Distance = …… m [2]

**(ii)** A 1.50 Ω resistor is connected across points A and B (in parallel with cell E). Determine the new distance of the contact J from X, such that there is no deflection in the galvanometer.

Distance = ……. m [3]

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**5** **(a)** A copper disc of radius $r$ is made to spin at a constant rate between the poles of an electromagnet as shown in **Fig. 5.1**. When a voltmeter was connected across points P and R (see **Fig. 5.2**) by means of frictionless brushes, an e.m.f. of 10.0 mV was measured.

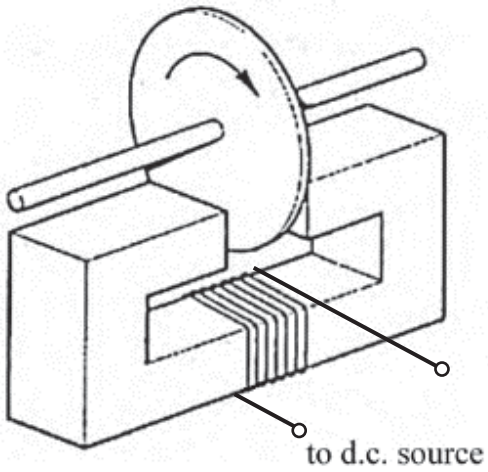


**Fig. 5.1**

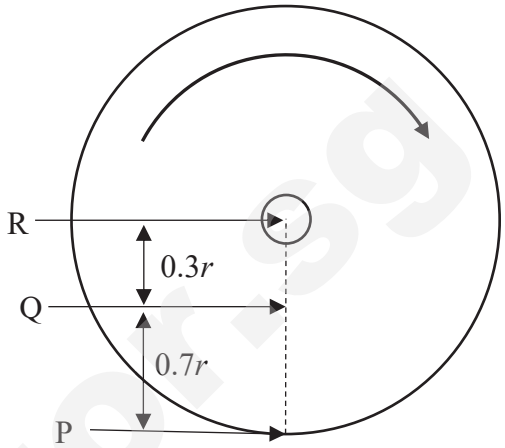


**Fig. 5.2**

**(i)** Explain how an e.m.f. is formed across PR when the disc spins.

……

……

……

…… [2]

**(ii)** Calculate the e.m.f. measured if the frictionless brushes were connected across QR. State your assumption.

e.m.f. = …… V [2]

Assumption: …….. [1]



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**(iii)** Hence calculate the e.m.f. generated when the brushes are connected across PQ.

e.m.f. generated = ……. V [1]

**(b)** In part **(a)**, P is at a higher potential compared to R.

**(i)** On **Fig. 5.2**, indicate clearly the direction of the magnetic field acting on the disc. [1]

**(ii)** On **Fig. 5.1**, indicate the polarity of the ends of the electromagnet facing the disc, using the letters 'N' and 'S'. [1]

**(iii)** On **Fig. 5.1**, indicate clearly the direction of current in the coil. [1]

**(c)** Suppose that a much larger magnet is now used such that the whole disc is subjected to a uniform magnetic flux density of $B$, in contrast to where only the bottom region of the disc is being subjected to the magnetic flux density of $B$.
State how this change would affect the value of e.m.f. across PR.

……..

…… [1]

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6 **(a)** A radiation detector is placed close to a radioactive source. The detector does not surround the source. Suggest a reason why the activity and the measured count rate may be different.

…… [1]

**(b)** The variation with time $t$ of the measured count rate in **(a)** is shown in **Fig. 6**.

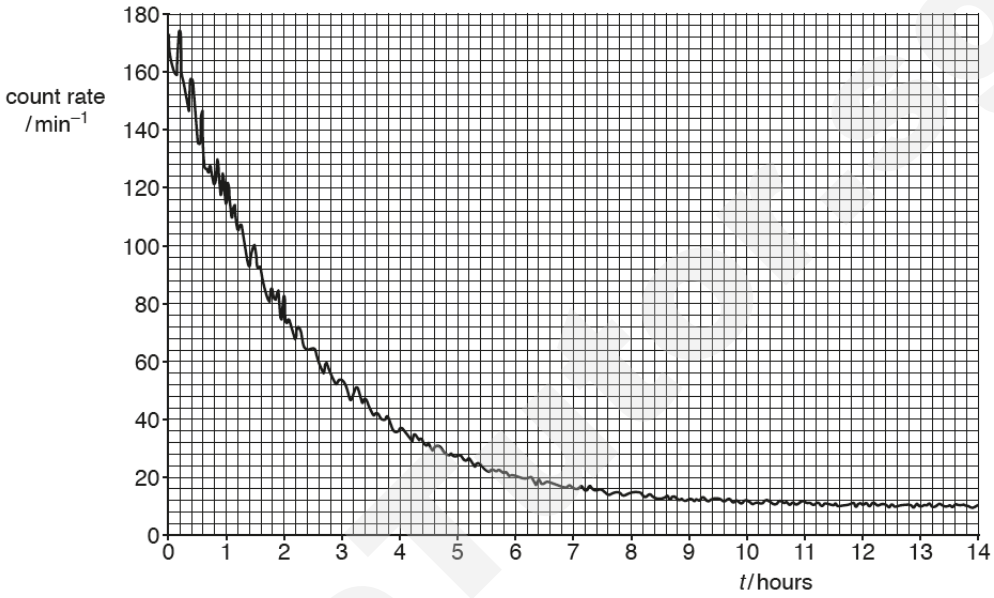


**Fig. 6**

**(i)** State the feature of **Fig. 6** that indicates the random nature of radioactive decay.

…… [1]

**(ii)** Use **Fig. 6** to determine the half-life of the radioactive isotope in the source.

Half-life = ..... hours [4]



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**(c)** The readings in **(b)** were obtained at room temperature. A second sample of this isotope with the same mass is heated to a temperature of 500 °C. The initial count rate at time $t = 0$ is the same as that in **(b)**. The variation with time $t$ of the measured count rate from the heated source is determined.

State, with a reason, the difference, if any, in

**(i)** the half-life,

……..

……..

……..

…… [2]

**(ii)** the measured count rate over a specific time interval.

……..

……..

……..

…… [2]

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## Section B

Answer **one** question from this section in the spaces provided.

**7** **(a)** Define simple harmonic motion.

……..

……..

……..

……..... [2]

**(b)** **(i)** Define angular frequency $\omega$ and state its relationship to the periodic time $T$ of simple harmonic motion.

……..

……..

……..

……..... [2]

**(ii)** The angular frequency $\omega$ of a simple pendulum undergoing small oscillations is related to its length $L$ by the formula $\omega^2 = g/L$ where $g$ is the acceleration due to gravity. Derive a formula for the period of small oscillations of the pendulum.

[1]



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**(iii)** A small smooth ball is making small oscillations near the bottom of a smooth semi-circular saucer a shown in **Fig. 7.1**.

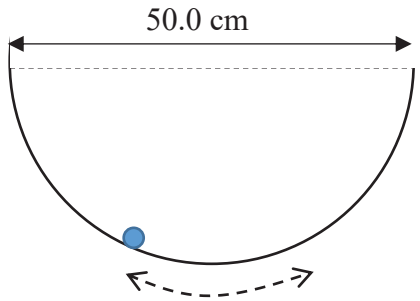


**Fig. 7.1**

With reference to **(b)(ii)**, determine the periodic time $T$ of the oscillations of the ball. Explain how you arrived at your answer.

$T$ = …….. [3]

**(c)** **(i)** State what is meant by an ideal gas.

……

……

…….. [2]

**(ii)** Show how the Ideal Gas Equation reduces to Boyle's Law under the right conditions. State those conditions.

……

……

……

…… [2]



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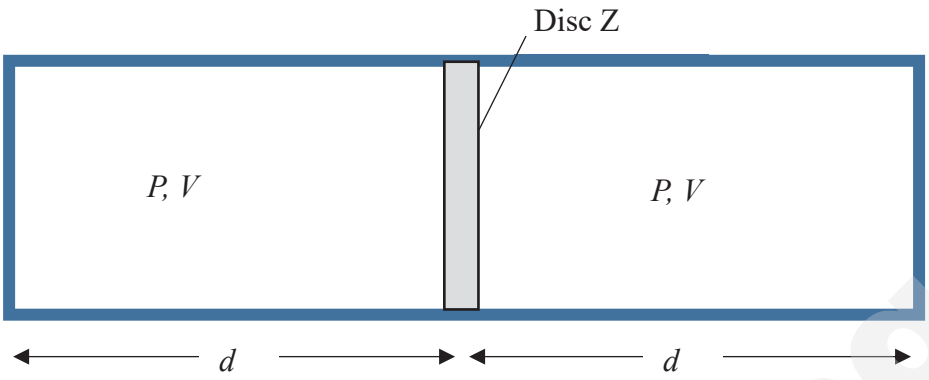


**Fig. 7.2**

A thin, frictionless disc Z of mass $m$ divides an air-tight, cylindrical container into two equal chambers as shown in **Fig. 7.2**. The chambers contain an ideal gas, and the gas pressure is $P$ in each of the two chambers. The length of each chamber is $d$, and the volume is $V$. The area of the disc is $A$. The disc can move freely and horizontally in the container.

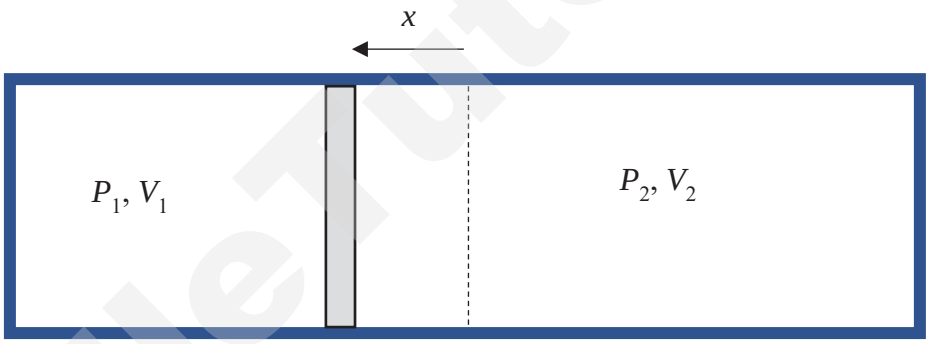


**Fig. 7.3**

The disc is now displaced to the left by a *small* distance $x$. The forces acting on the disc corresponding to pressures $P_1$ and $P_2$ are respectively $F_1$ and $F_2$. When released, the piston oscillates simple harmonically about its equilibrium position.

**(iii)** Draw the forces $F_1$ and $F_2$ acting on the disc in **Fig. 7.3**. [1]


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**(iv)** Assuming Boyle's Law is valid, show that

$$F_1(d - x) = F_2(d + x) = PAd$$

when the disc is in the position shown in **Fig. 7.3**,

[2]

**(v)** Using Newton's Second Law, show that

$$ma = -2\frac{PAdx}{d^2 - x^2}$$

where $a$ is the acceleration of the piston.

[2]

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**(vi)** Hence derive an expression for the period $T$ of motion of the disc.

[2]

**(vii)** Calculate $T$ given that $P = 100$ Pa, $A = 100$ cm$^2$, $d = 0.50$ m and $m = 1.0$ kg.

$T$ = …….. s [1]

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**8** **(a)** **(i)** State what is meant by photoelectric effect.

……

…… [1]

**(ii)** State two observations of photoelectric effect which provided evidence of the particulate nature of electromagnetic radiation.

……

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…… [2]

**(iii)** Describe, using a circuit diagram, an experiment to determine the maximum kinetic energy of photoelectrons.

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…… [4]

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**(b)** State the forms of energy associated with an orbiting electron in an atom.

……

…… [1]

**(c)** **Fig. 8.1** shows a cooler region of hydrogen gas surrounding a hot gas cloud emitting white light. Point C lies within the cooler hydrogen gas.

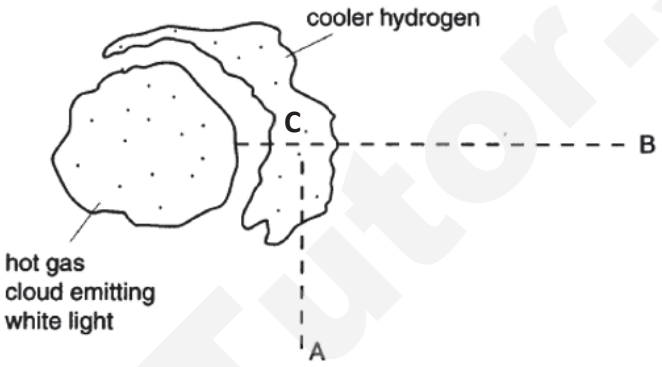


**Fig. 8.1**

**(i)** Using a prism or diffraction grating, state and explain the types of line spectra that can be observed from

**1.** point A, along the line AC.

……

……

……

…… [2]

**2.** point B, along the line BC.

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…… [2]



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**(ii)** **Fig. 8.2** shows some of the energy levels of a hydrogen atom.

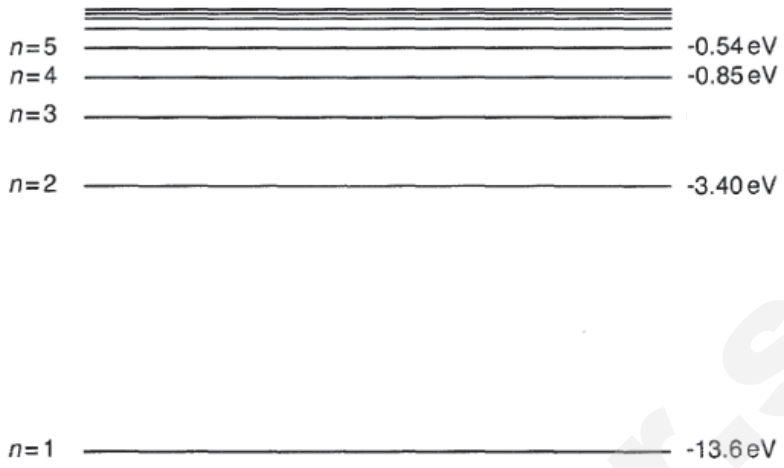


**Fig. 8.2**

**1.** Calculate the frequency of the electromagnetic radiation emitted when an electron makes a transition between energy levels $n = 4$ and $n = 2$ shown in **Fig. 8.2**.

Frequency = …… Hz [1]

**2.** The frequency of radiation emitted when an electron makes a transition between energy levels $n = 4$ and $n = 3$ is $1.60 \times 10^{14}$ Hz. Determine the wavelength of the electromagnetic radiation when an electron makes a transition between energy levels $n = 3$ and $n = 2$.

Wavelength = …… m [2]



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**(d)** A neutron of mass 1.00 u is travelling with velocity $1.0 \times 10^5$ m $s^{-1}$.

**(i)** Calculate the de Broglie wavelength of the neutron.

Wavelength = …… m [2]

**(ii)** Explain why it is much more difficult to demonstrate the wave nature of neutrons than it is for electrons. Assume that a neutron beam is available.

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…… [3]

******** END *******

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**VICTORIA JUNIOR COLLEGE**
**2019 JC2 Physics Preliminary Practical Examination**
**Higher 2**

Name : _____ CT group : _____

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**PHYSICS** **9749/04**
**5 Sep 2019**
**THURSDAY**

**($2\frac{1}{2}$ Hours)**

**READ THESE INSTRUCTIONS FIRST**

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

You will be allowed a maximum of 1 hour to work with the apparatus for Questions 1 and 2, and a maximum of 1 hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

| Shift |
|---|
| |
| **Laboratory** |
| |

Write your answers in the spaces provided on the question paper.

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

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

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

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

| For Examiners' use | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| Total | |

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**1**. In this experiment, you will investigate how the motion of an oscillating system depends on the mass attached to the system.

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

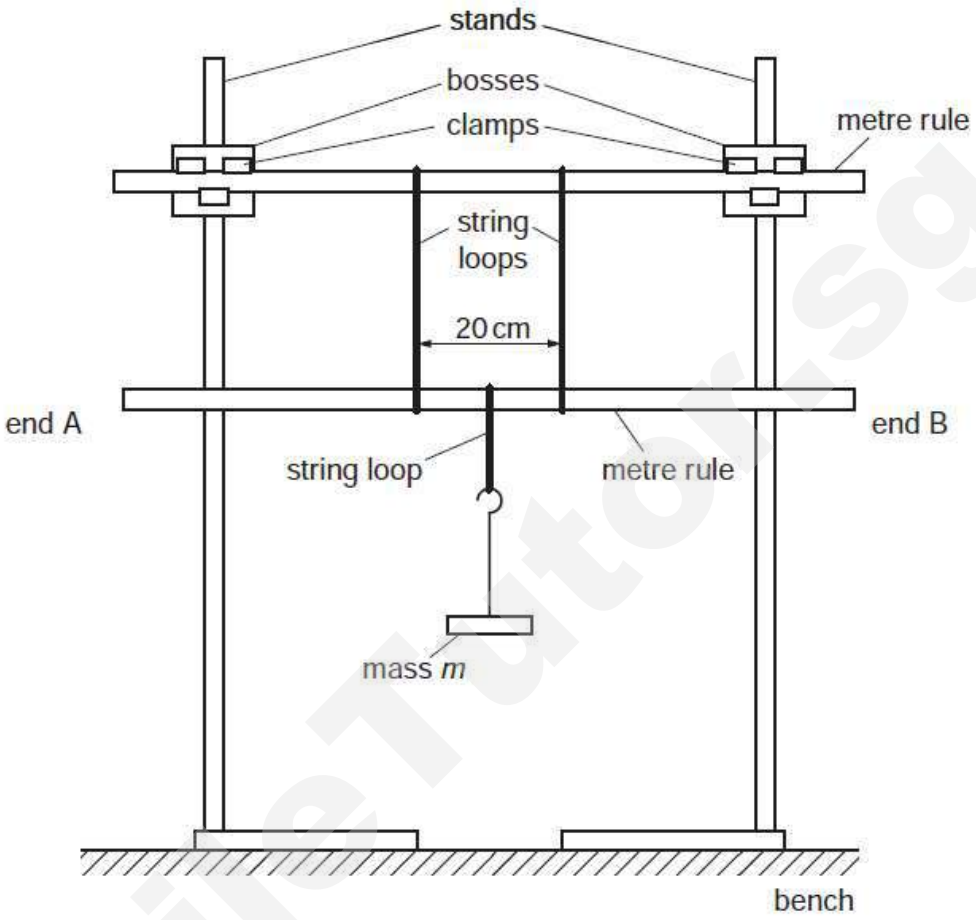


**Fig. 1.1**

Using the string provided, make two loops of string of approximately 40 cm in **circumference** each. Slide the two loops of string onto the rule on top and fix this rule in the clamps.

Adjust the clamps until the rule is parallel to the bench. Slide a second rule into the two loops. Both rules should have their markings facing you. The strings should be vertical, 20 cm apart and at equal distances from the centre of the second rule.

**(i)** By using the mass hanger and selecting an adequate number of slotted masses, make mass *m* to be approximately 0.20 kg.

**(ii)** Tie a string from the middle of the bottom rule to the mass hanger. The distance from the bottom of the rule to the top of mass hanger should be about 10 cm. Move the end A of the bottom rule towards you and the end B away from you. Release the rule and watch the movement.

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Determine the time taken for one oscillation $T$.

$T$=…….... [2]

**(iii)** Estimate the percentage uncertainty in your value of $T$.

Percentage uncertainty in $T$=…….... [2]

**(b)** Increase $m$ to approximately 0.40 kg and repeat (a)(ii).

$m$ =……..kg

$T$=…….... [1]

**(c)** It is suggested that the quantities $m$ and $T$ are related by the equation

$$\frac{1}{T^2} = km$$

where $k$ is a constant.

**(i)** Use your answers in **(a)** and **(b)** to determine two values of $k$. Give your values of $k$ to an appropriate number of significant figures, together with its unit.

First value of $k$ =……....
Second value of $k$ =……..……..... [2]

**(ii)** State whether the results of your experiment support the suggested relationship in **(c)** by referring to **(a)(iii).**

……

……

……[2]

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**(d)** State one significant source of error in this experiment and an improvement to overcome it.

……

……

……

……

[2]

**(e)** The behaviour of the oscillating system also depends on the circumference of the two long vertical string loops. It is suggested that the square of the period $T$ is proportional to the circumference of these loops.

Explain how you would investigate the relationship using the same apparatus.

Your account should include

- your experimental procedure
- control of variables
- how you would use your results to show the relationship is valid or otherwise.

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…...……[4]

[15 marks]

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**2**. In this experiment, you will stretch a rubber band by suspending a load of mass *m* from it.

**(a) (i)** Set up the apparatus as shown in **Fig. 2.1.**

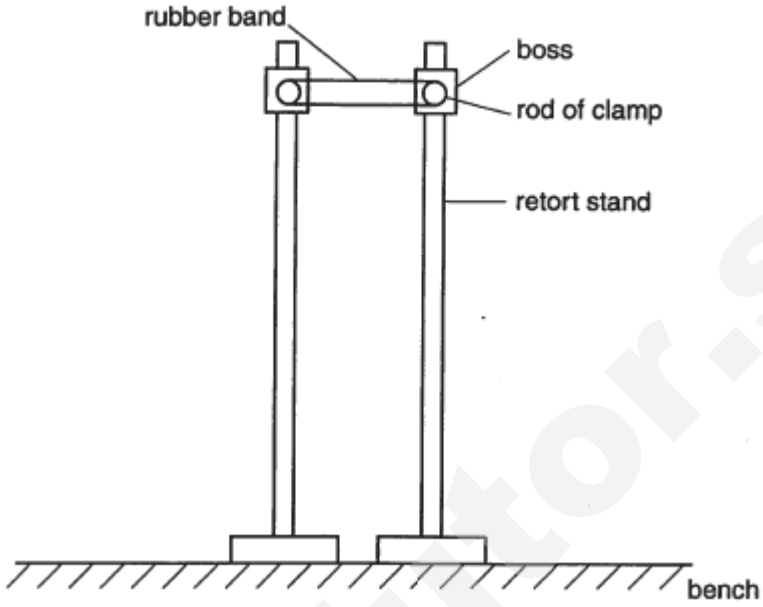


**Fig. 2.1**

Ensure that the rods of the two clamps are at the same height above the bench.

Position the two stands so that the rubber band is *just* about taut. Stabilise the stands with a brick placed on the bases of the stands.

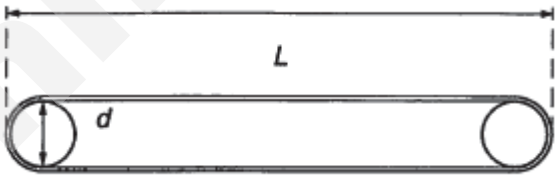


**Fig. 2.2**

Measure and record the length *L* as shown in **Fig. 2.2**.

*L* =……..[1]

**(ii)** Measure with a vernier caliper and record the diameter *d* of the rod as shown in **Fig. 2.2**

*d* = ……[1]

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**(b)** **(i)** Suspend the 100 g mass hanger from the centre of the lower part of the rubber band as shown in **Fig. 2.3**.

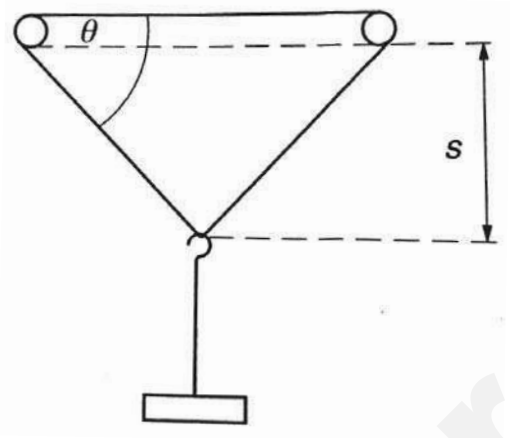


**Fig. 2.3**

Determine and record the displacement *s* of the rubber band as shown in **Fig. 2.3**.

*s* = ……[2]

**(ii)** Use your values from **a(i)** and **b(i)** to determine the angle $\theta$ as shown in **Fig.2.3.**

$\theta$=……..[2]

**(iii)** Justify the number of significant figures which you have given for $\theta$.

.....

.....

……..…. [1]

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**(c)** A student suggested that $m$, $s$ and $\theta$ are related by the expression

$$m = k\left[s - \frac{L\sin\theta}{2}\right]$$

where $k$ is a constant.

Use your results to determine a value for $k$ with its unit.

$k$ = ..... [1]

[8 marks]

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**3** In this experiment you will investigate how the current in a wire depends on the length of the wire. You will use the results of your experiment to determine a value for the resistivity of the material of wire Z.

**(a)** Set up the circuit in **Fig. 3.1**.The potential divider circuit comprises three dry cells in series and is connected to a resistance wire W.

Set the multimeter to read current up to10 A. Attach a connecting lead from the multimeter to point X on wire W. Connect the other lead from the multimeter to the bare wire Z at the zero end of the metre rule at point O. The lead should be attached as close as possible to the zero mark on the rule.

Using another connecting lead with a crocodile clip, attach the clip to point P of wire Z on the metre rule. Connect the other end of the lead to point Y on wire W so that the potential difference between points X and Y is a fraction of the total potential difference across the resistance wire W. Monitor the potential difference across XY using an analogue voltmeter.

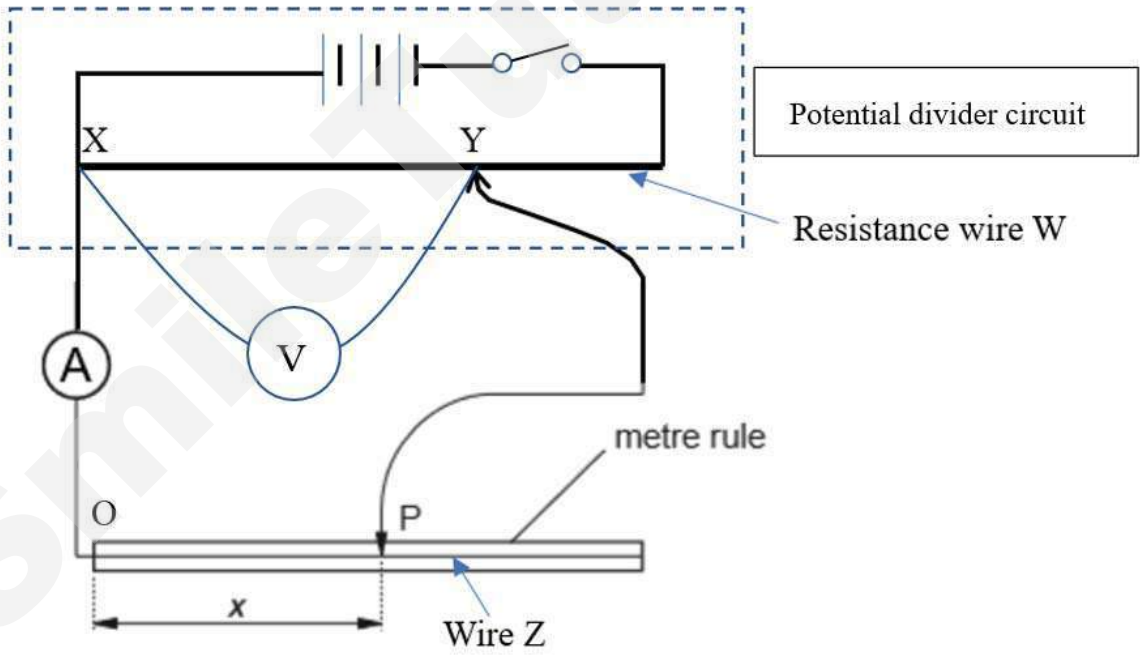


**Fig. 3.1**

**(b) (i)** Place the connecting clip P onto the wire such that $x$ = 40 cm. Adjust the power supply in the potential divider circuit to give a constant output voltage of 2 V across XY. Measure and record the length $x$ and the current $I$.

$x$ = ..... m[1]

$I$ = ..... A [1]

Note: switch off the circuit when not taking measurements as the wires can become quite hot.

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**(ii)** State one way of improving the precision in the measurement of $x$.

……..

……..

……[1]

**(c)** Change the value of $x$ and repeat **(b)(i)** until you have six sets of readings of $x$ and current $I$ for values of $x$ from 40 cm to 90 cm inclusive. You will need to adjust the potential divider circuit to maintain a constant output potential difference of 2 V across XY for each measurement of $x$ and $I$. Include in your table of results values for lg $x$ and lg $I$.

[3]

**(d) (i)** Plot a graph of lg $x$ (y-axis) against lg $I$ (x-axis). [2]

**(ii)** Draw the line of best fit. [1]

**(iii)** Determine the gradient and y-intercept of this line.

Gradient = ……[1]

y-intercept = ……[1]

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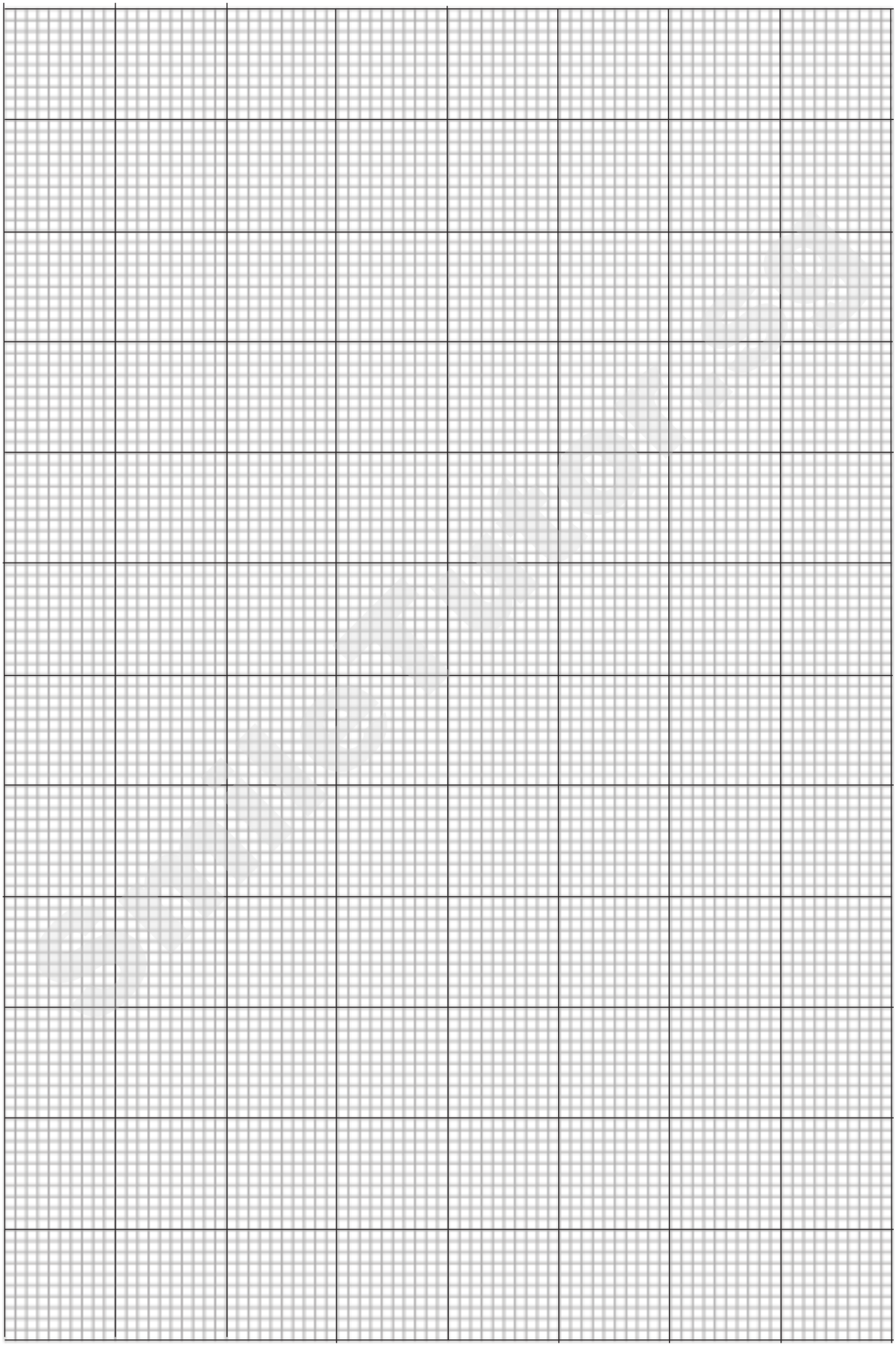

**(e)** $x$ and $I$ are related by a simple power law of the form

$$x = kI^n$$

where $n$ and $k$ are constants.

Use your answers from **(d) (iii)** to find the values of $k$ and $n$. You need not be concerned with the units of these quantities.

$k$ = ……

$n$ = ……[3]

**(f)** A simple theoretical treatment of this circuit gives

$$k = \frac{VA}{\rho}$$

where $V$ is the potential difference across wire Z, $A$ is the cross-sectional area of the wire and $\rho$ is the resistivity of the material of the wire.

**(i)** Remove the crocodile clip from wire Z. Use a micrometer screw gauge to measure the diameter $d$ of the wire.

$d$ = ……mm[1]

**(ii)** Determine the cross-sectional area $A$ of the wire.

$A$ = …….. $m^2$[1]

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**(iii)** Determine the percentage uncertainty in $A$.

Percentage uncertainty in $A$ = ……..%[2]

**(g)** Using your answers from **(e)** and **(f)**, determine a value for $\rho$ together with its unit.

$\rho$ = ……[1]

**(h)** The experiment is repeated with a wire of the same material but twice the diameter. Suggest what value of $k$ would be obtained.

$k$ = ……[1]

[20 marks]

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4. The study of how fluids flow through tubes is important for medical applications, amongst other uses. For example, the rate at which medication is delivered to bed-bound patients via intravenous needles must be properly controlled to avoid adverse reactions.

The volume rate of flow $Q$ of an incompressible liquid through a long and narrow horizontal tube is thought to depend on the difference in liquid pressure $\Delta p$ between its two ends as well as the radius $r$ of the tube, amongst other variables, according to the relation

$$Q = k(\Delta p)^x r^y$$

where $k$, $x$ and $y$ are constants. This relation is valid when the liquid flow is smooth and not turbulent (chaotic).

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

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to

**(a)** the equipment you would use
**(b)** the procedure to be followed
**(c)** how you would establish a steady flow rate through the tube
**(d)** the control of variables
**(e)** any precautions that should be taken to improve the accuracy and safety of the experiment.

[12 marks]

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********** END OF PAPER ********

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**VICTORIA JUNIOR COLLEGE**

**SUGGESTED ANSWERS TO 2019 PHYSICS H2P1 PRELIM EXAMS**

Q1.
Assume a person's head to be the shape of a sphere and half of it is covered with hair.
Diameter of a person's head, $d \approx 20$ cm
Surface area of head covered with hair,
$A = 2\pi r^2 = 2\pi(20/2)^2 \approx 628$ cm$^2$
Assume there are 2 strands of hair in an area of 1 mm$^2$
Number of hair on a person's head = 62800 x 2 = 125600
Closest estimate is 100 000

**Ans: D**

Q2.
The new calibrated graph passes through the origin and is parallel to the original graph.
When reading on meter Q is 5.0 V, from the new graph, reading is 7.4 V.

**Ans: D**

Q3.
Total distance travelled by the car over 10 s = 20 (2.0) + 40 (2.0) + 60 (6.0) = 480 m
Overall average speed of the car = 480 / (2.0 + 2.0 + 6.0) = 48 m s$^{-1}$

**Ans: D**

Q4.

To hover at rest,
Upward force on suit = weight of suit = $W$
By Newton's 3rd Law,
Downward force that accelerate ions = upward force = $W$
By Newton's 2nd Law,

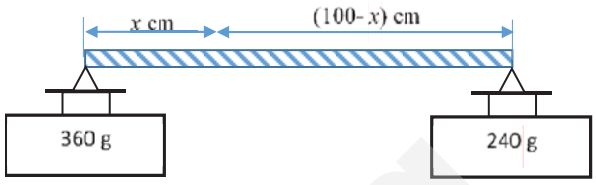
$$F = \frac{dp}{dt} = \frac{dm}{dt} \times \Delta v$$

$$\frac{dm}{dt} \times 30{,}000 = 250 \times 9.81$$

$\therefore$ mass of ions expelled per unit time = $dm/dt$ = 0.082 kg s$^{-1}$.

**Ans: B**

Q5.




Let the centre of gravity be $x$ in cm from the left hand end of the rod. Then the c.g. will be (100 - $x$ ) in cm from the right hand end of the rod. Taking moments about the c.g. should give net zero moments. Hence
(360 x 10$^{-3}$)g $x$ = (240 x 10$^{-3}$)g (100 - $x$)
$600x = 24000$
$x = 40$ cm
As the geometrical cetre is at the 50 cm mark, the c.g. is 10 cm left of the geometrical centre.

**Ans: A**

Q6
The total forward force produced, $F = f + ma$
= 160 +1200×0.20 = 400 N
Total power output developed = $Fv$
= 400×10 = 4.0 kW

**Ans: D**

Q7
Work done by person= gain in GPE of box + work done against friction
= $mgh + fd$, where $d$ is the distance moved along the slope.
= 200×1.5 +150×1.5/sin(30°) = 750 J

**Ans: D**

Q8
Given $r_A = 4r_B$, $f_A = f_B = \frac{1}{60}$ Hz,
Using $a_c = r\omega^2$, $\omega = 2\pi f = 0.10467$ rad s$^{-1}$
$10 = r_A(2\pi 0.0167)^2$
$r_A = 913$ m
$v_B = r_B\omega = \frac{1}{4}r_A\omega = 23.89 \approx 24$ m s$^{-1}$
$a_B = r_B\omega^2 = \frac{1}{4}r_A\omega^2 \approx 2.50$ m s$^{-2}$

**Ans: B**



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Q9

At X:

$N + mg = mv^2/r$

$N = mv^2/r - mg$

$v = \sqrt{rg}$ when $N \approx 0$

Since GPE at X and Y is the same, KE at X = KE at Y.

At Y:

$mg - N = mv^2/2r$

$N = mg - m(rg)/2r$

$N = mg/2$

**Ans: B**

Q10

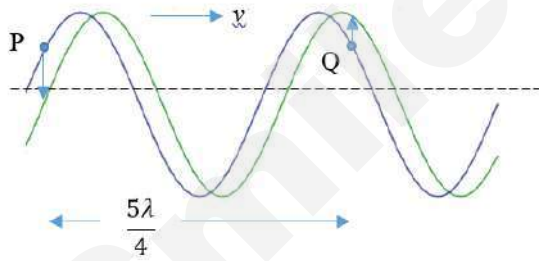
$v = f\lambda$

Wavelength $\lambda$ = 320 / 400 = 0.80 m

$\frac{\emptyset}{2\pi} = \frac{x}{\lambda}$ or $\frac{\emptyset}{2\pi} = \frac{0.20}{0.80}$; $\phi = \frac{\pi}{2}$ rad

**Ans: C**

Q11




**Ans: B**

Q12

The object takes a total of 2.0 + 6.0 = 8.0 s to make a complete oscillation. Hence the period is T = 8.0 s.

Angular frequency $\omega = \frac{2\pi}{T} = \frac{2\pi}{8.0}$

≈ 0.79 rad $s^{-1}$

**Ans: A**

Q13

The root mean square speed of the helium atoms is given by $v_{rms} = \sqrt{\frac{3RT}{M_m}}$. Since temperature $T$ and molar mass $M_m$ are constant, the root mean square speed of helium atoms is the same in both sections of the container. Option B seems to be the answer.

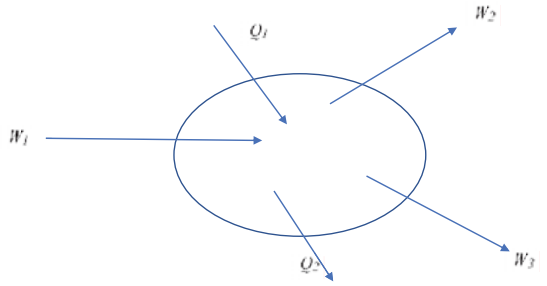
The gas pressure is given by $p = \frac{nRT}{V}$. Since $V$ and $T$ are constant but not the number of moles $n$, the pressure is not the same in both sections.

Since force is proportional to pressure $p$ exerted by the molecules on the wall, the force exerted by molecules in the two sections is not the same. Also, since force $F$ is given by $F = \frac{N(2mv)}{t}$ by N2L, ($m$ and $v$ are the mass and average speed of the helium atom) the rate of collisions $\frac{N}{t}$ of the wall by the atoms in both sections will not be the same.

The Ideal Gas equation can also be written as $pV = \frac{M}{M_m} RT$ or $p = \frac{\rho}{M_m} RT$ where $M_m$ and $\rho$ are the molar mass and density of helium respectively. Since $T$ is constant but not pressure $p$, the gas density $\rho$ is also not the same in both sections.

**Ans: B**

Q14



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The First Law of Thermodynamics states that $\Delta U = Q + W$

where $\Delta U$ is the change in internal energy of a system, $Q$ is the net heat inflow into the system, and $W$ is the net work done on the system.

Hence $\Delta U = (Q_1 - Q_2) + (W_1 - W_2 - W_3)$

**Ans: B**

Q15
Increasing the frequency of the vibration of the bar with the speed of the wave constant causes the wavelength to decrease and hence the diffraction effect will be reduced for the same slit width.

**Ans: A**

Q16

$$I = nAve \Rightarrow v = \frac{I}{nAe}$$

$$v = \frac{1.0}{(6.0\text{x}10^{28})(1.0\text{x}10^{-6})(1.6\text{x}10^{-19})}$$

$\approx 1.0 \text{ x } 10^{-4} \text{ m s}^{-1} = 0.1 \text{ mm s}^{-1}$

**Ans: C**

Q17
Total resistance of circuit
$= 3.0 + (1/6 + 1/6)^{-1} = 6.0\ \Omega$
Total current in circuit = 12 / 6.0 = 2.0 A
Current through Y = 2.0 / 2 = 1.0 A

**Ans: B**

Q18
Effective resistance across Y and voltmeter
$= R / 2$
Potential difference across Y and voltmeter
$= [(R/2) / (R + R/2)](6.0) = 2.0$ V

**Ans: B**

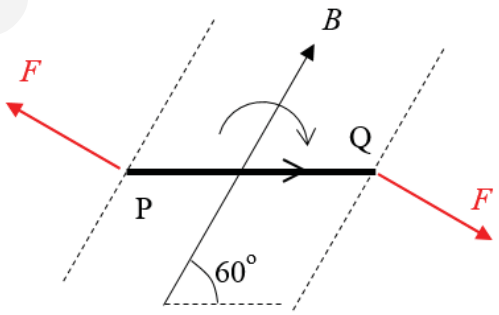
Q19
The electric potential will be negative near to both negative charges. The electric field E is related to the potential gradient by the equation $E = -\frac{dV}{dx}$.

**Ans: C**

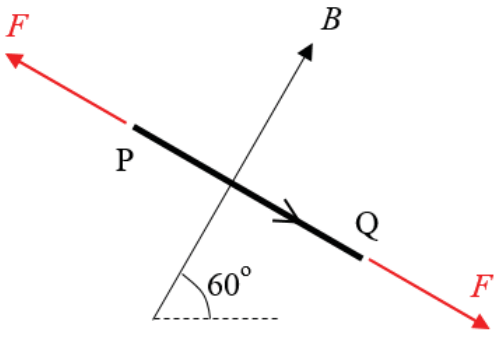
Q20
As the electric field acts in the negative $y$-direction, and the charge is negative, the force acting on it will be directed in the positive $y$-direction. There is no force in the $x$-direction. Hence, the trajectory will be parabolic in nature, with the particle accelerating in the $+y$-direction.

**Ans: B**

Q21




Initial orientation




Final orientation

**Ans: B**



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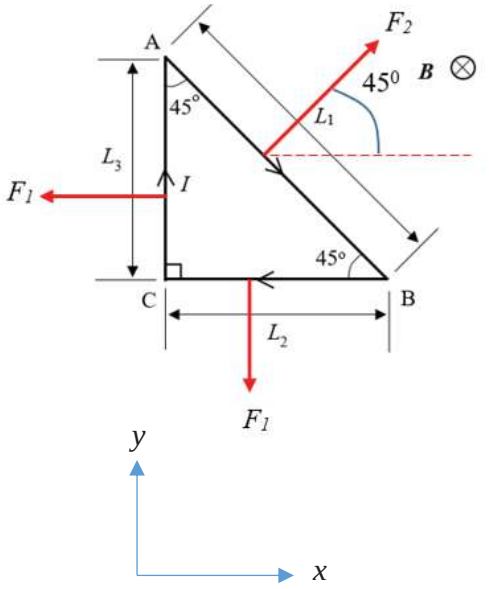
Q22




Along y-direction,
$F_y = F_2 sin45^0 - F_1 = BIL_1 sin45^0 - BIL_2$
$= BIL_2 - BIL_2 = 0$
Along x-direction, $F_x = F_2 cos45^0 - F_1$
$= BIL_1 cos45^0 - BIL_2$
$= BIL_2 - BIL_2 = 0$
Therefore net resultant magnetic force = 0
**Ans: D**

Q23
Since both situations involve a North pole approaching the same end of the coil, the needle must deflect in the same direction. Since the speed of rotation is doubled, the rate of change of flux linkage is increased, the needle movement must be more than 10 units.

**Ans: C**

Q24
The r.m.s. value of an alternating current produces the same heating effect as a steady direct current of the same magnitude when each is passed through a given resistance.

**Ans: A**

Q25
Einstein's photoelectric equation:
$hf = \phi + eV_s$
$4.7 \times 10^{-19} = \phi + (1.6 \times 10^{-19})(0.50)$
$\phi = 3.9 \times 10^{-19}$ J

**Ans: C**

Q26
Lowering the intensity but having the frequency the same (still UV light), means that fewer photons are impinging upon the metal per unit time. This means that fewer electrons are emitted per unit time. The maximum KE of the electrons stays the same as the frequency of light is the same. This follows from the equation $hf = \phi + K_{max}$.

**Ans: C**

Q27
The bombarding electron carries away 20.0 – 10.2 = 9.8 eV and not 3.4 eV.

**Ans: B**

Q28
Momentum of electron *is* $p = mv$
$\Delta p = m\Delta v = 9.11\times10^{-31}\times500\times0.000100 = 4.56\times10^{-32}$ kg m s$^{-1}$
Heisenberg's Uncertainty Principle:
$\Delta p \Delta x \geq h$ . Calculating, $\Delta x \geq 0.015$ m.

**Ans: C**

Q29

Using Energy released = total BE of products – total BE of reactants

$\Delta E = BE_{^3He} - 2BE_{^2H}$
$\Delta E = 3\times2.54 - 2\times2\times1.09$
$\Delta E = 3.26$ MeV

**Ans: C**



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Q30
Let $C$ be original number of counts due to the α-source.

Let $B$ be the background count.
$C + B = 300$….. (1)
$0.5C + B = 155$ ……(2)
Solving, $C = 290$ and B = 10.
Lead would block all the counts due to the α-source.
Hence, only background count of 10 is detected.

**Ans: C**

******** END *********

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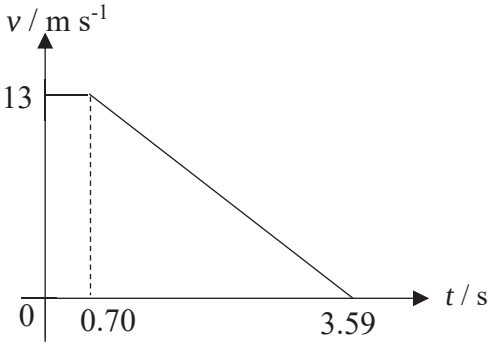
Q1(a)

Upon stepping on the brakes, $v = u + a\,t$

$0 = 13 + (-4.5)\,t$
$\boldsymbol{t = 2.89\ s}$

1(b)



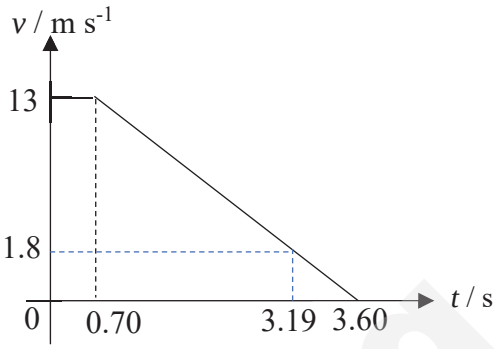

1(c)
Total displacement travelled from the time the motorist sights the red light till the time the car comes to a stop = area under the velocity-time graph
=13 (0.70) + (1/2)(13)(2.89)
= 27.9 m

Distance from stop line = 27.9 – 25
= **2.9 m**

1(d)
Find time for twig to fall vertically through 50 m:
$s = u\,t + ½\,a\,t^2$
$50 = 0 + ½\,(9.81)\,t^2$
$t = 3.19$ s

Horizontal distance travelled by twig in 3.19 s = 6.0 (3.19) = 19.1 m

In 3.19 s, the velocity of the car is
$v = 13 – 4.5(3.19\text{-}0.70) = 1.8$ m s$^{-1}$




Distance covered by the car is
$13(0.70) + \frac{1}{2}(13 + 1.8)(3.19 - 0.70)$
= 27.5 m

Since the twig has travelled a shorter distance compared to the car, it will not hit the car.

Q2(a)
Power is work done per unit time or rate of doing work

2(b)(i)
$P = Fv$
= 2000×45 = **90 kW**

2(b)(ii) 1. Work done = Power×time
= $90\times10^3\times3.0\times60 = 1.62\times10^7$ J

2(b)(ii)2.
Increase in GPE $= mgh$
= 1200×9.81×3.3×3.0×60
= $\boldsymbol{6.99\times10^6\ J}$

2(b)(ii)3.
Work done against air resistance = Total work done – gain in GPE
= $1.62\times10^7 - 6.99\times10^6 = \boldsymbol{9.21\times10^6\ J}$

2(b)(iii) Let air resistance be $R$.
$Rd = 9.21\times10^6$, where $d$ = distance travelled by the plane in 3.0 min.
$R = 9.21\times10^6/(45\times3.0\times60) =$ **1.14 kN**

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Q3
Given: $m$ = 20.2u
= 20.2 x 1.66 x $10^{-27}$ kg = 3.35 x $10^{-26}$ kg;
$M_s$ = 12.0 kg; $V$ = 8.0 x $10^{-3}$ $m^3$;
$n$ = 4.50 mol; $T$ = 300 K;

Specific heat capacity of steel
$c_s = 448\ \text{J kg}^{-1}\ \text{K}^{-1}$

Molar heat capacity of neon
= $C_n$ = 12.5 J $mol^{-1}$ $K^{-1}$

Specific heat capacity of water
$c_w = 4186\ \text{J kg}^{-1}\ \text{K}^{-1}$

Specific latent heat of fusion of water
$l_f$ = 3.33 x $10^5$ J $kg^{-1}$

Density of water $\rho_w$ = 1.00 x $10^3$ kg $m^{-3}$

Density of ice $\rho_i$ = 917 kg $m^{-3}$

3(a)
Using the Ideal Gas Equation,

$$p = \frac{nRT}{V}$$

$$p = \frac{(4.50)(8.31)(300)}{8.0\text{x}10^{-3}}$$

**$p$ = 1.40 x $10^6$ Pa**

3(b)
Using the Pressure Law for constant mass of gas and volume, we have

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$p_2 = \left(\frac{1.40\text{x}10^6}{300}\right)273$$

**$p_2$= 1.27 x $10^6$ Pa**

3(c)
Loss of energy of neon gas + loss of energy by steel canister = gain in energy by ice in melting

$$nC_n(300-273) + M_s c_s(300-273) = M_i l_f$$

$$M_i = \frac{(4.50)(12.5)(27) + (12.0)(448)(27)}{3.33\text{x}10^5}$$

**= 0.440 kg**

4(a)(i)
Diffraction of light refers to bending or spreading of light through an aperture or around an obstacle of dimensions comparable to the wavelength.

4(a)(ii)
Diffraction grating formula: $\frac{1}{N}sin\theta = n\lambda$
Or $sin\theta = Nn\lambda$
To see images on the screen, $\theta < 90^0$ or $sin\theta < 1$
$\therefore\ Nn\lambda < 1$ or $n < \frac{1}{N\lambda}$
The maximum order of lines $n_{max}$ is the largest value of $n$ expressed as an integer.

4(b)(i) Gradient
= (0.44 – 0.28)/[(550 – 350)×$10^{-9}$] = **8.0×$10^5$ $m^{-1}$**

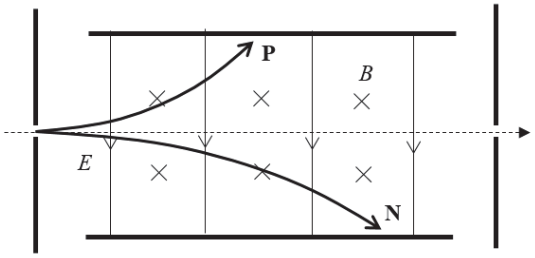
4(b)(ii) Diffraction Grating formula:
$n\lambda = dsin\theta$, or $2\lambda = dsin\theta$
Plotting $sin\theta$ vs $\lambda$, the gradient = 2/$d$
8.0×$10^5$ = 2/$d$ $\Rightarrow$ **$d$ = 2.5×$10^{-6}$ m**

4(b)(iii) $\lambda = dsin\theta$, plotting $sin\theta$ vs $\lambda$ gives gradient = 1/$d$
Hence a straight line with half the original gradient will be obtained.
The line will have the same y intercept *at the origin of the graph*.

Q5(a)(i)
For zero deflection, net force on ion = 0
$\therefore$ electric force = magnetic force
$qE = Bqv$

$$\therefore v = \frac{E}{B} = \frac{1210}{0.015} = \mathbf{8.1 \times 10^4\ m\ s^{-1}}$$

5(a)(ii)

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5(b)(i)
For circular motion,
Centripetal force = magnetic force

$$\frac{mv^2}{r} = Bqv$$

$$\therefore r = \frac{mv}{Bq}$$

The positive ions are deflected downward into the lower circular path of radius = 1.2 cm.

$$\therefore r = \frac{mv}{Bq}$$

$$1.2 \times 10^{-2} = \frac{m \times 8.1 \times 10^4}{1.6 \times q}$$

$$\therefore \frac{q}{m} = \mathbf{4.2 \times 10^6\ C\ kg^{-1}}$$

The negative ions are deflected upward into the upper circular path of radius = 1.8 cm.

$$\therefore r = \frac{mv}{Bq}$$

$$1.8 \times 10^{-2} = \frac{m \times 8.1 \times 10^4}{1.6 \times q}$$

$$\therefore \frac{q}{m} = \mathbf{2.8 \times 10^6\ C\ kg^{-1}}$$

5(b)(ii)
For the singly-charged positive ion,

$$\frac{q}{m} = \frac{(e)}{N_n(u)} = 4.2 \times 10^6$$

where
$e$ = elementary charge = $1.6 \times 10^{-19}$ C,
$N_n$ = no. of atomic mass units,
$u$ = atomic mass unit = $1.66 \times 10^{-27}$ kg ≈ mass of a nucleon.

[1]

$$N_n = \frac{1.6\text{x}10^{-19}}{(4.2\text{x}10^6)(1.66\text{x}10^{-27})}$$

$$N_n \approx 23$$

Hence, the positive ions could **sodium ions** ($Na^+$).

For the negative ion,

$$\frac{q}{m} = \frac{(e)}{N_n(u)} = 2.8 \times 10^6$$

$$N_n \approx 34$$

Hence, the negative ions could be chlorine ions ($Cl^-$).

Q6(a)
The binding energy per nucleon of the α-particle is significantly higher than the deuterium nucleus and is particularly stable for its mass number and hence more likely to be produced.

6(b)
Mass number $A = 224 - 4 = 220$

Proton number $Z = 88 - 2 = 86$

Neutron number $= 220 - 86 = 134$

6(c)
Due to the conservation of mass-energy, the difference in mass is converted into the kinetic energy of the products of the decay.

6(d)
Energy released = [Mass reactants – mass products]$c^2$
= [224.0202– (220.0114+4.0026)] x 1.66 x $10^{-27}$ x $(3.0 \text{ x} 10^8)^2$
= 9.2628 x $10^{-13}$ J
= 5.789 MeV

$K_\alpha + K_{Rn} = 5.789$ MeV

Hence, energy of α-particle = 5.789 – 0.1037 = **5.686 MeV**

6(e)

$N = \frac{5.686\text{x}10^6}{31} = 1.83\text{x}10^5$ ionisations

Since the range of α-particles is about 3 cm (Accept 2 to 5 cm)
No. of ion-electron pairs per unit length

$$= \frac{1.83 \times 10^5}{3 \times 10^{-2}} = 6.1 \times 10^6\ \text{m}^{-1}$$

since one ionisation produces an ion-electron pair.

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Q7(a)

$$\frac{Q}{t} = kA\frac{\theta_1 - \theta_2}{\Delta x}$$

$$k = \frac{Q\Delta x}{tA(\theta_1 - \theta_2)}$$

Base units of k = $\frac{(\text{kg m}^2\text{s}^{-2})(\text{m})}{(\text{s})(\text{m}^2)(\text{K})}$

= **kg m s$^{-3}$ K$^{-1}$**

7(b)

The negative sign is used to show that the temperature $\theta$ decreases in the direction of $x$.

7(c)(i)

Mass of water $M = \rho V$

$= \rho(\pi r_1{}^2 L)$

= (1000)(π) (4.0x10$^{-2}$)$^2$ (10.0x10$^{-2}$)

= **0.503 kg**

7(c)(ii)

Total surface area would include the top and bottom of the mug.

$A = 2\pi r_1{}^2 + 2\pi r_1 L$

= (2π)(4.0x10$^{-2}$)$^2$

+ (2π)(4.0x10$^{-2}$)(10.0x10$^{-2}$)

≈ **0.0352 m$^2$**

7(c)(iii)

The rate of loss of energy by the tea water = rate of energy lost through the walls and top and bottom of the mug.

$$\frac{Q}{t} = kA\frac{\theta_1 - \theta_2}{\Delta x} = \frac{Mc(\Delta T)}{t}$$

$$\Delta T = \frac{kAt(\theta_{tea} - \theta_{room})}{(\Delta x)Mc}$$

Hence

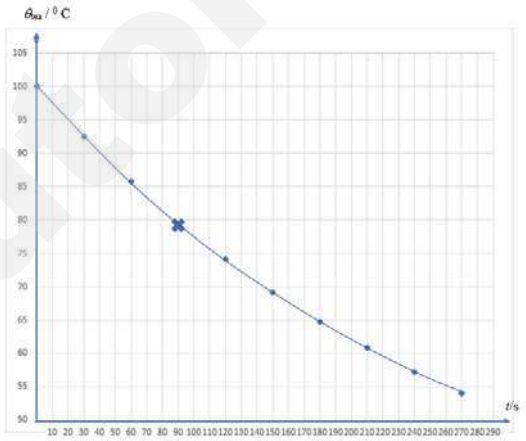
$$\Delta T = \frac{(1.0)(0.0352)(30)(\theta_{tea} - \theta_{room})}{(5.0\text{x}10^{-3})(0.503)(4180)}$$

Hence $\boldsymbol{\Delta T = 0.10(\theta_{tea} - \theta_{room})}$

(7d)(i)

| Time after pouring $t$/s | Initial $\theta_{tea}$/ $^0$ C | Temperature change in 30 s $\Delta T$/ $^0$ C | Final $\theta_{tea}$/ $^0$ C |
|---|---|---|---|
| 0 | 100 | 7.5 | 92.5 |
| 30 | 92.5 | 6.8 | 85.7 |
| 60 | 85.7 | 6.1 | 79.6 |
| 90 | **79.6** | **5.5** | **74.1** |
| 120 | 74.1 | 4.9 | 69.2 |
| 150 | 69.2 | 4.4 | 64.8 |
| 180 | 64.8 | 4.0 | 60.8 |
| 210 | 60.8 | 3.6 | 57.2 |
| 240 | 57.2 | 3.2 | 54.0 |
| 270 | 54.0 | 2.9 | 51.1 |

7(d)(ii)




[2]

7(d)(iii)

For the tea to drop from 100 $^0$C to 55 $^0$C, the time is about 260 s.

7(e)(i)

$A = 2\pi rL =$

$(2\pi)(4.0\text{x}10^{-2})(10.0\text{x}10^{-2}) = 0.0251$ m$^2$

Using $\frac{Q}{t} = kA\frac{\theta_1 - \theta_2}{\Delta x}$, we have

$$\frac{Q}{t} = (1.0)(0.0251)\frac{(90 - 25)}{5.0\text{x}10^{-3}}$$

= **326 W**

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7(e)(ii)

Using $\frac{dQ}{dt} = \frac{k2\pi L(\theta_1 - \theta_2)}{ln\left(\frac{r_2}{r_1}\right)}$, we have

$\frac{dQ}{dt} = \frac{(1.0)(0.628)(90-25)}{ln\left(\frac{0.045}{0.040}\right)} \approx$ **347 W**

7(e)(iii)

Percentage error is $\frac{347-326}{347}$ x 100 ≈ **6.1%**

7(f)

$P = \frac{Mc\Delta T}{t}$ or $t = \frac{Mc\Delta T}{P}$

$t = \frac{(0.503)(4180)(70-55)}{1.1 \text{ x } 10^3}$

≈**28.7 s**

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Q1(a)
Base quantities are physical quantities on the basis of which other quantities can be expressed, e.g. velocity can be expressed in terms of the base quantities of length and time.

Any one of the 7 base quantities: Length, mass, time, electric current, temperature, luminous intensity, amount of substance.

1(b)

$$\frac{\Delta C}{C}\text{x}100 = \left[\frac{\Delta\left(\frac{V}{t}\right)}{\left(\frac{V}{t}\right)} + 4\frac{\Delta r}{r} + \frac{\Delta L}{L} + \frac{\Delta \rho}{\rho}\right] \text{x } 100$$

$= 3\% \quad + \quad 4(1\%) + 0.5\% + 2\ \%$

The radius of the pipe has the most significant uncertainty which accounts for the greatest percentage uncertainty of 4 % for C.

1(c)(i)
$F = ma$
$a = 0.20/2.0 =$ **0.10 m s$^{-2}$**
in a **westerly** direction

1(c)(ii)
Resolving the initial velocity in the easterly direction,
$u_e = 1.41 \cos 45° = 1.0$ m s$^{-1}$
Resolving the initial velocity in the northerly direction,
$u_n = 1.41 \cos 45° = 1.0$ m s$^{-1}$

At the end of 10 s, taking east as positive direction,
final velocity in the easterly direction,
$v_e = u_e + at$
$= 1.0 + (-0.10)(10) =$ **0 m s$^{-1}$**
Therefore, the resultant velocity = **1.0 m s$^{-1}$** in a **northerly** direction.

Q2(a)
At constant speed, reaction force = weight of man.
$\therefore mg = 670$ N
$\therefore$ ***m* = 68.3 kg**.

2(b)
Between 2.0 s and 6.0 s, $R > mg$.

Since the man is slowing down or decelerating, he must be moving downward initially.
By N2L, $mg - R = m(-a)$ or $R > mg$

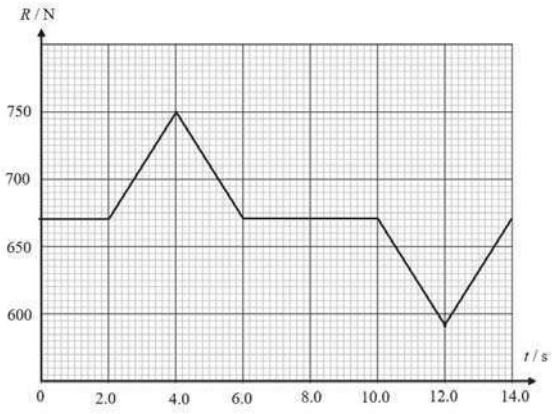
2(c)
At $t = 2.0$ s, the lift was moving with velocity $u$ before decelerating and coming to a stop at $t = 6.0$ s By Impulse-Momentum Theorem applied to between 2.0 s and 6.0 s where there is a change of momentum and hence change in velocity,

$$\Delta p = \int_2^6 F\,dt$$

$$68.3(0 - u) = \frac{1}{2} \times (6.0 - 2.0) \times (750 - 670)$$

$\therefore u = -2.34$ m s$^{-1}$.
Hence, initially speed = **2.34 m s$^{-1}$.**

2(d)



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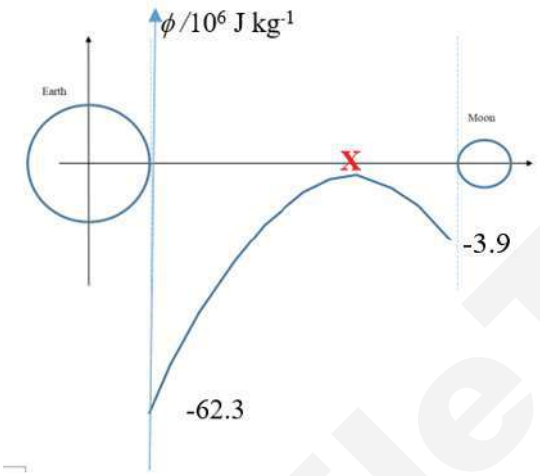
2(e)
The total external force that the lift motor must counter is given by:

$$F_{external} = M_{car}g + M_{load}g - M_{counterweight}g$$

$$\therefore F_{external} = 1200 \times 9.81 + 420 \times 9.81 - 1320 \times 9.81 = 2943 \text{ N}$$

As the lift car is moving with constant speed,
power exerted by lift motor = $P = F \times v$
= 2943 × 2.34 = **6890 W.**

Q3(a)




3(b)(i)
The neutral point is the position along a straight line between the Earth and the Moon where an object experiences no net gravitational force from both the Earth and the Moon.

X should be marked where the graph is at a maximum since $-\frac{d\phi}{dr} = g = 0$

3(b)(ii)

GPE gained = (potential at neutral point– potential at earth's surface)$m$
$6.1 \times 10^{10} = [\phi_0 - (-62.3 \times 10^6)]1000$
where $\phi_0$ = potential at neutral point
**$\phi_0$ = -1.3 x 10⁶ J kg⁻¹**

3(b)(i)

The satellite is located left of the neutral point,
This corresponds to the net gravitational force on the satellite being directed towards the Earth, allowing the satellite to orbit the Earth.

3(b)(ii)
Let orbital radius be $r$.
At all times, the satellite will be between the Earth and the Moon.

$$mr\omega^2 = F_E - F_M$$

where $m$ is the mass of the satellite

$$\frac{GM_E m}{r^2} - \frac{GM_m m}{(D-r)^2} = mr\omega^2$$

Q4(a)(i)

When light shone on LDR, resistance of LDR is 420 Ω.
p.d across LDR $= \frac{420}{420+8200} \times (4.0 - (-2.0)) = 0.29$ V

Hence potential at P, $V_P$ = 0.29 – 2.0
= **-1.71 V**

4(a)(ii)
When LDR in the dark, resistance of LDR = 134 kΩ.
p.d across LDR $= \frac{134\ \text{k}\Omega}{134\ \text{k}\Omega + 8.2\ \text{k}\Omega} \times 6.0$
=5.65 V
Hence potential at P, $V_P$ = 5.65 – 2.0
= **3.65 V.**

4(a)(iii)
The alarm is placed in parallel with the LDR.When the laser beam is shining on the LDR, the resistance of the LDR will be low. By the potential divider principle, the p.d. across the LDR and alarm will be low. The alarm will remain turned off.



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When the burglar blocks the laser beam, the resistance of the LDR will be high. Hence the p.d across the LDR and alarm will be high. This will turn on the alarm.

4(b)(i)
There will be no deflection in the galvanometer when the p.d across JY = 1.5 V.
Let the balance length (between J and Y) be $L$. Then

$$V_{JY} = \left(\frac{L}{1.00}\right)\frac{1.50}{(1.50+0.50)} \times 4.0 = 1.5$$

$L$ = 0.500 m.

Hence distance from X = 1.00 – $L_{JY}$
= **0.500 m.**

4(b)(ii)
When 1.50 Ω connected with the 1.5 V cell, the terminal p.d across the 1.50 Ω is

$$V = \frac{1.50}{1.50+0.50} \times 1.5 = 1.13\ V$$

There will null deflection when $V_{JY}$ = 1.13 V. Then

$$V_{JY} = \left(\frac{L'}{1.00}\right)\frac{1.50}{(1.50+0.50)} \times 4.0 = 1.13$$

$L'$ = 0.377 m.

Hence distance from X = 1.00 – 0.377
= **0.623m**.

Q5(a)(i)
Consider a line between P and R. When the disc spins, the line sweeps through the region of the magnetic field, cutting the magnetic flux lines.
By Faraday's Law, the change of magnetic flux with time results in an emf appearing between points P and R.

Q5(a)(ii)
Assume that the magnetic field is uniform across the region of PR.

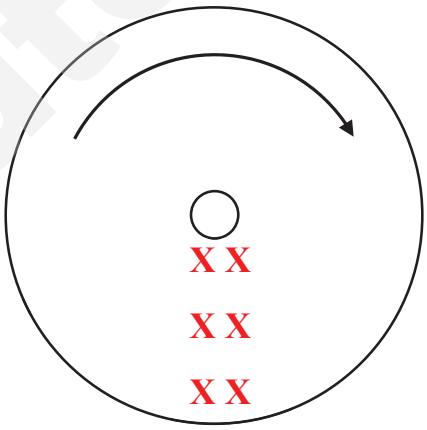
Using emf $\varepsilon = B\pi r^2 f$

$$\frac{\varepsilon_1}{\varepsilon_2} = \left(\frac{r_1}{r_2}\right)^2$$

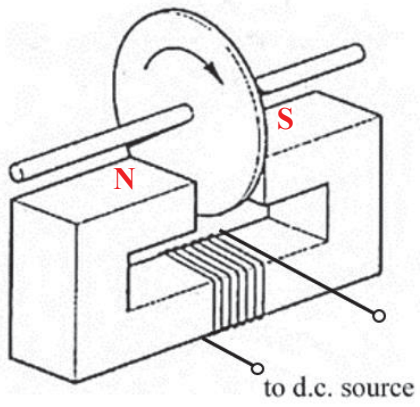
$$\varepsilon_2 = \left(\frac{0.3r}{r}\right)^2 \varepsilon_1 = \mathbf{0.90\ mV}$$

Q5(a)(iii)
Because $\varepsilon_{QR}$ = 0.90 mV and since $\varepsilon_{PR}$ = 10.0 mV,
the $\varepsilon_{PQ} = 10 - 0.90 = \mathbf{9.1\ mV}$

Q5(b)(i)




5(b)(ii)



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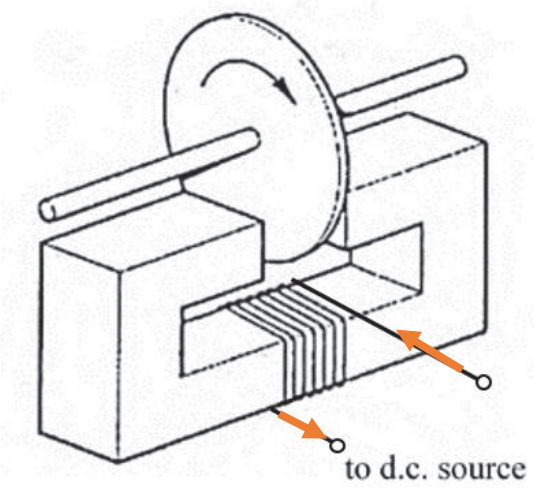
5(b)(iii)




Q5(c)
When the flux density is over the whole disc, the emf generated between the points PR will again be 10.0 mV.

Q6(a)

- Radiation emitted does not all enter the detector
- absorption in air before reaching detector
- detector not sensitive to all radiations
- background radiation

Any one point.

6(b)(i)
The curve is not smooth or curve fluctuates/curve is jagged .

6(b)(ii)
From graph, background count = 9 count per min.
At $t$ = 0, count rate due to source alone = 170-9 =161 count per min
At half-life, count rate = 161/2 + 9 = 89.5 count per min
From graph, half life = 1.5 hr

OR
[At $t$ = 1 hr, count rate due to source alone = 116-9 =107 count per min
At half-life, count rate = 107/2 + 9 = 62.5 count per min
From graph, half life = 2.5 -1 = 1.5 hr
Half-life = 1.5 hr]

6(c)(i)
There is no change in half life.
Decay is spontaneous, independent of physical factors such as temperature.

6(c)(ii)
The count rate is likely to be different.
Decay is random resulting in fluctuations in reading.

**SECTION C**

Q7(a)
Simple harmonic motion refers to the oscillatory motion of an object about an equilibrium position such that its acceleration is proportional to its displacement and is always directed towards the equilibrium position.

7(b)(i)
Angular frequency $\omega$ is $2\pi$ times the frequency of an object's oscillatory motion, i.e. $\omega = 2\pi f$.
It is related to the period $T$ by the equation $\omega = \frac{2\pi}{T}$

7(b)(ii)
Given $\omega^2 = \frac{g}{l}$

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



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(7b)(iii)
The ball bearing is behaving like the bob of a pendulum with length $l$ equal to the radius $r$ of the semi-circular saucer.
Using
$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{l}{g}}$, we have

$$T = 2\pi\sqrt{\frac{0.25}{9.81}}$$

$\boldsymbol{T \approx 1.0\ s}$

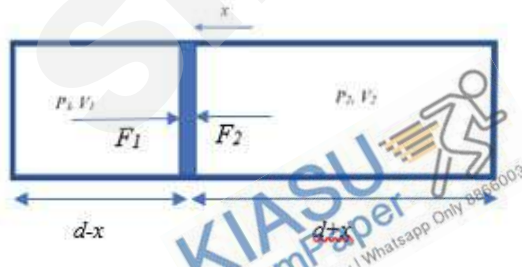
7(c)(i)
An ideal gas obeys the Ideal Gas equation $pV = nRT$ where $p$ = gas pressure, $V$ = gas volume, $n$ = number of moles of gas,
$R$ = molar gas constant, and
$T$ = thermodynamic temperature.

It is a gas in which inter-molecular forces of interaction are negligible.

7(c)(ii)
From $pV = nRT$, we have $pV$ = constant (Boyle's Law)

The gas must have a fixed mass and the temperature must remain constant for a change of volume and pressure.

7(c)(iii)




7(c)(iv)
Boyle's Law: $P_1V_1 = P_2V_2 = PV$
$P = \frac{F}{A}$ and $V = Ad$
$\therefore \boldsymbol{F_1(d-x) = F_2(d+x) = PAd}$

7(c)(v)
By N2L, $F_2 - F_1 = ma$

$$F_1\left(\frac{d-x}{d+x}\right) - F_1 = ma$$

$$F_1\left(\frac{d-x-d-x}{d+x}\right) = ma$$

$$\frac{PAd}{(d-x)}\left(\frac{-2x}{d+x}\right) = ma$$

$\therefore \boldsymbol{\frac{-2PAd}{d^2-x^2}x = ma}$

7(c)(vi)
When $d >> x$, we have

$$a = \frac{-2PAd}{md^2}x$$

Since $a \propto -x$, the motion is simple harmonic, with $\omega^2 = \frac{2PA}{md}$

The period is $\boldsymbol{T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{md}{2PA}}}$

7(c)(vii)

$$T = 2\pi\sqrt{\frac{(1.0)(0.50)}{2(100)(100\text{x}10^{-4})}}$$

$\boldsymbol{\approx 3.1\ s}$

Q8(a)(i)
Photoelectric Effect: when light of a high enough frequency is shone on a metal surface, electrons are emitted.

8(a)(ii) [Any 2]
(1) There is a minimum frequency of radiation required, below which photoelectric emission does not occur.
(2) There is no time lag between the illumination of the metal surface by energetic radiation and the emission of photoelectrons,
(3) The maximum kinetic energy of the photoelectron is dependent on the frequency of light but independent of the intensity of the radiation.

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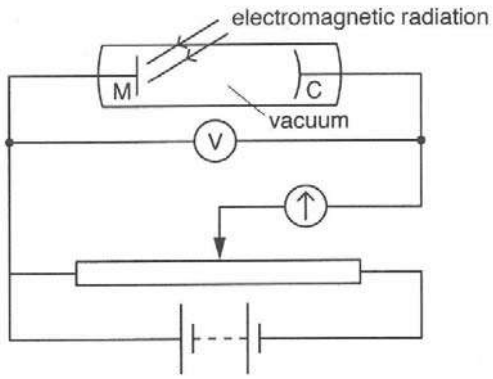
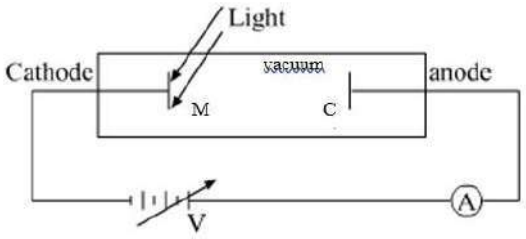
8(a)(iii)




Or




Apply a variable p.d. $V$ across 2 plates, the emitter (M) and collector (C). C is negative with respect to M. Start with $V = 0$, and shine the light through the window at M. As electrons are emitted by M and collected by C, the ammeter will register a current.

Now increase the retarding p.d. $V$ until the ammeter just shows zero current. The p.d. that just causes the current to drop to zero is the stopping potential $V_s$. Then, maximum kinetic energy of electrons is $= eV_s$, where $e$ = charge of 1 electron.

8(b)

There is kinetic energy of the electron moving around the nucleus of the atom and the electrical potential energy of interaction of the electron with the nucleus.

8(c)(i)1.

From point A, emission line spectrum from the hydrogen will be observed.

The cooler hydrogen will absorb parts of the spectrum of white light and reemit in all directions. Some of the coloured lines will be seen at A

8(c)(i)2.

At point B, an absorption line spectrum from the hydrogen will be observed.

This is because some specific spectral wavelengths from the hot gas will be absorbed by the cooler hydrogen. Hence the full colour spectrum of white light will have missing wavelengths represented by a set of dark lines.

8(c)(ii)1.

Transition from $n = 4$ and $n = 2$: $\Delta E = hf$

$\Rightarrow (3.40\text{-}0.85) \times 1.6 \times 10^{-19} = 6.63 \times 10^{-34} \times f$

$\Rightarrow f =$ **$6.15 \times 10^{14}$ Hz**.

8(c)(ii)2.

$(E_4 - E_2) = (E_4 - E_3) + (E_3 - E_2)$.

Thus, $hf_{42} = hf_{43} + hf_{32} \Rightarrow f_{42} = f_{43} + f_{32}$.

i.e. $6.15 \times 10^{14} = 1.60 \times 10^{14} + f_{21}$

$\Rightarrow f_{21} = 4.55 \times 10^{14}$ Hz.

Hence, the emitted wavelength, $\lambda_{21} = c/f_{21}$

= **$6.59 \times 10^{-7}$ m**.

8(d)(i)

$p = h/\lambda$

$1.66\times10^{-27}\times1.0\times10^{5} = h/\lambda$

**$\lambda = 3.99\times10^{-12}$ m**

8(d)(ii)

For diffraction to be observable, the wavelength must be comparable to the dimension of the aperture the wave is passing through.

The wave nature of electrons can be observed in electron diffraction experiments because the typical inter-atomic separation in crystals is about $10^{-10}$ m which is comparable to that of the de Broglie wavelength of the free electron travelling at



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the speed of $1.0 \times 10^5$ m $s^{-1}$.

It is difficult to observe diffraction effects involving neutrons since their wavelengths are much shorter compared to the inter-atomic separation of crystals.

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VJC 2019 Physics Prelim Practical Exam mark Scheme

Expt 1

| | |
|---|---|
| 1(a)(ii) | *N* oscillations chosen such that total time $t > 10$s<br>*t* recorded to 1 dp (accept 2 dp in sec) [1]<br><br>average time taken for *N* oscillations [1]<br><br>***N* = 10 oscillations**<br>**$t_1$ = 14.6 s, $t_2$ = 15.1 s**<br>**Average *t* = (14.6+15.1) /2 = 14.9 s. Period = 14.9/10 = 1.49 s.** |
| 1(a)(iii) | $\Delta t$ from 0.2 s to 0.6 s [1]<br><br>Percentage uncertainty to 2sf.<br>Uncertainty $\frac{\Delta t}{t} \times 100\% = \frac{\Delta T}{T} \times 100\%$ [1]<br><br>**$(0.3/14.9)100\% = 2.0\%$** |
| 1(b) | Allow ecf.<br>*T* accurately calculated. [1]<br><br>***N* = 15 oscillations**<br>**$t_1$ = 16.6 s, $t_2$ = 16.7~~7~~ s**<br>**Average *t* = (16.6+16.7)/2 = 16.7 s. Period = 16.7/15 = 1.11 s.** |
| 3(c)(i) | Values of *k* accurately calculated to appropriate sf. [1]<br><br>Units of *k* indicated [$kg^{-1}s^{-2}$] [1]<br><br>**$k_1 = 1/(0.200 \times 1.49^2) = 2.25\ kg^{-1}\ s^{-2}$**<br>**$k_2 = 1/(0.400 \times 1.11^2) = 2.03\ kg^{-1}\ s^{-2}$** |
| 3(c)(ii) | Test for logical conclusion. $\frac{\Delta k}{k}$ calculated from 3(c)(i) [1]<br><br>If $\frac{\Delta k}{k} > 2\frac{\Delta T}{T}$ then relationship is likely to be invalid.<br>If $\frac{\Delta k}{k} < 2\frac{\Delta T}{T}$ then relationship is likely to be valid. [1]<br><br>**$2(\Delta T/T) \times 100\% = 4.0\%$**<br>**$(k_1 - k_2)/k_1 \times 100\%$**<br>**= [(2.25-2.03)/2.25] x100% = 9.8%**<br>**Since $\frac{\Delta k}{k} > 2\frac{\Delta T}{T}$, the data do not support the relationship.** |



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| | |
|---|---|
| 3(d) | Any of the following (1m for error 1m for improvement)<br>- String loops not equal in length, causing bottom ruler to be not horizontal, leading to non-uniform oscillations -> use spirit level to check<br>- Mass tends to oscillate rather than staying still. -> secure masses directly to ruler using tape.<br>-Loops can slide along ruler during oscillations -> tape down the loops onto ruler where the string makes contact with the ruler.<br>- any other logical reasons. |
| 3(e) | 1. Set up experiment in the same way in the previous experiment.<br>2. Before forming the loops, measure the length of each string with a ruler. This will be the circumference of the loops that will be formed.<br>3. Oscillate the bottom ruler about the central vertical axis.<br>4. Time *N* oscillations using a stopwatch such that total time t>10s.<br>5. Repeat and take average for the time for *N* oscillations.<br>6. Divide time taken by *N* to obtain period of oscillation<br>7. Repeat steps 2 to 6 varying circumference from 30 cm to 80 cm to obtain 6 data points.<br><br>Two marks for procedures<br>Measurement of circumference and period with metre rule and stopwatch respectively [1]<br>Repeat measurement of period and circumference to get 6 sets of data [1]<br><br>Control of variables [1m – any one point]<br>1. Same rules<br>2. Same mass used.<br>Explanation: a different ruler or mass will affect the tensions in the strings and hence the oscillation period of the system.<br><br>Showing relationship [1m]<br>1. Since it is suggested that $T^2 \propto Circumference$, plot $T^2$ vs circumference.<br>2. If the graph is a straight line passing through the origin, the relationship holds. |

Expt 2

| No. | Marking Point | Marks |
|---|---|---|
| 2(a)(i) | Record $L$ to 0.1 cm, 15.0 cm $< L <$ 17.0 cm<br>**$L$ =16.2 cm** | 1 |
| (ii) | Record $d$ to 0.05 mm.<br><br>**$d$ = 8.30 mm** | 1 |



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| | | |
|---|---|---|
| (b)(i) | • calculate using $s$ = distance between horizontal portion of rubber band & top of hanger – diameter $d$ of rod<br><br>$(d + s) = 6.3$ cm<br><br>• Record $s$ to 0.1 cm<br><br>$s = 6.3$ cm – 0.830 = 5.5 cm<br>*(Accept s from 4.8 cm to 5.8 cm)* | 1<br><br>1 |
| (ii) | • calculate using $\tan\theta = \frac{s}{1/2\,L}$<br>• correct s.f. for $\theta$<br>$\tan\theta = \frac{5.5}{\frac{1}{2}(16.2)} \Rightarrow \theta = 34^0$ | 1<br><br>1 |
| (iii) | It is 2 sf because the least number of sf present in $s$ and $L$ is $s$ which is 2 sf. | 1 |
| (c) | $k$ calculated correctly with units<br><br>$k = \frac{m}{s - \frac{L\sin\theta}{2}} = \frac{0.100}{0.055 - \frac{0.162\sin 34^0}{2}} = 10$ kg m$^{-1}$ | 1 |

Expt 3

3(b)(i) Expect to see x read to nearest mm. [1]

$x = 0.400$ m

Expect to see $I$ to 2 decimal places in A. [1]

$I = 0.25$ A

3(b)(ii) Use connector with sharp edge. [1]

3(c) 6 sets of readings. [1].

Correct number of decimal places for lg($x$/m) and lg($I$/A). Check a value randomly of lg($x$/m) and a value for lg(I/A) for correct calculation. [1]

Consistency of raw readings in the table of results. Apply to $x$ and $I$ only. Expect to see all the values of $x$ given to the nearest millimetre.

[1]



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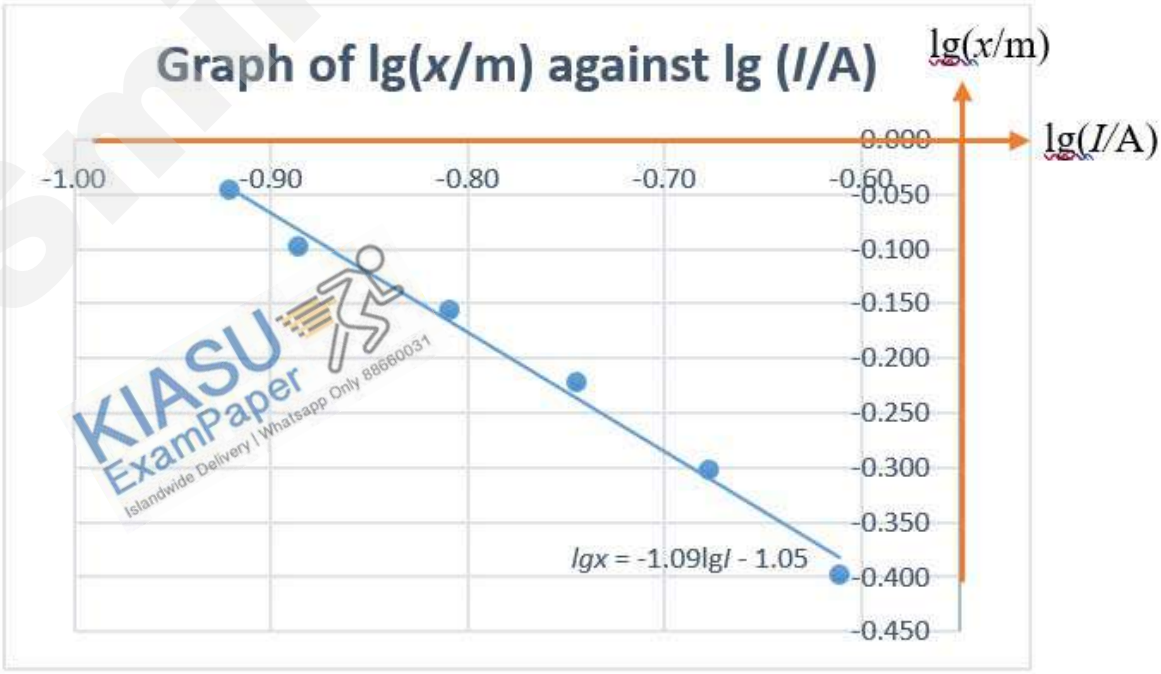
| $x$/m | $I$/A | lg ($I$/A) | lg ($x$/m) |
|---|---|---|---|
| 0.400 | 0.25 | -0.61 | -0.398 |
| 0.500 | 0.21 | -0.68 | -0.301 |
| 0.600 | 0.18 | -0.74 | -0.222 |
| 0.700 | 0.16 | -0.81 | -0.155 |
| 0.800 | 0.13 | -0.89 | -0.097 |
| 0.900 | 0.12 | -0.92 | -0.046 |

3(d)(i) Each axis must be labelled with a quantity. Do not allow lgx/m. Scales must be such that the plotted points occupy more than half the graph grid in both the x and y directions. Do not allow more than 3 large squares between scale markings. Do not allow awkward scales (e.g. 3:10, 6:10, 7:10, etc.). [1]

The number of plots must correspond to the number of observations (at least 6). Do not award this mark if the number of plots is less than the number of observations. Check one suspect plot. Circle this plot. Tick if correct. If incorrect then mark the correct position with a small cross and use an arrow to indicate where the plot should have been. Allow errors less than half a small square. [1]

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(ii) There must be a reasonable balance of points about the line of best fit. If one of the plots is a long way from the trend of the other plots then allow this plot to be ignored when the line is drawn. Allow only one anomalous point. [1]

(iii) Gradient: the hypotenuse of the triangle must be greater than half the length of the drawn line. If read-offs are inaccurate by half a small square, or more, then zero. The value of the gradient must be negative. ~~Value should be around -1.0.~~
Accept -1.15 ≤ gradient ≤ -0.85 [1]

**Gradient = -1.09**

y-intercept. Check the read-off. Value must be within half a square. Accept correct substitution from a point on the line into $y = mx + c$. Allow ecf from (d)(iii) gradient for $m$. [1]

**y-intercept = -1.05**

3(e) $\lg x = n \lg I + \lg k$ [1]

Value for $n$ (from gradient). Allow ecf from (d)(iii) [1]

**gradient. $n$ = –1.09.**

Value for $k$ (from $10^{\text{y-intercept}}$). Allow ecf from (d)(iii) [1]
(Working must be checked.)

$\lg k$ = y-intercept.

**$k = 10^{\text{y-intercept}} = 10^{-1.05} = 0.089$**

3(f)(i) Value of diameter of wire (Accept 0.17 mm ≤ $d$ ≤ 0.21 mm). Zero reading must be shown.
[1]

**Zero error = -0.055 mm**
**$d_1$ = 0.130 mm**
**$d_2$ = 0.135 mm**
**$\langle d \rangle$ = 0.133 mm**
**Corrected $d$ = 0.133 – (-0.055) = 0.19 mm**

(ii) Cross-sectional area correct [1]

$$A = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{0.19\times10^{-3}}{2}\right)^2 = 2.8\times10^{-8}\ \text{m}^2$$



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(iii) Percentage uncertainty in area [2]
(One mark for percentage uncertainty in $d$. One mark for % uncertainty x 2.)

**Percentage uncertainty in A** $= 2 \times \frac{\Delta d}{d} \times 100 = 2 \times \frac{0.01}{0.19} \times 100 = 11\%$

3(g) Correct value of $\rho$. Expect to see $\rho = 4.3 \times 10^{-7}$ to $8.3 \times 10^{-7}$ Ω m. Correct units.

$\rho = \frac{VA}{k} = \frac{2.0(2.8 \times 10^{-8})}{0.089} = 6.3 \times 10^{-7}$ Ω m

[1]

3(h) $k$ = 4 x previous value. Allow ecf (g). [1]

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Planning:

**Mark Scheme for Planning Qn**

| | | |
|---|---|---|
| Diagram [1] | D1 | Labelled diagram showing method of establishing constant pressure head (e.g., constant flow tank) and of determining the volume flow rate. |
| Procedure [4] | P1 | Workable method to vary $\Delta p$ (e.g., adjusting height of constant flow tank above tube). |
| | P2 | Method to calculate $\Delta p$ (e.g., $\Delta p = h\rho g$) |
| | P3 | Workable method to measure volume flow rate $Q$, with appropriate working. |
| | P4 | Correct method of measuring radius $r$ (e.g., use of travelling microscope). Reject use of unsuitable instruments, e.g., vernier calipers, micrometer screw gauge. |
| Control of variables [1] | C1 | Ensuring that other variables remain fixed (explain at least one):<br>• Ensure that the length of the tube remains constant as the flow rate may be affected by the fluid drag with tube inner walls.<br>• Ensure that the same liquid is used so that the viscosity is kept constant.<br>• Ensure that the temperature of the liquid remains constant as it will affect the viscosity. |
| Analysis [4] | A1 | Linearising the equation into:<br>$\lg Q = \boldsymbol{x} \lg(\Delta p) + \boldsymbol{y} \lg r + \lg \boldsymbol{k}$ |
| | A2 | • Plot a graph of lg $Q$ against lg ($\Delta p$) (when $r$ is kept constant).<br>• Equate gradient to $x$. |
| | A3 | • Plot a graph of lg $Q$ against lg $r$ (when $\Delta p$ is kept constant).<br>• Equate gradient to $y$. |
| | A4 | • Plot a graph of $Q$ against $(\Delta p)^x r^y$ (using all data and the values of $Q$, $\Delta p$ and $r$ obtained earlier).<br>• Equate gradient to $k$.<br>(or any other workable method). |



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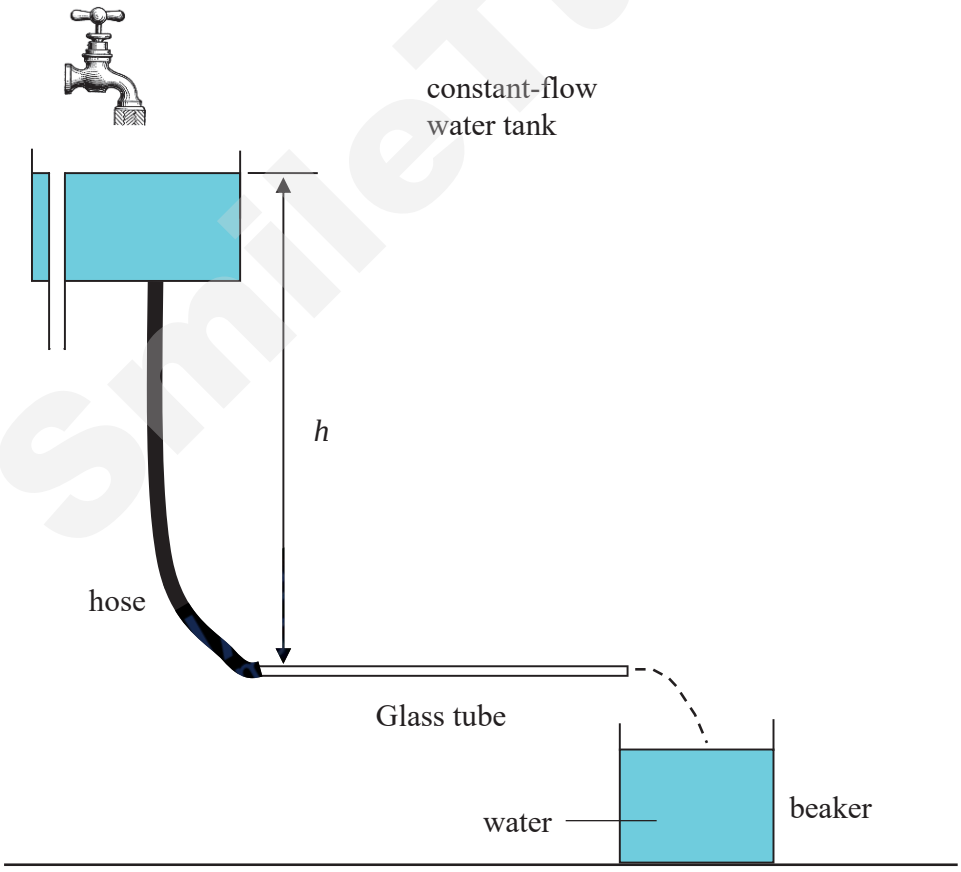
| | | |
|---|---|---|
| Accuracy precaution [1] | R1 | • Ensure that the tube remains level as any tilt will affect the pressure difference between its ends.<br>• Ensure that the flow is smooth and not turbulent by observing the outflow of liquid from the open end of the tube, by limiting the flow rate and radius.<br>• Ensure that the flow rate is steady before performing measurements. |
| Safety precaution [1] | S1 | Any reasonable safety precaution:<br>• Avoid performing experiment near electrical sockets. |

**Suggested Solution for Planning Question**:

Diagram:



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Procedure:

1. Set up the apparatus as shown in the diagram.
2. Prepare several glass tubes of equal length but with different internal radii.
3. Use a retort stand to clamp a glass tube horizontally.
4. Use a travelling microscope to measure the diameter $d$ of the bore of the glass tube.
5. Calculate the radius $r$ of the tube using $r = d/2$.
6. Set up a constant-flow tank and connect the water outlet to one end of the glass tube with rubber hose.
7. Use a metre rule to measure the vertical distance $h$ from water level in the constant-flow tank to the centre of the tube's bore.
8. Calculate the pressure difference $\Delta p$ between the ends of the glass tube is calculated using $\Delta p = h\rho g$, where $\rho$ is the density of the water.
9. Allow the water to flow from the constant-flow tank and out from the open end of the glass tube. The flow rate will be steady if the height $h$ is constant and the glass tube is horizontal.
10. Quickly move an empty, dry beaker in place to collect the water exiting the glass tube and start a stopwatch at the same time.
11. After a time interval $t$, remove the beaker quickly the water stream, and measure the mass $m$ of the water collected.
12. Calculate the volume flow-rate $Q$ using $Q = \frac{m/\rho}{t}$, where $\rho$ is the density of the water.
13. Repeat steps 3 to 12 and vary the height $h$ while keeping the tube bore radius $r$ constant. Height $h$ is varied by adjusting the vertical position of the tube with respect to the constant-flow tank.
14. Repeat steps 3 to 12 and vary the radius $r$ by using glass tubes with different bore sizes, while keeping the height $h$ constant.

Analysis:

$$Q = k(\Delta p)^x r^y$$

$$\therefore \lg Q = x \lg(\Delta p) + y \lg(r) + \lg k$$

Using the data from step 13, plot a graph of lg $Q$ against lg($\Delta p$).

$x$ is equal to and obtained from the gradient of this graph.

Using the data from step 14, plot a second graph of lg $Q$ against lg($r$).

$y$ is equal to and obtained from the gradient of this graph.



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Using all of the data from steps 13 and 14, and the values of $x$ and $y$ which have been found from the first two graphs, plot a third graph of $Q$ against $(\Delta p)^x r^y$.

$k$ is equal to and obtained from the gradient of this graph.

Control of variables:

Besides the control of the experimental variables $\Delta p$ and $r$ explained above, the following variables must be kept constant for the experiment to work successfully.

1. The length of the tube must remain constant as the flow rate may be affected by the fluid drag with tube inner walls which will vary with tube length.
2. The same liquid must be used so that the viscosity (which affects flow-rate) is kept constant.
3. Ensure that the temperature of the liquid remains constant as it will affect the viscosity.

~~(Write at least two)~~

Precautions:

Accuracy:

1. Ensure that the tube remains level as any tilt will affect the pressure difference between its ends.
2. Ensure that the flow is smooth and not turbulent by observing the outflow of liquid from the open end of the tube, by limiting the flow rate and radius.
3. Ensure that the flow rate is steady before performing measurements.

~~(Write at least two)~~

Safety:

1. Avoid performing experiment near electrical sockets to prevent electrocution.
2. Mount the constant-flow tank securely so that it does not fall and hit people.

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# PHYSICS 9749/01

Paper 1 Multiple Choice **19 September 2019**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.
Write your name and class on the Answer Sheet in the spaces provided unless this has been done for you.

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

**Read the instructions on the Answer Sheet very carefully.**

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


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**Data**

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

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**Formulae**

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

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**1** Which statement is not a reasonable estimate?

**A** Atmospheric pressure at sea level is about $1 \times 10^5$ Pa.

**B** Light takes $5 \times 10^2$ s to reach us from the Sun.

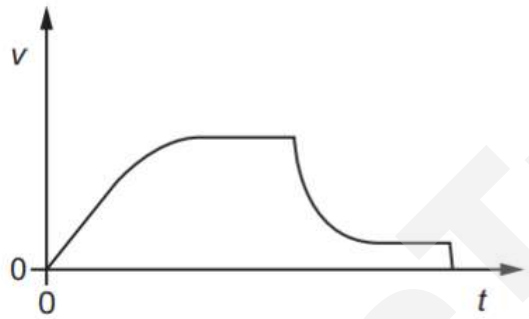
**C** The frequency of ultraviolet light is $3 \times 10^{12}$ Hz.

**D** The average lifespan of a man is about $2 \times 10^9$ s.

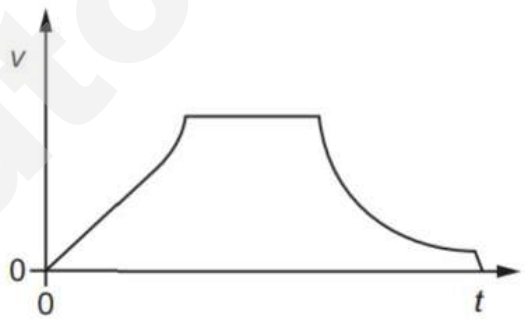
**2** A parachutist falls vertically from rest at time $t = 0$ from a hot-air balloon. She falls for some distance before opening her parachute.

Which graph best shows the variation with time $t$ of the speed $v$ of the parachutist?

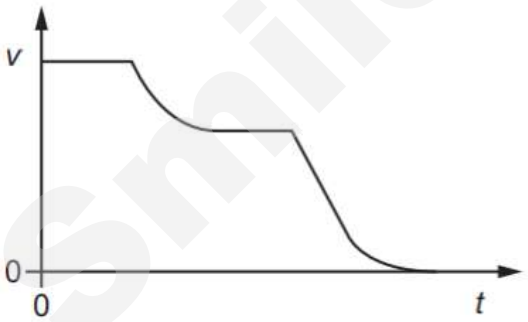
**A**



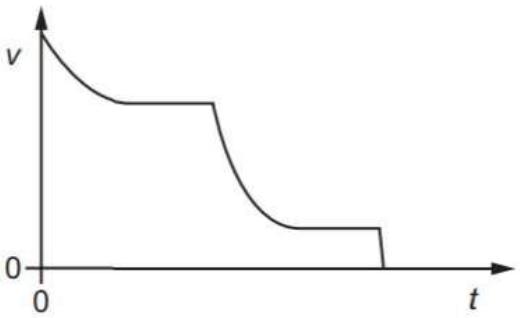

**B**




**C**




**D**

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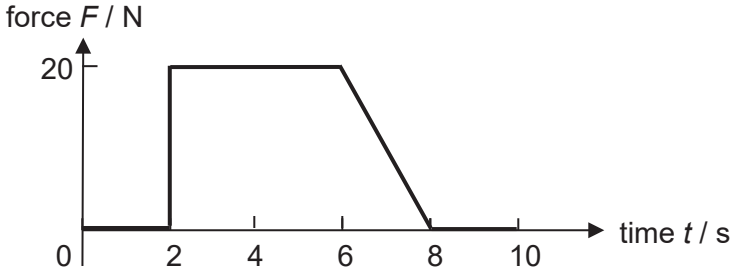
**3** The graph shows the variation with time $t$ of a force $F$ acting on a 2.0 kg mass.




What is the change in the speed of the body during this period of 10 s?

**A** 5.0 m $s^{-1}$ **B** 50 m $s^{-1}$

**C** 90 m $s^{-1}$ **D** 100 m $s^{-1}$

**4** Two smooth blocks of masses 0.2 kg and 1.0 kg, are connected by a light, inextensible string running over a smooth pulley. One block is placed on a smooth table and the other hangs over the table via the string and pulley. Two possible such cases are shown in Fig. A and Fig. B below.

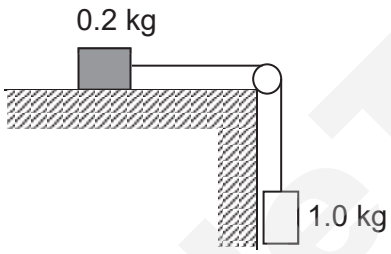



**Fig. A**

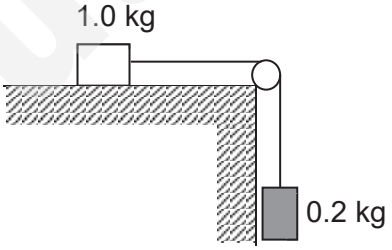



**Fig. B**

If the blocks in both Fig. A and Fig. B are released from rest, what is the ratio of the acceleration of the blocks in Fig. A to that in Fig. B?

**A** 1:1 **B** 5:1 **C** 6:1 **D** 10:1

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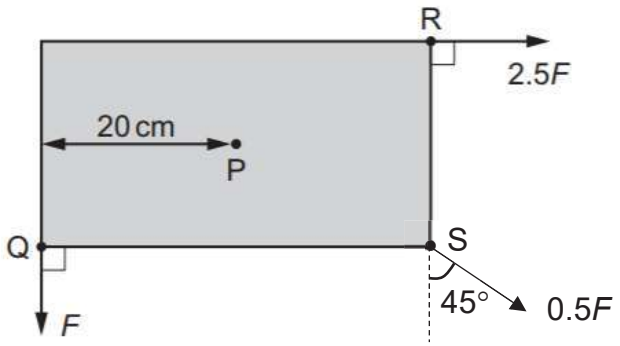
**5** A uniform rectangular board is supported by a frictionless pivot at its centre point P.




Three forces act in the plane of the board in the direction as shown in the figure above. Force *F* acts at corner Q, force 2.5*F* acts at corner R and force 0.5*F* acts at corner S. The perpendicular distance between the line of action of force *F* and point P is 20 cm. The board is in equilibrium.

What is the area of the board?

**A** 160 $cm^2$ **B** 480 $cm^2$ **C** 640 $cm^2$ **D** 1600 $cm^2$

**6** An astronaut throws a stone horizontally near to the surface of the Moon, where there is no atmosphere.

Which row describes the horizontal and vertical forces acting on the stone after release?

| | horizontal force | vertical force |
|---|---|---|
| **A** | non-zero and constant | constant |
| **B** | non-zero and constant | decreasing |
| **C** | zero | decreasing |
| **D** | zero | constant |

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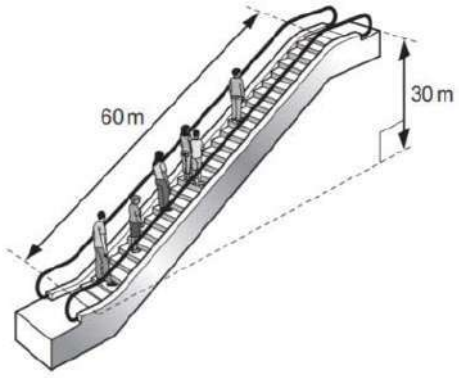
**7** An escalator is 60 m long and lifts passengers through a vertical height of 30 m, as shown.

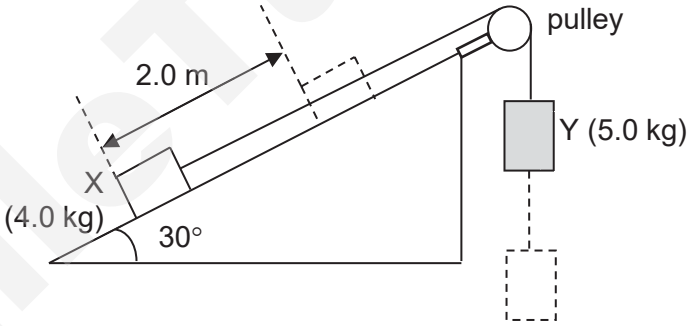



The escalator is used by passengers of average mass 60 kg and the power to overcome friction is 2.0 kW regardless of load.

How much power is required to drive the escalator when it is carrying 20 passengers and is travelling at 0.75 m $s^{-1}$?

**A** 4.4 kW **B** 6.4 kW **C** 8.8 kW **D** 10.8 kW

**8** Two bodies X and Y are connected by a light inextensible cord that is passed over a light free-running pulley as shown.




X lies on a smooth plane inclined at 30° to the horizontal whereas Y is suspended vertically. The mass of X and Y is 4.0 kg and 5.0 kg respectively. When the two bodies are released from rest, X moves up the plane.

What is the total kinetic energy of the system after X has travelled 2.0 m along the inclined plane?

**A** 20 J **B** 59 J **C** 137 J **D** 177 J

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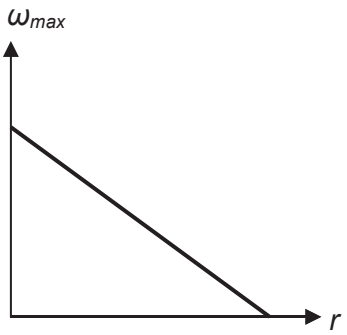
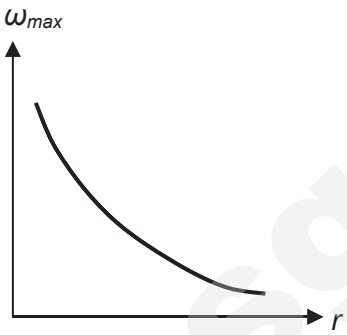
**9** A coin is placed on a rough turntable at a distance $r$ from the centre of the turntable. The largest possible angular velocity that the turntable can rotate without the coin sliding off is $\omega_{max}$. Which of the following graphs best represents the relation between $\omega_{max}$ and $r$?

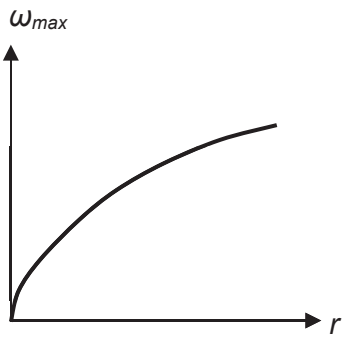
**A**



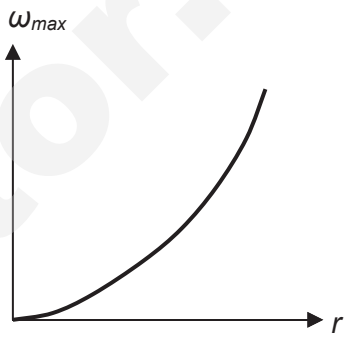

**B**



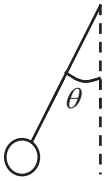

**C**




**D**




**10** A car is moving at a constant speed of 5.5 m $s^{-1}$ and is making a turn of radius 12 m. A small pendulum bob of mass 20 g hanging inside the car is observed to tilt at an angle $\theta$ to the vertical as shown below.




What is the value of angle $\theta$?

**A** 14° **B** 15° **C** 45° **D** 76°

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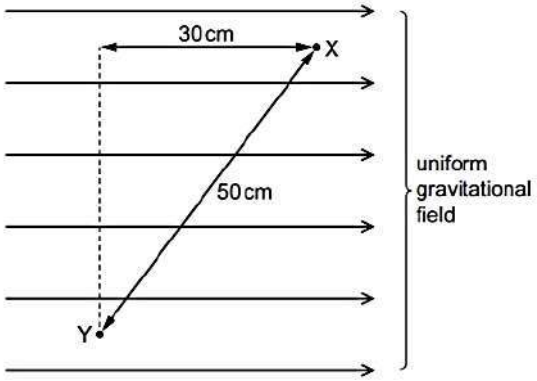
**11** A mass at point X inside a uniform gravitational field experiences a gravitational force of 0.200 N. It has 1.00 J of gravitational potential energy.




The mass is then moved to point Y. What is its new gravitational potential energy?

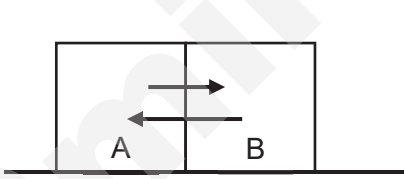
**A** 0.90 J **B** 0.94 J **C** 1.06 J **D** 1.10 J

**12** The density of argon at a pressure of $1.00 \times 10^5$ Pa and at a temperature of 300 K is 1.60 kg $m^{-3}$.

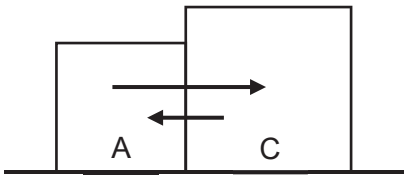
What is the root-mean-square speed of argon molecules at this temperature?

**A** 216 m $s^{-1}$ **B** 250 m $s^{-1}$ **C** 306 m $s^{-1}$ **D** 433 m $s^{-1}$

**13** Object A is at room temperature of 25°C. Objects B and C are of unknown temperature and placed in contact with A separately as shown below.




Situation 1




Situation 2

The arrows represent the input and the output of thermal energy for each object just after being place in contact.

The length of each arrow corresponds to the quantity of energy transferred.

What are the initial temperatures of B and C?

| | object B | object C |
|---|---|---|
| **A** | above 25°C | above 25°C |
| **B** | above 25°C | below 25°C |
| **C** | below 25°C | above 25°C |
| **D** | below 25°C | below 25°C |

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**14** The first law of thermodynamics may be stated in terms of

$\Delta U$, the **increase** in internal energy of the system,

$Q$, the energy transferred **from** the system by heating,

$W$, the work done **by** the system.

What is the formula connecting these quantities?

**A** $\Delta U = Q + W$

**B** $\Delta U = -Q + W$

**C** $\Delta U = Q - W$

**D** $-\Delta U = Q + W$

**15** A mass of 2.0 kg attached to a light spring is oscillating on a smooth horizontal surface at a frequency of 1.0 Hz. The other end of the spring is fixed to a wall. The amplitude of oscillation of the spring-mass system is 4.0 cm.

What is the speed of the mass when it is at a distance 3.0 cm from its equilibrium position?

**A** 2.6 cm $s^{-1}$ **B** 3.9 cm $s^{-1}$ **C** 17 cm $s^{-1}$ **D** 24 cm $s^{-1}$

**16** The top row of bars represents a set of particles inside the Earth and at rest.

The lower row represents the same particles at one instant as a longitudinal wave passes from left to right through the Earth.



What should be measured to determine the amplitude of the oscillations of the particles in the lower row as the wave passes?

**A** half the maximum displacement of the particles from their position at rest

**B** half the maximum distance apart of the particles

**C** the maximum displacement of the particles from their position at rest

**D** the maximum distance apart of the particles

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**17** What is an example of the diffraction of a wave?

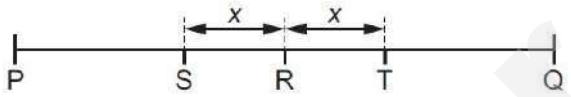
**A** laser light travelling along an optic fibre

**B** light waves forming images on a cinema screen

**C** microwaves passing the edge of a metal plate

**D** sound waves diverging as they pass through air

**18** P and Q are fixed points at the end of a string. A transverse stationary wave of constant maximum amplitude is formed on the string.




P, R and Q are the only points on the string where the displacements are always zero. S and T are two points on the string at a distance *x* from R.

Points S and T have

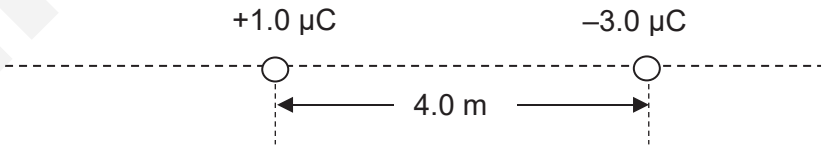
**A** the same amplitude and are in phase.

**B** the same amplitude and a phase difference of 180°.

**C** different amplitudes and are in phase.

**D** different amplitudes and a phase difference of 180°.

**19** Two charges of magnitudes +1.0 μC and –3.0 μC are separated by a distance of 4.0 m as shown.




At which position along the line joining the two charges is the net electric field strength zero?

**A** 1.5 m to the left of the positive charge

**B** 5.5 m to the left of the positive charge

**C** 1.5 m to the right of the negative charge

**D** 5.5 m to the right of the negative charge

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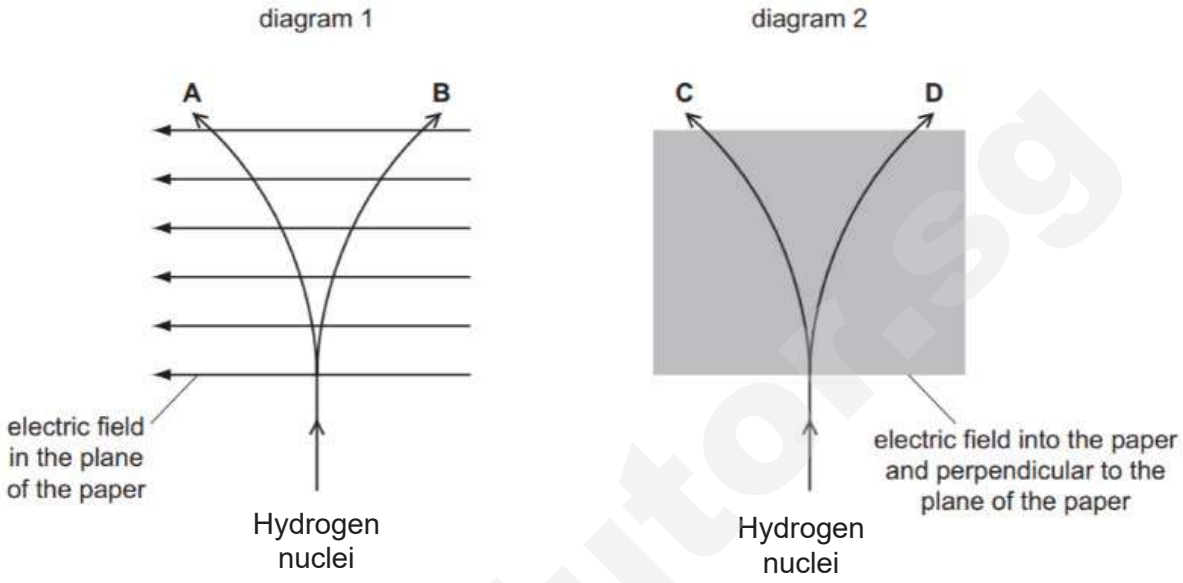
**20** A beam of hydrogen nuclei is directed into an electric field and is deflected by it.

Diagram 1 shows an electric field in the plane of the paper. Diagram 2 shows an electric field directed perpendicular to the plane of the paper.

The lines **A**, **B**, **C** and **D** represent possible paths of the hydrogen nuclei beam. All paths are in the plane of the paper. Which line best represents the path of the nuclei inside the field?




**21** A cylindrical piece of soft, electrically-conducting material has resistance $R$. It is rolled out so that its length is doubled but its volume stays constant.

What is its new resistance?

**A** 0.50 $R$ **B** $R$ **C** 2 $R$ **D** 4 $R$

**22** The current $I$ in a metal wire is given by the expression shown.

$$I = A\,n\,v\,q$$

What does the symbol $n$ represent?

**A** the number of atoms per unit volume of the metal

**B** the number of free electrons per atom in the metal

**C** the number of free electrons per unit volume of the metal

**D** the total number of electrons per unit volume of the metal

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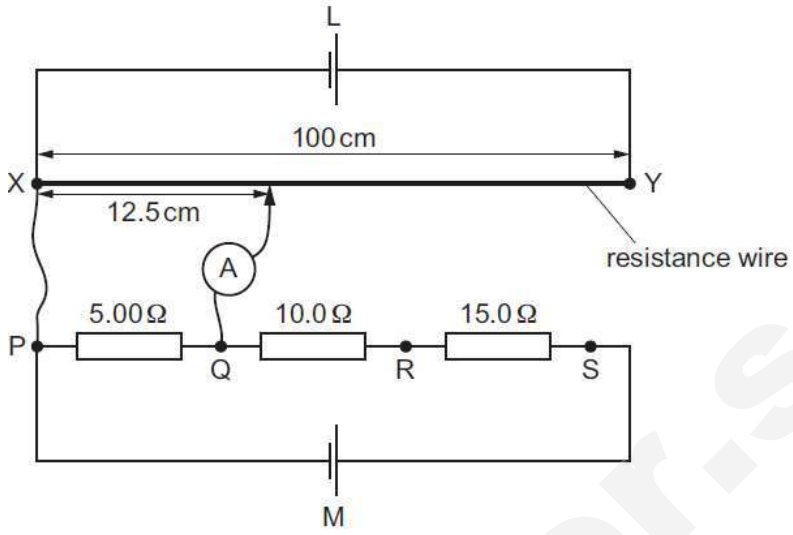
**23** A uniform resistance wire XY of length 100 cm is connected in series with a cell L. Another cell M is connected in series with resistors of resistances 5.00 Ω, 10.0 Ω and 15.0 Ω.




The potential difference (p.d.) between P and Q is balanced against 12.5 cm of the resistance wire, so that the ammeter reads zero.

The p.d. across the other resistors is then balanced against other lengths of the resistance wire.

Which balanced lengths of resistance wire correspond to the connection points given in the table?

| | balanced lengths / cm | | |
|---|---|---|---|
| connection points | Q and R | Q and S | P and R |
| **A** | 12.5 | 62.5 | 37.5 |
| **B** | 25.0 | 62.5 | 37.5 |
| **C** | 25.0 | 75.0 | 37.5 |
| **D** | 25.0 | 62.5 | 12.5 |

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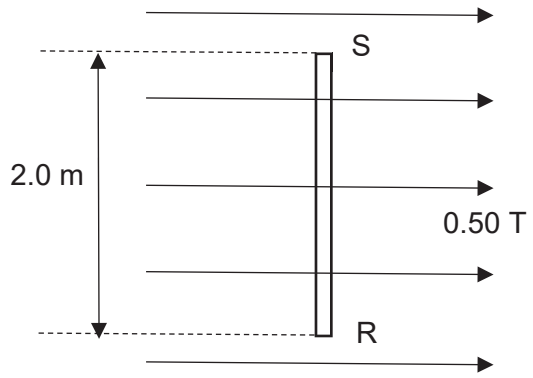
**24** The diagram shows a current-carrying conductor RS of length 2.0 m placed perpendicularly to a magnetic field of flux density 0.50 T. The resulting force on the conductor is 1.0 N acting into the plane of the paper.




What is the magnitude and direction of the current?

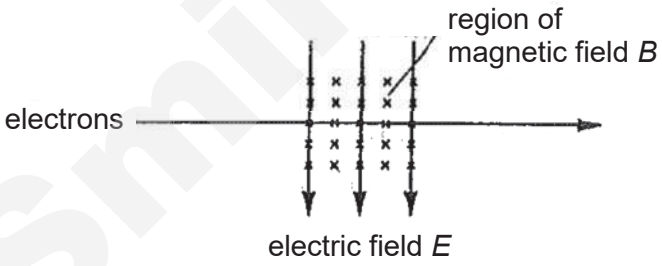
**A** 1.0 A from R to S

**B** 1.0 A from S to R

**C** 2.0 A from R to S

**D** 2.0 A from S to R

**25** A beam of electrons enters a region in which there are magnetic and electric fields directed at right angles. It passes straight through without deviation.




A second beam of protons travelling twice as fast as the first is then directed along the same line.

How is the second beam deviated?

**A** downwards in the plane of the paper

**B** upwards in the plane of the paper

**C** out of the plane of the paper

**D** into the plane of the paper

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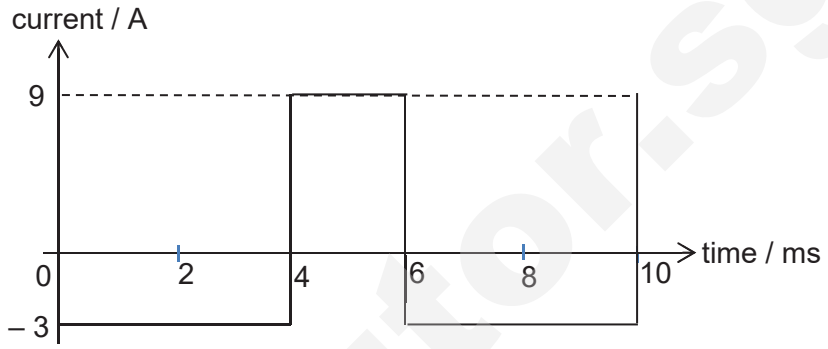
**26** A flat circular coil of 500 turns, each of diameter 30 mm, is placed such that a uniform magnetic field passes normally through its plane. Over a period of 60 ms, the flux density is reduced steadily from 20 mT to zero, then increased steadily to 20 mT in the opposite direction.

Which of the following is the average e.m.f. induced in the coil during this period?

**A** 0 **B** 0.12 V **C** 0.24 V **D** 0.94 V

**27** The graph shows the variation with time of an alternating current passing through a 3.5 Ω resistor. What is the mean power dissipated by the resistor?




**A** 5.7 W **B** 20 W **C** 88 W **D** 120 W

**28** Which of the following statements regarding X-ray spectra is incorrect?

**A** X-rays are emitted when fast-moving electrons are rapidly decelerated by a metal target.

**B** The minimum wavelength $\lambda_{min}$ of the X-ray spectra is dependent on the tube voltage used to accelerate the electrons striking the metal target.

**C** The intensity spikes in the X-ray spectra are characteristic of the metal target material.

**D** The $K_\beta$ peaks are more intense than the $K_\alpha$ peaks as X-ray photons emitted when electrons transit from M shell to K shell have higher frequency.

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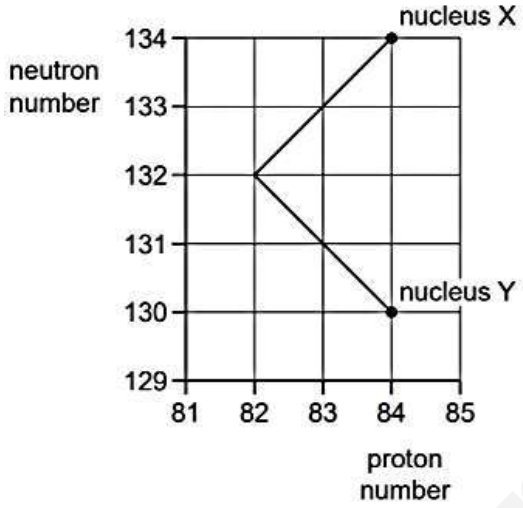
**29** X is a radioactive nucleus. It goes through a series of decays until Y, which is stable, is formed.




What are emitted during the series of decays?

**A** one $\alpha$-particle followed by one $\beta$-particle

**B** one $\alpha$-particle followed by two $\beta$-particles

**C** two $\alpha$-particles followed by one $\beta$-particle

**D** two $\alpha$-particles followed by two $\beta$-particles

**30** Examination of $\gamma$-rays emitted by a nucleus reveals a line spectrum. This is probably because

**A** the orbital distance of electrons in the nucleus is quantised.

**B** there is a constant value of mass defect for the formation of the nucleus from individual protons and neutrons.

**C** the energy of nucleons is discrete.

**D** electrons, on entering the nucleus, decelerate and release the radiation.

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YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
**Higher 2**

CANDIDATE NAME

CG

INDEX NO

# PHYSICS 9749/02

Paper 2 Structured Questions **2 September 2019**

**2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

Write your name and class 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, highlighters, glue or correction fluid/tape.

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 | |
|---|---|
| **Paper 2** | |
| **1** | **/10** |
| **2** | **/10** |
| **3** | **/10** |
| **4** | **/8** |
| **5** | **/7** |
| **6** | **/13** |
| **7** | **/22** |
| **Penalty** | |
| **Paper 2 Total** | |
| | **/80** |



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**Data**

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

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**Formulae**

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

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

**1** A remote-controlled toy car moves up a ramp and travels across a gap to land on another ramp, as illustrated in Fig. 1.1.

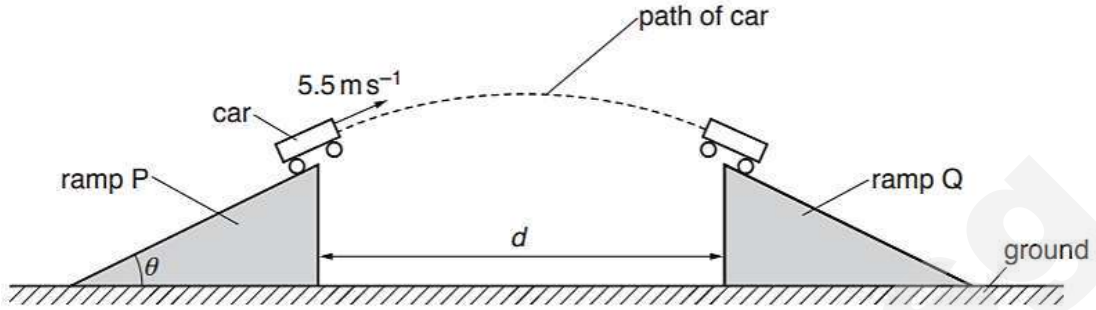


**Fig. 1.1**

The car leaves ramp P with a velocity of 5.5 m s$^{-1}$ at an angle $\theta$ = 33° to the horizontal. The car lands at the top of ramp Q. The top of both ramps are at the same height and the ramps are a distance *d* apart.

Air resistance is negligible.

**(a) (i)** Determine the time taken for the car to travel across the gap.

time taken = …….. s [2]

**(ii)** Calculate the horizontal distance *d*.

*d* = …….. m [1]

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**(iii)** The percentage uncertainty in the time is ± 2.0%. The actual uncertainty in the measurement of the speed of the car is ± 0.2 m $s^{-1}$.

Calculate the percentage uncertainty in *d*.

percentage uncertainty = …….. % [2]

**(iv)** Use your answers in **(ii)** and **(iii)** to determine the value of *d*, with its actual uncertainty to an appropriate number of significant figures.

*d* = …… ± …… m [1]

**(v)** Calculate the ratio

$$\frac{\text{kinetic energy of the car at its maximum height}}{\text{kinetic energy of the car as it leaves ramp P}}.$$

ratio = ……... [2]

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**(b)** Ramp Q is removed. The car leaves ramp P with the same velocity as before and now lands directly on the ground. The car leaves ramp P at time $t = 0$ and lands on the ground at time $t = T$.

On Fig.1.2, sketch the variation with time $t$ the vertical component $v_y$ of the car's velocity from $t = 0$ to $t = T$. The numerical values of $v_y$ and $t$ are not required.

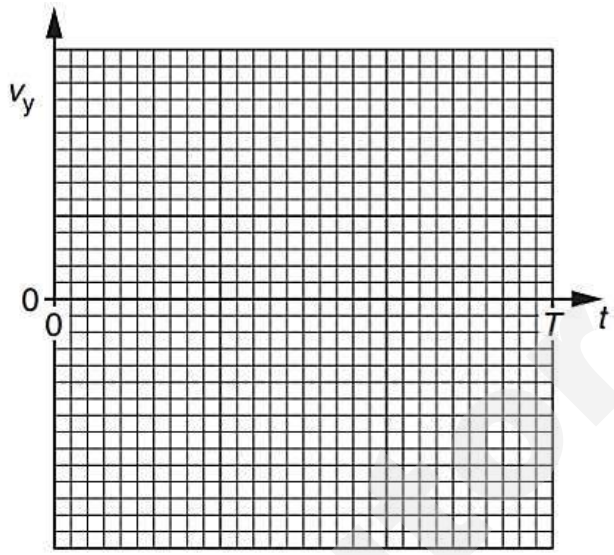


**Fig. 1.2**

[2]

[Total: 10]

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**Please turn over for Question 2.**

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**2** A tritium nucleus moves towards a deuterium nucleus as illustrated in Fig. 2.1




tritium deuterium

**Fig. 2.1**

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 the neutron each have the same mass *m*. The collision is elastic.

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

……

……

……[2]

**(b)** At one instant during the collision between the nuclei, they are both travelling **in the same direction** with the same speed.

Calculate this speed, in terms of *v*.

speed = …….. *v* [2]

**(c)** Explain why it is **not** possible for the nuclei to stop at the same instant during the interaction.

……

……

……...[2]

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**(d)** Determine the final speed of each nucleus in terms of $v$.

speed of deuterium = …….. $v$

speed of tritium = …….. $v$ [4]

[Total: 10]

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**3** A battery of electromotive force (e.m.f.) 4.5 V and negligible internal resistance is connected to two filament lamps P and Q and a resistor R, as shown in Fig. 3.1

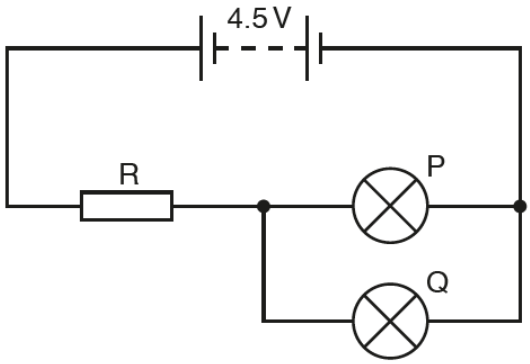


**Fig. 3.1**

The current in lamp P is 0.15 A.

The $I$-$V$ characteristics of the filament lamps are shown in Fig. 3.2.

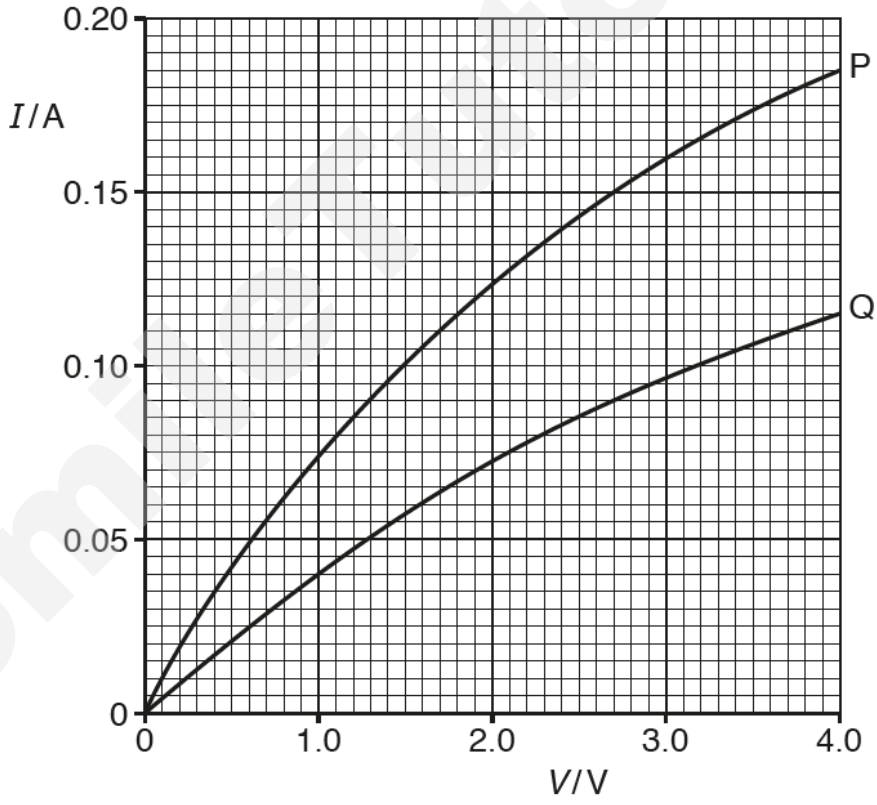


**Fig. 3.2**

**(a)** Use Fig. 3.2 to determine the current in the battery.

current = …….. A [2]

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**(b)** **(i)** Calculate the resistance of resistor R.

resistance = …….. Ω [2]

**(ii)** Draw the $I$-$V$ characteristics of resistor R in Fig. 3.2. [1]

**(c)** The filament wires of the two lamps are made from material with the same resistivity at their operating temperatures in the circuit. The diameter of the wire of lamp P is twice the diameter of the wire of lamp Q.

Determine the ratio

$$\frac{\text{length of filament wire of lamp P}}{\text{length of filament wire of lamp Q}}$$

ratio = …….. [3]

**(d)** The filament wire of lamp Q breaks and stops conducting.

State and explain, with the aid of Fig. 3.2, the effect on the resistance of lamp P.

……

……

……

……[2]

[Total: 10]

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**4** A horseshoe magnet is placed on a top pan balance. A rigid copper wire is placed between the poles of the magnet, as illustrated in Fig. 4.1

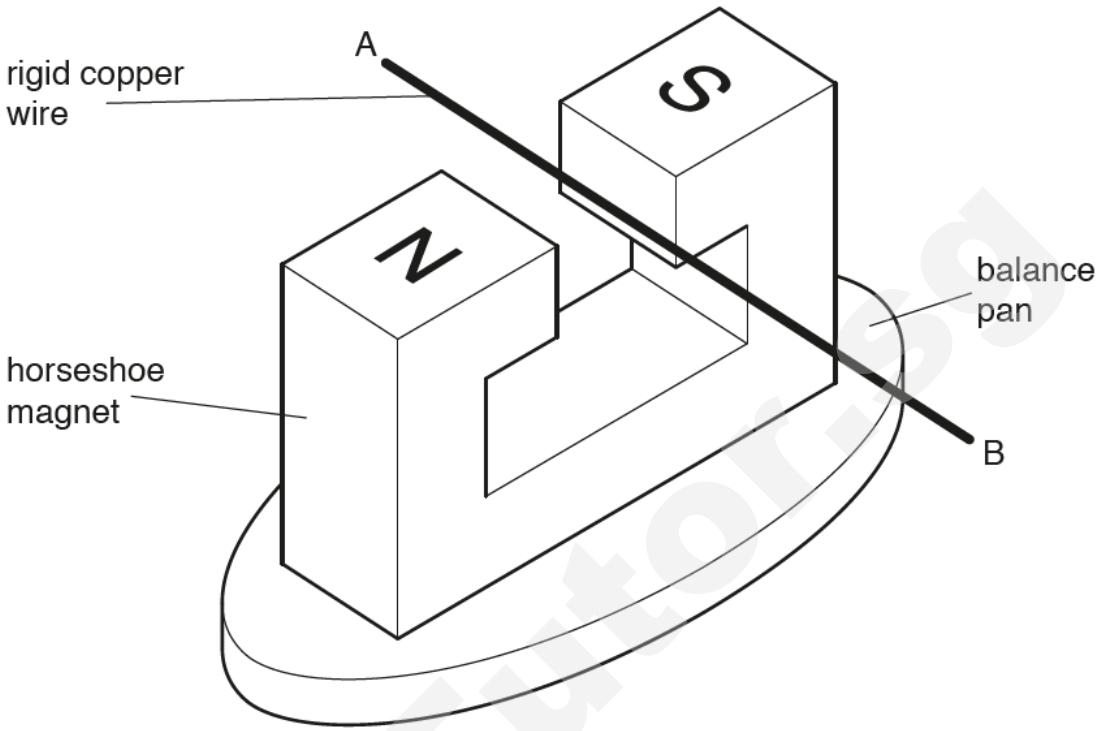


**Fig. 4.1**

The wire is clamped at ends A and B.

**(a)** When a direct current flows in the wire, the reading on the balance is seen to **decrease**. State and explain the direction of

**(i)** the magnetic force acting on the wire,

……..

……..

……..

……..[3]

**(ii)** the current in the wire.

……..

……..

……..[2]

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**(b)** A direct current of 4.6 A in the wire causes the reading on the balance to change by $4.5 \times 10^{-3}$ N.

The direct current is now replaced by an alternating current of frequency 40 Hz and root-mean-square (r.m.s.) value of 4.6 A.

On the axes of Fig. 4.2, sketch a graph to show the change in balance reading over a time of 50 ms.

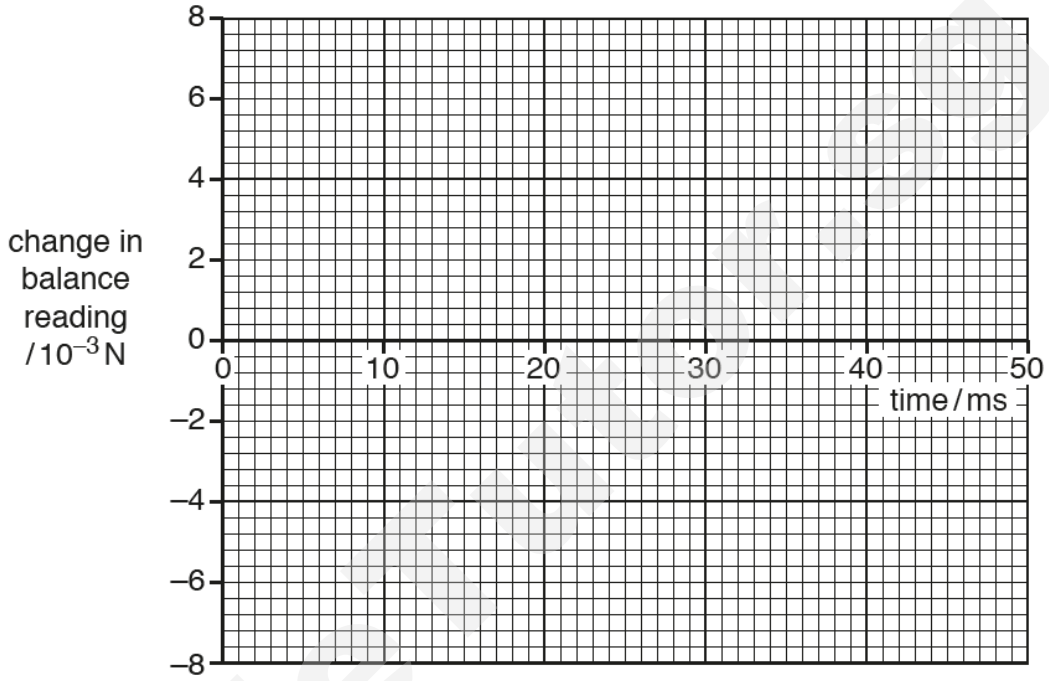


**Fig. 4.2**

[3]

[Total: 8]

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**5** **(a)** State *Faraday's law of electromagnetic induction*.

……

……

……[1]

**(b)** A solenoid S is wound on a soft-iron core, as shown in Fig. 5.1

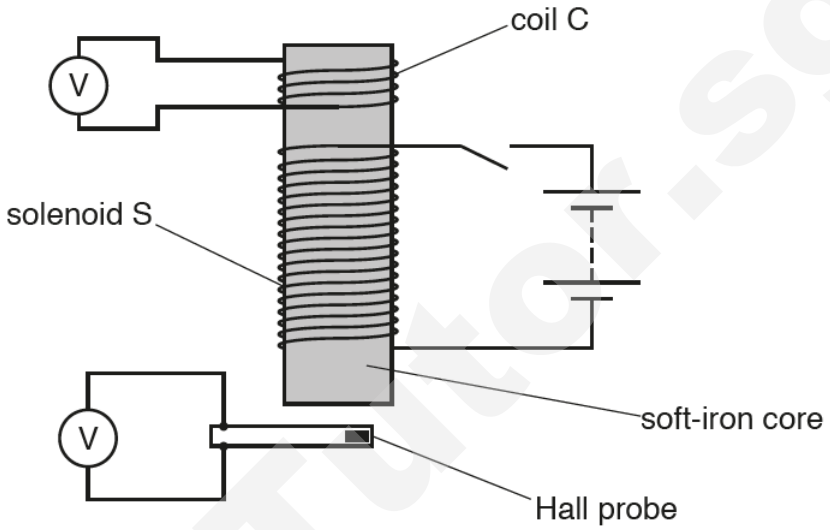


**Fig. 5.1**

A coil C having 120 turns of wire is wound to one end of the core. The area of cross-section of coil C is 1.5 $cm^2$.

A Hall probe is placed close to the other end of the core.

When there is a constant current in solenoid S, the flux density in the core is 0.19 T. The reading on the voltmeter connected to the Hall probe is –0.20 V.

The current in solenoid S is now reversed in a time of 0.13 s at a constant rate.

**(i)** Calculate the reading on the voltmeter connected to coil C during the time that the current is changing.

reading = …… V [2]

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**(ii)** Complete Fig. 5.2 for the voltmeter readings for the time before, during and after the direction of the current is reversed.

| | before current changes | during current change when current is zero | after current changes |
|---|---|---|---|
| reading on voltmeter connected to coil C/ V | ..... | ..... | ..... |
| reading on voltmeter connected to Hall probe/ V | −0.20 | ..... | ..... |

**Fig. 5.2**

[4]

[Total: 7]

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**6** **(a)** A child starts to skate from rest in a straight line along a horizontal asphalt surface. The force of rolling (static) friction between her skates and the road is constant at 160 N.

Fig. 6.1 shows the relationship between the driving force $F_D$ that she exerts and her distance $x$ from her starting position. She has a mass of 30.5 kg.

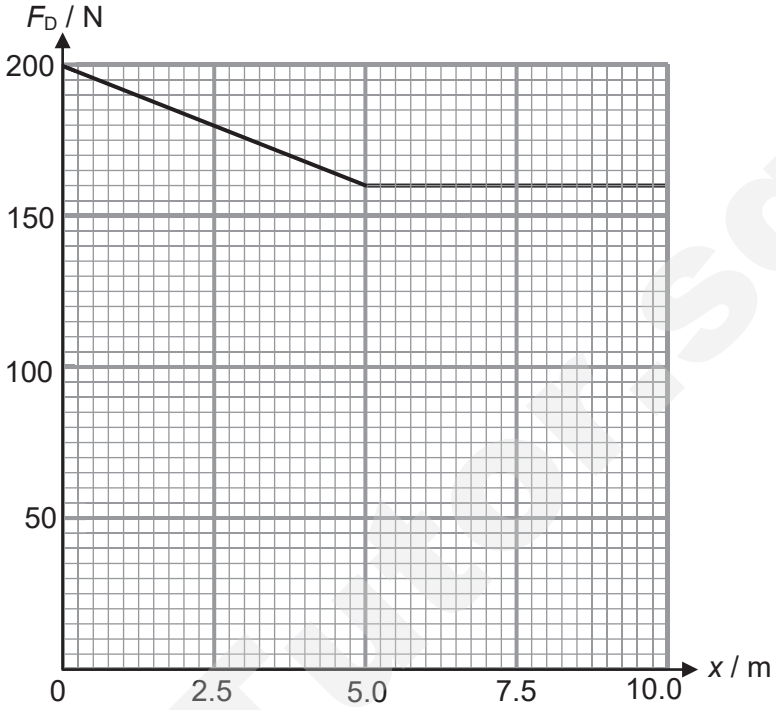


**Fig. 6.1**

**(i)** Calculate the work done by the child in the first 5.0 m of travel.

work done = ..... J [1]

**(ii)** Determine her speed after travelling 10.0 m.

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

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**(b)** Muons and anti-muons have the same mass. When a muon meets an anti-muon, both are destroyed and two gamma photons are formed. If the muon and anti-muon have negligible kinetic energy and the two photons have a total energy of $3.38 \times 10^{-11}$ J, determine the mass of a muon.

mass = ……. kg [2]

**(c)** A method of producing a range of artificial isotopes is 'neutron activation'. This is where a stable isotope is bombarded by a neutron to produce an unstable isotope, which in turn decays by beta emission to produce a new element.

By writing two nuclear equations, deduce the final isotope produced by neutron activation of deuterium, ${}^{2}_{1}\mathrm{H}$.

Equation 1: ……..

Equation 2: ……..

final isotope = …… [2]

**(d)** We now know that during beta decay, the neutrino is emitted. But before its discovery, physicists analysing emitted beta particles were perplexed by the continuous spread of its energy.

Explain why this continuous energy spectrum was a problem to physicists.

……..

……..

……[2]

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**(e)** One isotope of potassium, $^{40}_{19}K$ has a half-life of $1.37 \times 10^9$ years and decays to form argon, $^{40}_{18}Ar$, which is stable. A lunar sample of rock was discovered to contain both elements in the ratio

$$\frac{\text{number of K-40 atoms}}{\text{number of Ar-40 atoms}} = \frac{1}{6} .$$

**(i)** Estimate the age of this sample.

age = …… years [2]

**(ii)** State and explain whether the answer in **(e)(i)** is an underestimate or overestimate if some argon had escaped from the rock.

……

……

……..……...[2]

[Total: 13]

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**7** Singapore has enjoyed good quality tap water for more than five decades as a result of sound watershed management, effective water treatment processes and continued investments in Research & Development. Our tap water is well within the World Health Organization drinking water guidelines, and is suitable for drinking without any further filtration.

Raw water from various sources is conveyed by pipelines to the waterworks where it is chemically treated, filtered and disinfected. To ensure that the tap water is clean and safe, water samples are regularly collected and analysed chemically and bacteriologically at the Water Testing Laboratory. Samples of water at various stages of treatment at all waterworks, raw water from all sources, treated water from all service reservoirs and selected points in the distribution network are collected for daily or periodic analysis.

In these water treatment plants, it is important to monitor the water flow rates at the different stages of treatment so that the water pressures are kept at a safe acceptable level. One common way to monitor flow rate is to use the orifice meter.

An orifice meter is a piece of equipment used to measure the flow rate of a gas or a fluid. It mainly consists of an orifice plate, an orifice plate housing, and a meter tube. Fundamentally, it works on the Differential Pressure Measurement principle. The liquid or gas whose flow rate is to be determined is passed through the orifice plate. This creates a pressure drop across the orifice plate, which varies with the flow rate, resulting in a differential pressure between the outlet and inlet segments. This pressure drop is measured and used to calculate the flow rate of the fluid or gas.

There are several advantages of using the orifice meter. Firstly, it is cost-effective and quite easy to use. It occupies less space, making it ideal for space-constrained applications. It can be used to determine flow rates in small and large pipes. On top of that, it can be installed in the horizontal or vertical positions.

Fig. 7.1 shows a side view of an orifice meter, which consists of a thin orifice plate with a circular hole through it. There is a pressure tap upstream from the orifice plate and another just downstream. Both pressure taps are connected to a manometer. As a liquid passes through the orifice constriction, it experiences a drop in pressure across the orifice. The pressure drop is then used to measure the volume flow rate of the liquid. A front view of the orifice plate is included on the left for easy reference.

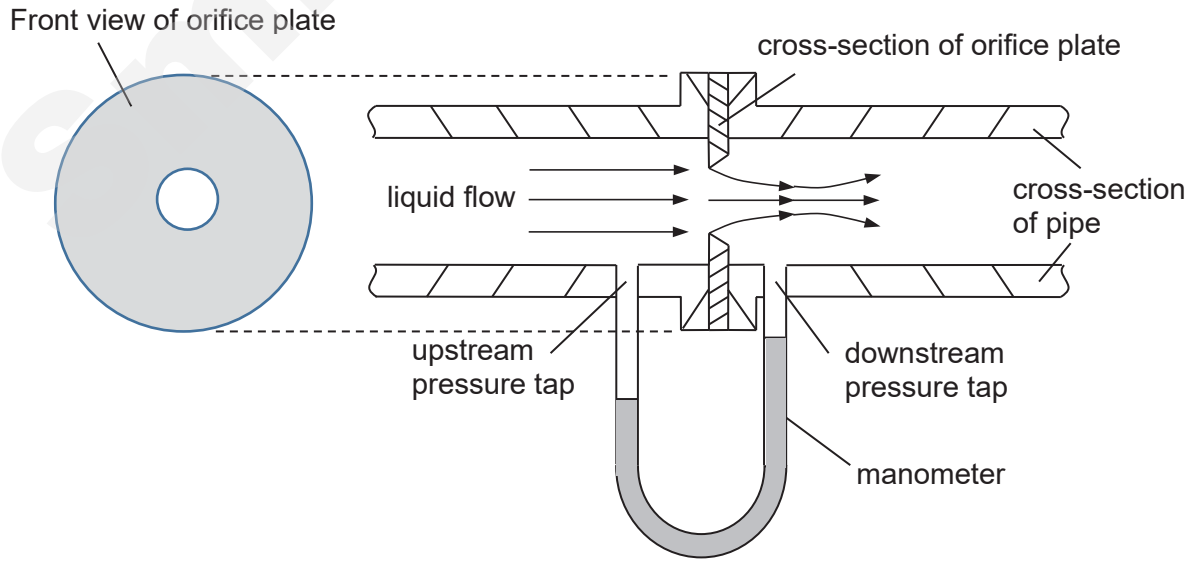


**Fig. 7.1**

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The volume flow rate and pressure drop across the orifice plate are $Q$ and $\Delta p$ respectively. The variation with $Q$ of $\Delta p$ is shown in Fig. 7.2.

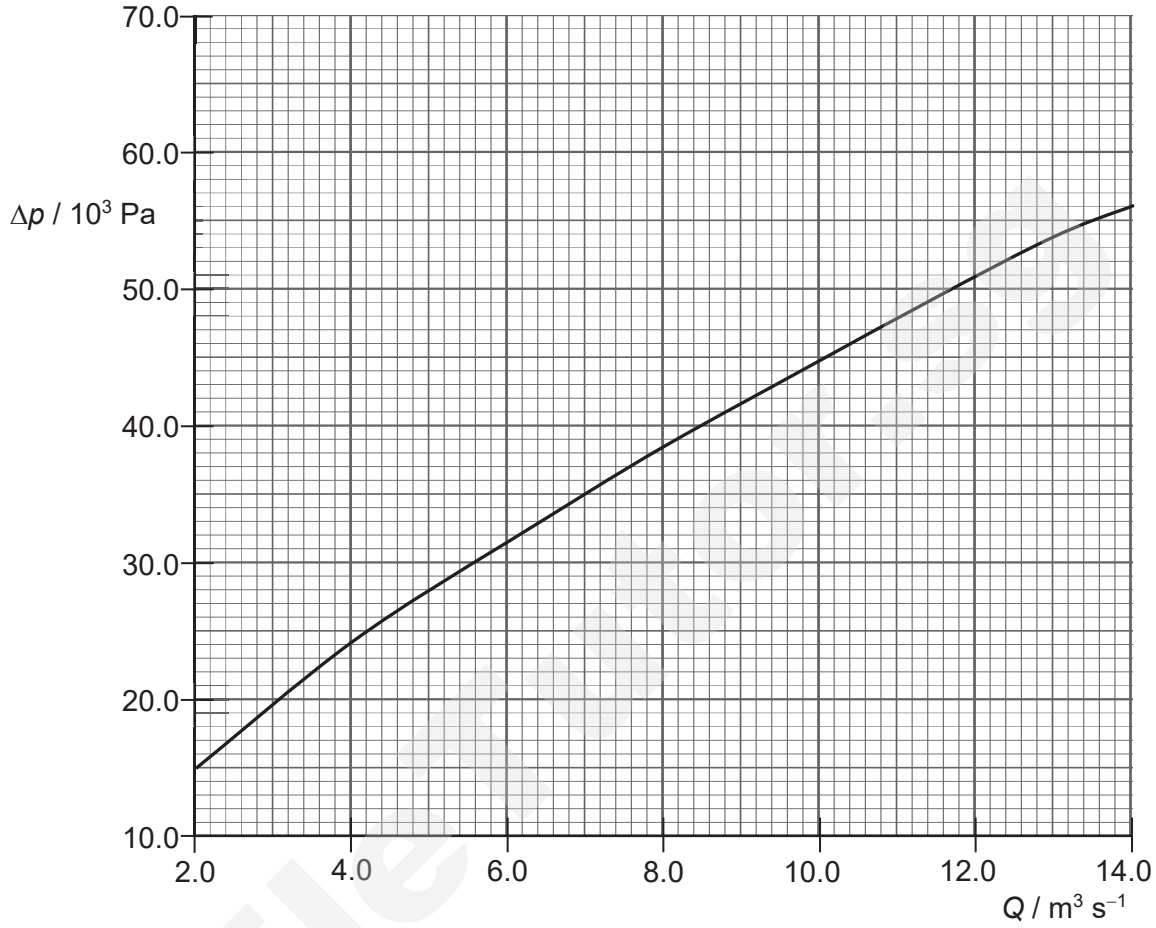


**Fig. 7.2**

**(a)** Describe, without calculation, the variation with $Q$ of $\Delta p$.

……

……

……[2]

**(b)** Suggest why there is a pressure difference between the upstream pressure and downstream pressure during a uniform water flow process.

……

……

……[2]

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**(c)** Suggest whether the pressure difference will be affected if the orifice meter is installed in a vertical position, instead of the horizontal position.

……

……

……[2]

**(d)** The relation between $\Delta p$ and $Q$ is thought to follow the expression

$$\Delta p = kQ^n ,$$

where $k$ and $n$ are constants.

Data from Fig. 7.2 are used to obtain values of lg ($\Delta p$ / Pa) and lg ($Q$ / $m^3\ s^{-1}$). These are plotted on the graph of Fig. 7.3.

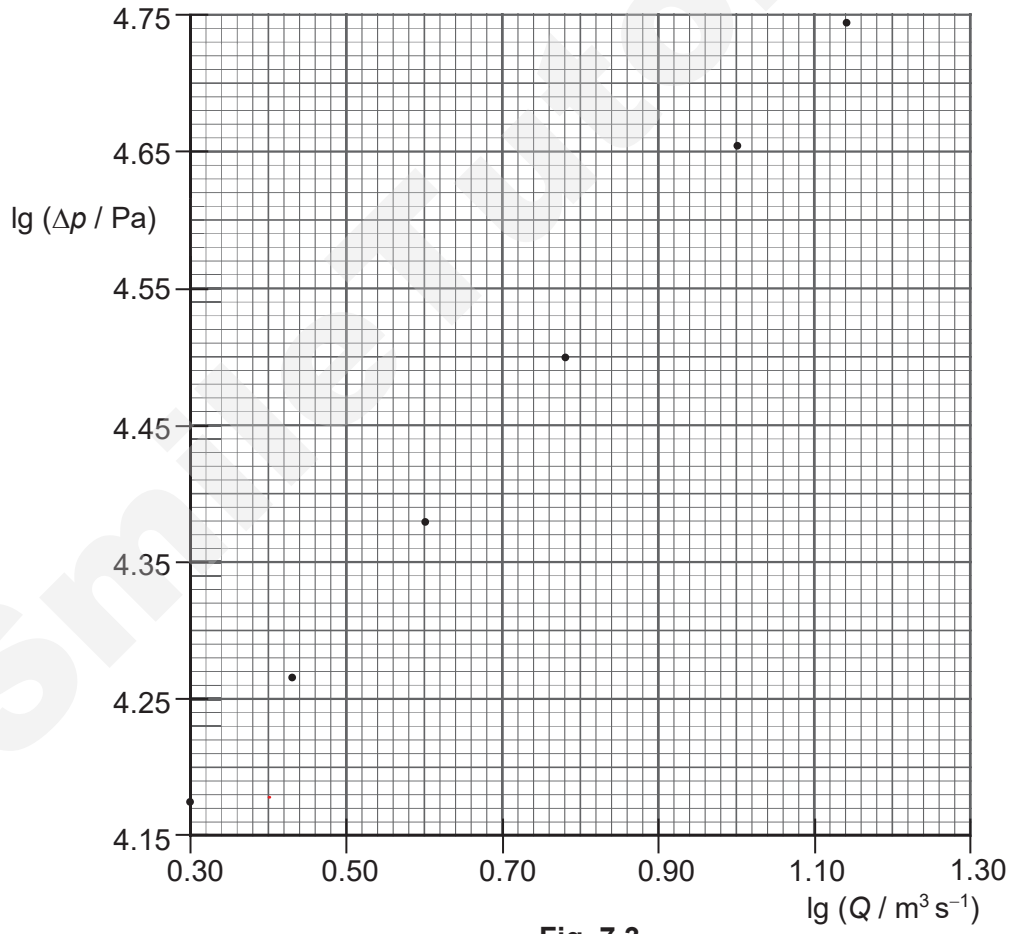


**Fig. 7.3**

**(i)** Use Fig. 7.2 to determine lg ($\Delta p$ / Pa) for $Q$ = 8.0 $m^3\ s^{-1}$.

lg ($\Delta p$ / Pa) = …… [2]

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**(ii)** On Fig. 7.3,

**1.** plot the point corresponding to $Q = 8.0\ m^3\ s^{-1}$,

**2.** draw the best fit line for all the points. [2]

**(iii)** Determine the gradient of the line drawn in **(ii) 2**.

gradient = ..... [2]

**(iv)** Using your answer in **(iii)**, determine the magnitude of $k$.

magnitude of $k$ = ..... [2]

**(v)** Determine the SI base units for $k$.

SI base units = ..... [2]

**(e)** Theory suggests that $k$ is given by the expression

$$k = \frac{\rho}{1.2\ A_o^2},$$

where $A_o$ is the area of the circular hole in the orifice plate and $\rho$ is the density of the liquid used.

**(i)** Use your answer in **(d)(iv)** to determine the radius $r$ of the hole if the liquid used is water of density 1000 kg $m^{-3}$.

$r$ = ..... m [2]

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**(ii)** On Fig. 7.3, sketch a second graph to represent the results for oil, instead of water.

[1]

**(iii)** On Fig. 7.2, sketch a second graph to represent the results for oil, instead of water.

[1]

**(iv)** Hence, state and explain how the design of the manometer needs to be different for the measurement of the volume flow rate of oil, instead of water.

……

……

……

……[2]

[Total: 22]

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JC 2 PRELIMINARY EXAMINATION
**Higher 2**

CANDIDATE NAME

CG

INDEX NO

# PHYSICS 9749/03

Paper 3 Structured Questions **17 September 2019**

**2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

Write your name and class 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, highlighters, glue or correction fluid/tape.

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

**Section A**
Answer **all** questions.

**Section B**
Answer **one** question only.

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

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

| For Examiner's Use | |
|---|---|
| **Paper 3** | |
| **Section A** | |
| **1** | **/8** |
| **2** | **/8** |
| **3** | **/16** |
| **4** | **/8** |
| **5** | **/6** |
| **6** | **/14** |
| **Section B** | |
| **7** | **/20** |
| **8** | **/20** |
| **Penalty** | |
| **Paper 3 Total** | |
| | **/80** |



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**Data**

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

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**Formulae**

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

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## Section A

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

**1** A solid cylinder is lifted out of oil by a wire attached to a motor. Fig. 1.1 shows two different positions X and Y of the cylinder during the lifting process.

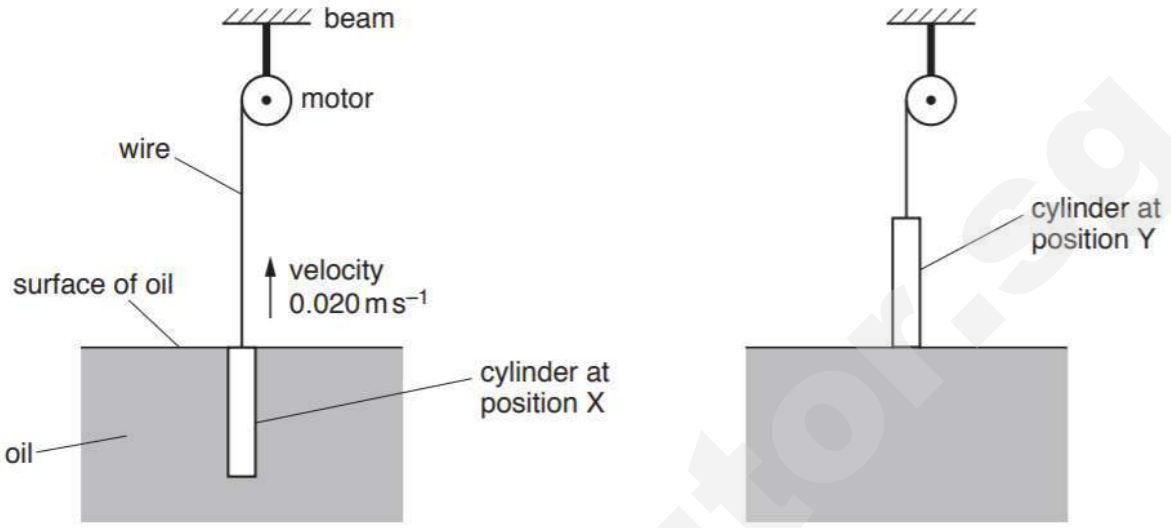


**Fig. 1.1**

The motor is fixed to an overhead beam.

The cylinder has a cross-sectional area of 0.018 $m^2$, length 1.2 m and weight 560 N.

The density of the oil is 940 kg $m^{-3}$.

Throughout the lifting process, the cylinder moves vertically upwards with a constant velocity of 0.020 m $s^{-1}$. The viscous force of the oil acting on the cylinder is negligible.

**(a)** For the cylinder at position X in Fig. 1.1, calculate the upthrust acting on the cylinder.

upthrust = ..... N [2]

**(b)** Calculate, for the moving cylinder at position X,

**(i)** the tension in the wire,

tension = ..... N [2]

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**(ii)** the power output of the motor.

power = …….. W [2]

**(c)** The cylinder is raised with constant velocity from position X to position Y.

Explain why the power output of the motor is seen to increase as the cylinder is raised. Numerical values are not required.

……

……

……

……[2]

[Total: 8]

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**2** A theme park ride is illustrated in Fig 2.1.

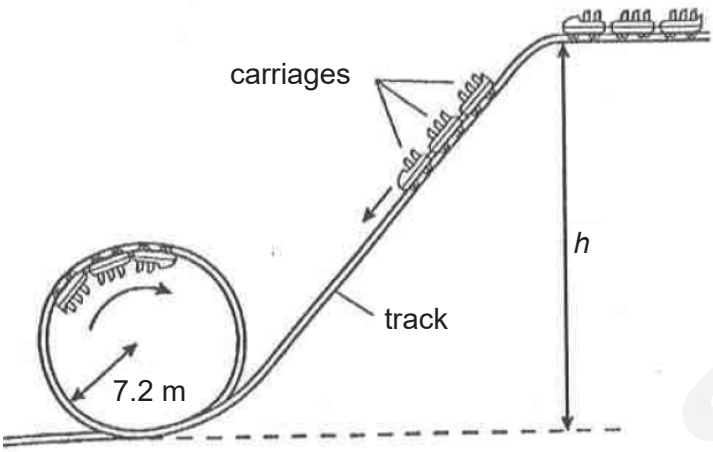


**Fig. 2.1**

The carriages accelerate down the slope and then loop the loop on a circular section of the track. The radius of the circular section of the track is 7.2 m. Each carriage and its passengers has total mass 800 kg. At the top of the loop, the carriage travels at 17 m $s^{-1}$.

**(a)** Calculate the force that the track exerts on the carriage at the top of the loop.

force = …….. N [2]

**(b)** Explain qualitatively how the centripetal acceleration of the carriage changes, if any, when the carriage is moving from the bottom to the top of the loop.

……

……

……

……

……[3]

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**(c)** For the carriage to have a speed of 17 m $s^{-1}$ at the top of the loop, it must have fallen from a height of *h*. Assume no dissipative forces.

**(i)** Determine the value of *h*.

*h* = …….. m [2]

**(ii)** State how the value of *h* should change when the total mass of the carriage and passengers is increased.

……..……..……

……..…..…..……[1]

[Total: 8]

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**3 (a) (i)** State what is meant by the *internal energy* of a system.

……

……

……

……[2]

**(ii)** Explain why, for an ideal gas, the change in internal energy is directly proportional to the change in thermodynamic temperature of the gas.

……

……

……

……

……[3]

**(b)** A cylinder of volume $1.8 \times 10^4$ cm$^3$ contains helium gas at pressure $6.4 \times 10^6$ Pa and temperature 25°C.

Helium gas may be considered to be an ideal gas consisting of single atoms.

Calculate, for the helium gas in the cylinder,

**(i)** the mean kinetic energy of a single helium atom,

mean kinetic energy = …….. J [1]

**(ii)** the number of helium atoms,

number = …….. [2]

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**(iii)** the total internal energy.

total internal energy = …….. J [1]

**(c)** Fig. 3.1 is an indicator diagram showing the cycle of changes of ideal gas pressure and volume in an engine. The cycle consists of two adiabatic changes and two isothermal changes. Adiabatic process is one whereby there is no net heat transfer to and from the system. Isothermal process is one whereby the temperature remains the same.

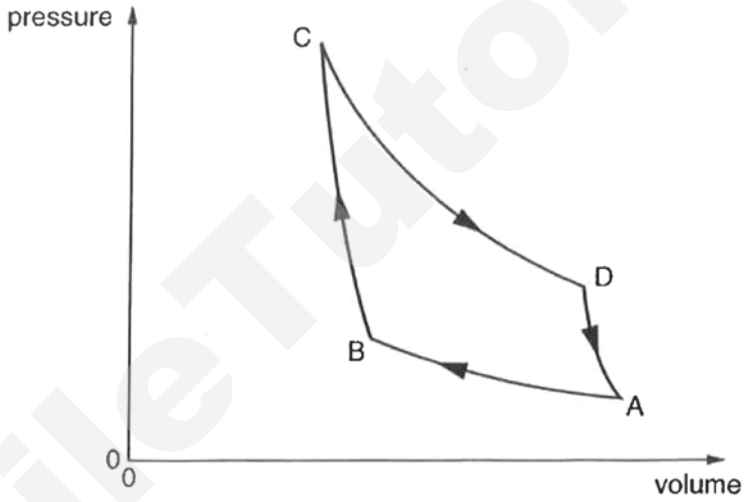


**Fig. 3.1**

**(i)** State which sections of the indicator diagram are the isothermal changes.

……..……..[1]

**(ii)** The coefficient of performance of the engine *P* is given by

$$P = \frac{\text{Heat delivered to gas (during change C to D)}}{\text{Work done on gas (during change A to B)}}$$

The heat delivered to gas (during change C to D) is 160 J.

Calculate the work done on gas during change A to B if the value of *P* is 1.6.

work done = …….. J [1]

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**(iii)** Fig. 3.2 shows some of the energy changes taking place in the engine.

| Sections | Increase in internal energy / J | Work done on gas / J | Heat supplied to gas / J |
|---|---|---|---|
| A → B | | | |
| B → C | + 70 | | |
| C → D | | | |
| D → A | | | |

**Fig. 3.2**

Complete Fig. 3.2. Show your working, if any, in the space provided below.

[5]

[Total: 16]

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**Please turn over for Question 4.**

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**4** A load is suspended from the free end of a helical spring.

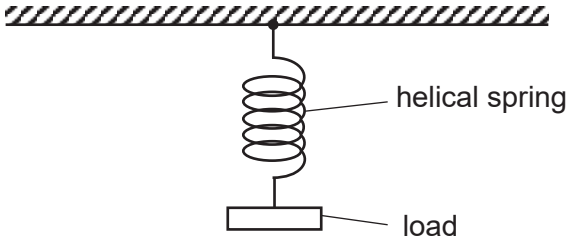


**Fig. 4.1**

The load is then displaced vertically downwards and released. The load undergoes simple harmonic oscillation. The variation of the displacement of the load $x$ with the time $t$ is given in Fig. 4.2 where the load is at its equilibrium position when $t = 0$.

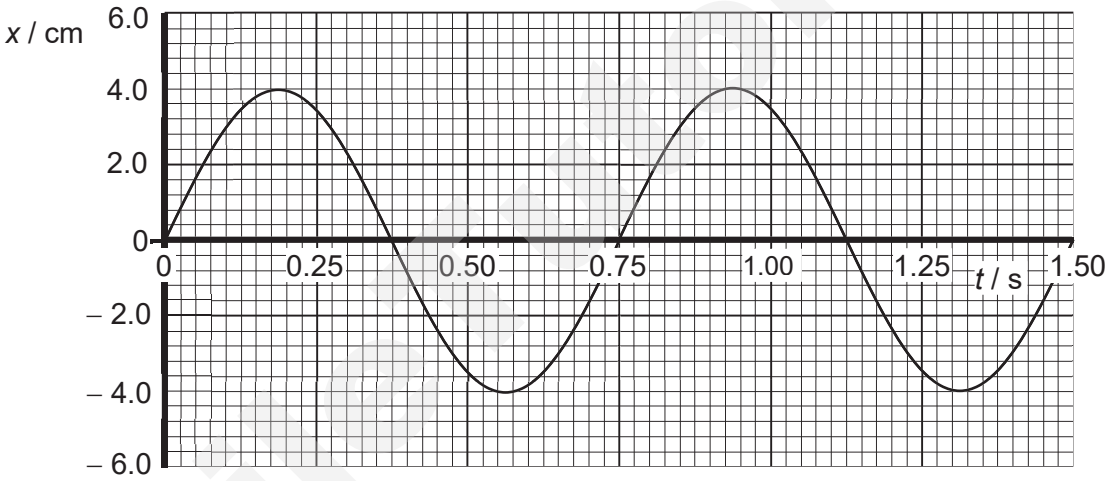


**Fig. 4.2**

**(a)** Determine the angular frequency of the oscillation.

angular frequency = …….. rad $s^{-1}$ [1]

**(b)** Determine the maximum acceleration experienced by the mass.

maximum acceleration = …….. m $s^{-2}$ [1]

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**(c)** Given that the tension acting on the mass at the lowest position is 25 N, show that the mass of the load is 2.0 kg.

[2]

**(d)** On Fig. 4.3, sketch the variation with time $t$ of the kinetic energy $E_k$ for the first 1.00 s.

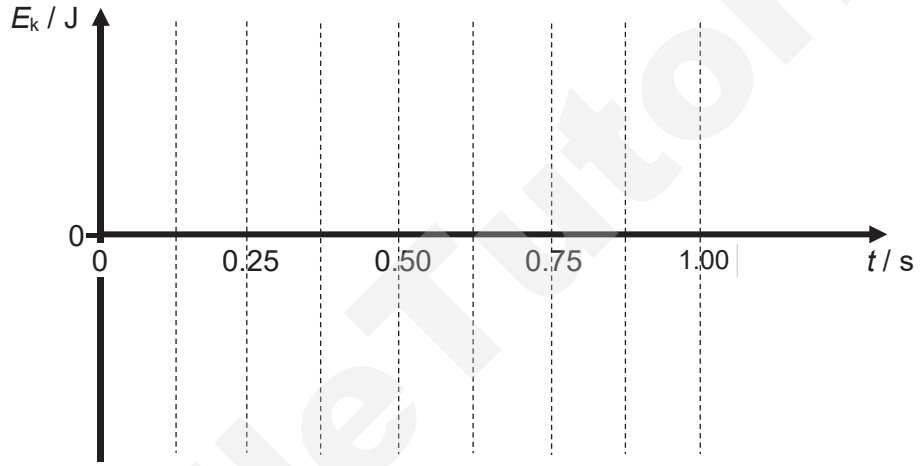


**Fig. 4.3**

[2]

**(e)** On Fig. 4.4, sketch the variation with displacement $x$ of the acceleration $a$ of the load.

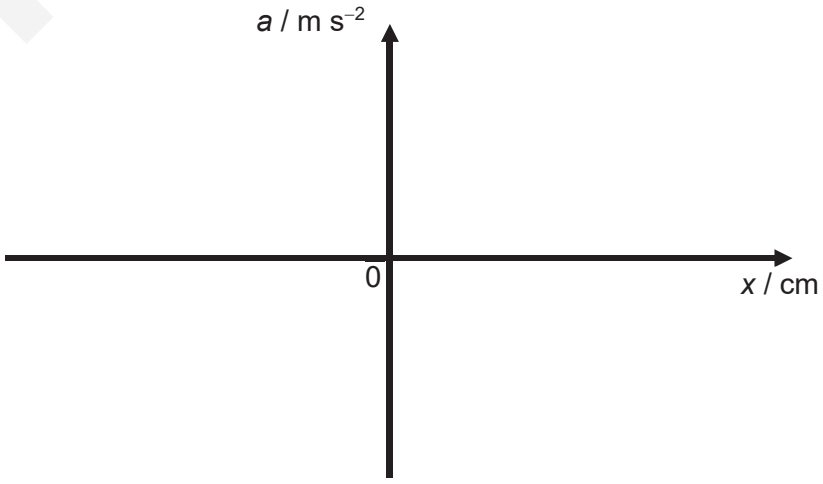


**Fig. 4.4**

[2]

[Total: 8]

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**5** A power station in China produces 3.0 MW of electrical power to be supplied to a town 25 km away. This power is generated at 25 kV and is subsequently stepped up to 125 kV using a transformer before the transmission. The transmission cables has a total resistance of 80 Ω and the station loses $0.25 for every 1 kWh of electrical energy lost in transmission cables.

**(a)** Determine the amount of power lost during transmission.

power lost = …….. W [2]

**(b)** Hence, calculate the amount of money lost by the station in a day.

money lost = $…….. [2]

**(c)** State two assumptions made in your calculations in **(b)**.

……

……

……[2]

[Total: 6]

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**6** White light is incident on a cloud of cool hydrogen gas, as illustrated in Fig. 6.1.

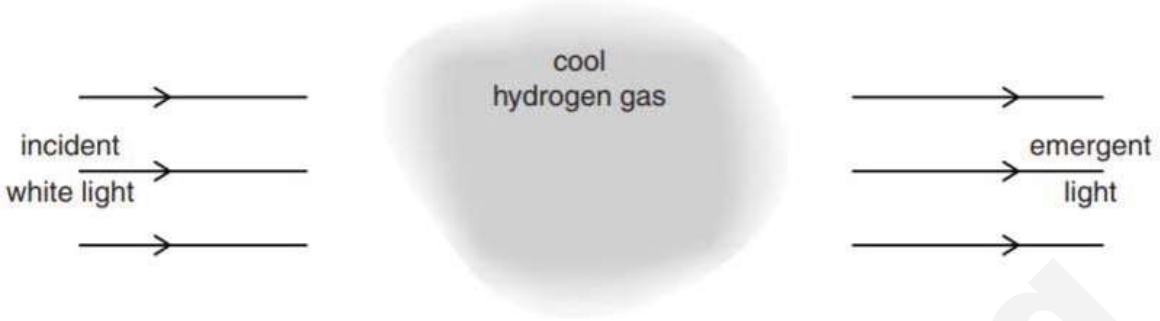


**Fig. 6.1**

**(a)** The spectrum of the light emerging from the cloud of cool gas is viewed using a diffraction grating.

Explain why this spectrum contains a number of dark lines.

……

……

……

……[3]

**(b)** The lowest electron energy levels of the gas atom are shown in Fig 6.2.

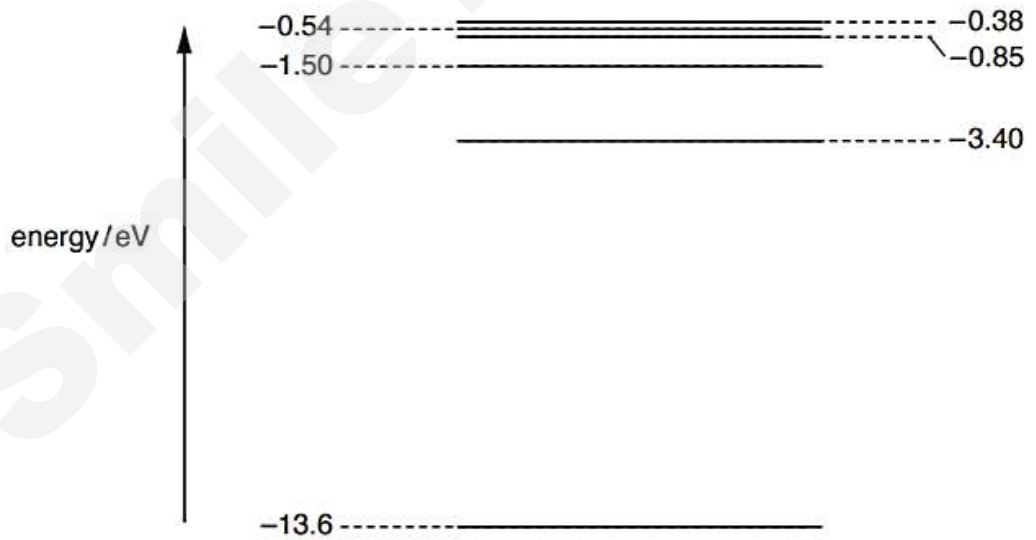


**Fig. 6.2** (not to scale)

**(i)** An electron is initially at the energy level –0.85 eV. State the total number of different wavelengths of photons that may be emitted as the electron de-excites.

number = …… [1]

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**(ii)** Photons resulting from electron de-excitation from the –0.85 eV energy level are incident on the surface of a sample of platinum.

Platinum has a work function energy of 5.6 eV.

Determine

**1.** the maximum kinetic energy, in eV, of a photoelectron emitted from the surface of the platinum,

maximum kinetic energy = …….. eV [2]

**2.** the wavelength of the photon producing the photoelectron in **(ii)1**,

wavelength = …….. m [1]

**3.** the estimated uncertainty of the photoelectron's position, given that the maximum velocity of the photoelectron is measured with an uncertainty of 15%.

uncertainty of position = …….. m [3]

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**(c)** The photoelectrons emitted are incident on a very thin carbon film, as illustrated in Fig. 6.3.

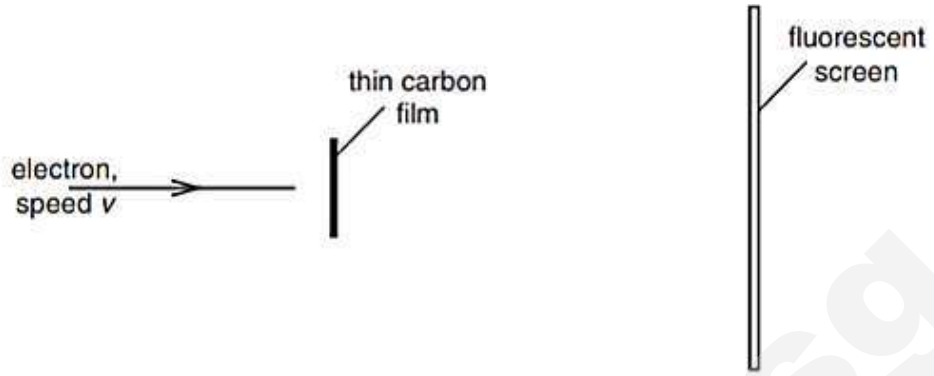


**Fig. 6.3**

The emergent electrons are incident on a fluorescent screen.

A series of concentric rings is observed on the screen.

**(i)** Suggest how the observed rings provide evidence for the wave nature of particles.

……

……

……[2]

**(ii)** The initial speed of the electrons is increased.

State and explain the effect, if any, on the radii of the rings observed on the screen.

……

……

……[2]

[Total: 14]

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## Section B

Answer **one** question from this Section in the spaces provided.

**7** A binary star system consists of two stars that orbit about a fixed point **O** as shown in Fig. 7.1.

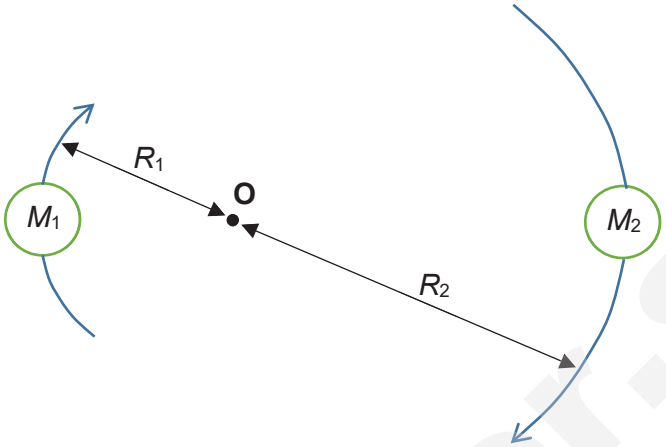


**Fig. 7.1**

The star of mass $M_1$ has a circular orbit of radius $R_1$ and the star of mass $M_2$ has a circular orbit of radius $R_2$. Both stars have the same angular speed $\omega$ about **O**.

**(a)** Using the symbols above and in the data list on page 2, write down the mathematical expression for

**(i)** the gravitational force, $F_A$, between the two stars,

[1]

**(ii)** the centripetal force, $F_B$, on the star of mass $M_2$.

[1]

**(b)** The stars orbit each other in a time of $1.26 \times 10^8$ s (~ 4 years). Calculate the value of $\omega$.

$\omega$ = ..... rad $s^{-1}$ [2]

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**(c)** **(i)** Show that the ratio of the masses of the stars is given by the expression

$$\frac{M_2}{M_1} = \frac{R_1}{R_2}.$$

[2]

**(ii)** The ratio of $\frac{M_2}{M_1}$ is equal to $\frac{1}{3}$ and the separation of the stars is $3.2 \times 10^{11}$ m.

Calculate the values of $R_1$ and $R_2$.

$R_1$ = ..... m

$R_2$ = ..... m [2]

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**(d)** The light from a particular binary star system is analysed by physicists. The time variation of the intensity of light received is shown in Fig. 7.2 below.

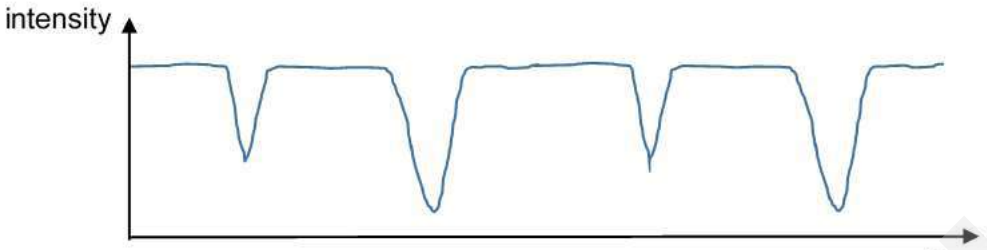


**Fig. 7.2**

By reference to the stars, suggest reasons for the shape of the graph above.

……

……

……[2]

**(e)** The potential in the gravitational field of a point mass increases with increasing distance from the mass.

Explain why the electric potential may increase or decrease with increasing distance from the charge.

……

……

……

……[2]

**(f)** The radius of a lithium ($^{7}_{3}\mathrm{Li}$) nucleus is $2.3 \times 10^{-15}$ m whereas the radius of a proton is $1.2 \times 10^{-15}$ m.

**(i)** Assuming that the lithium nucleus and proton act like point charges, determine the electric potential energy of the proton when it is just in contact with the lithium nucleus.

potential energy = …… J [3]

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**(ii)** A particle accelerator is an apparatus that accelerates subatomic particles so that they collide with each other. By reference to the answer in **(f)(i)**, suggest why such accelerators, are usually referred to as 'high energy' accelerators.

……

……

……

……[2]

**(g)** Fig. 7.3 shows part of a particle accelerator. Here, electrons are used.

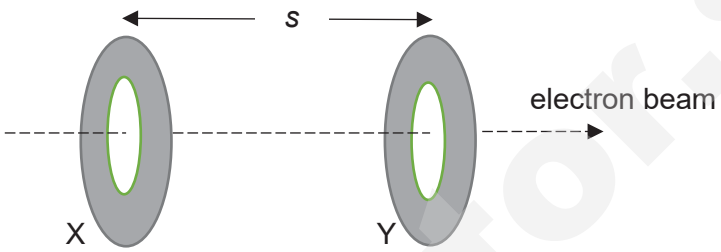


**Fig. 7.3**

The electrons pass through the opening in plate X with a speed of 6.0 Mm $s^{-1}$ and reach the opening of plate Y with a speed of 9.0 Mm $s^{-1}$. If the electric field region between X and Y is uniform and of strength $1.4 \times 10^5$ N $C^{-1}$, determine the value of *s*, the separation between the plates.

*s* = …… m [3]

[Total: 20]

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**8** **(a)** Fig. 8.1 shows the variation with time $t$ of the displacement $x$ of two progressive waves P and Q passing the same point with the same speed.

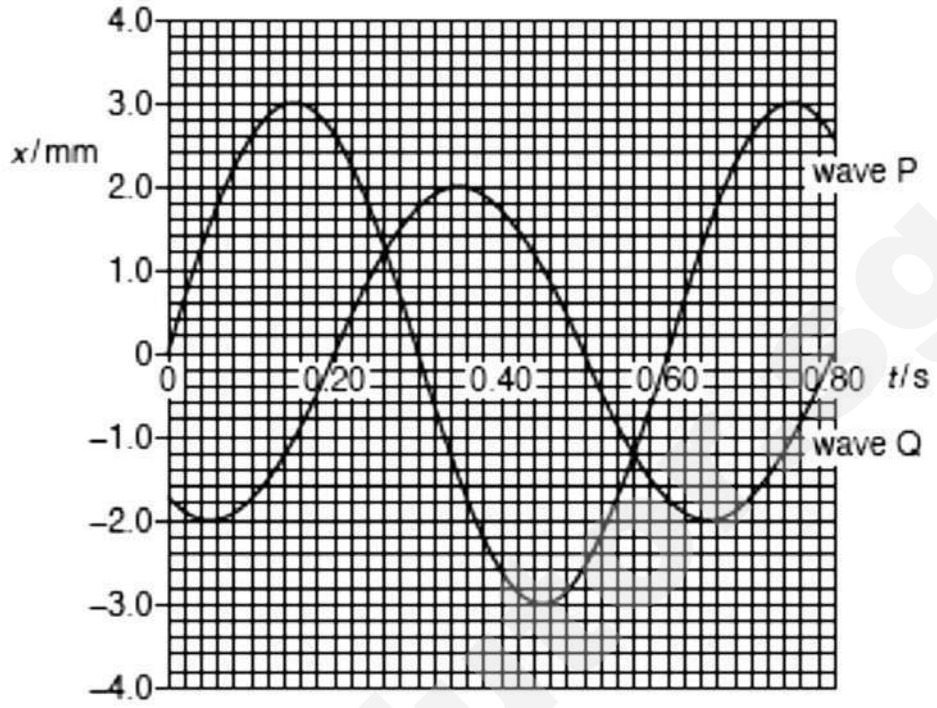


**Fig. 8.1**

The speed of the waves is 20 cm $s^{-1}$.

**(i)** Calculate the wavelength of the waves.

wavelength = ..... cm [1]

**(ii)** Determine the phase difference between the two waves

phase difference = ..... ° [1]

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**(iii)** Calculate the ratio $\frac{\text{intensity of wave Q}}{\text{intensity of wave P}}$.

ratio = ..... [2]

**(iv)** The two waves superimpose as they pass the same point. Use Fig. 8.1 to determine the resultant displacement at time $t$ = 0.45 s.

displacement = ..... mm [1]

**(b)** An arrangement for demonstrating the interference of light is shown in Fig. 8.2.

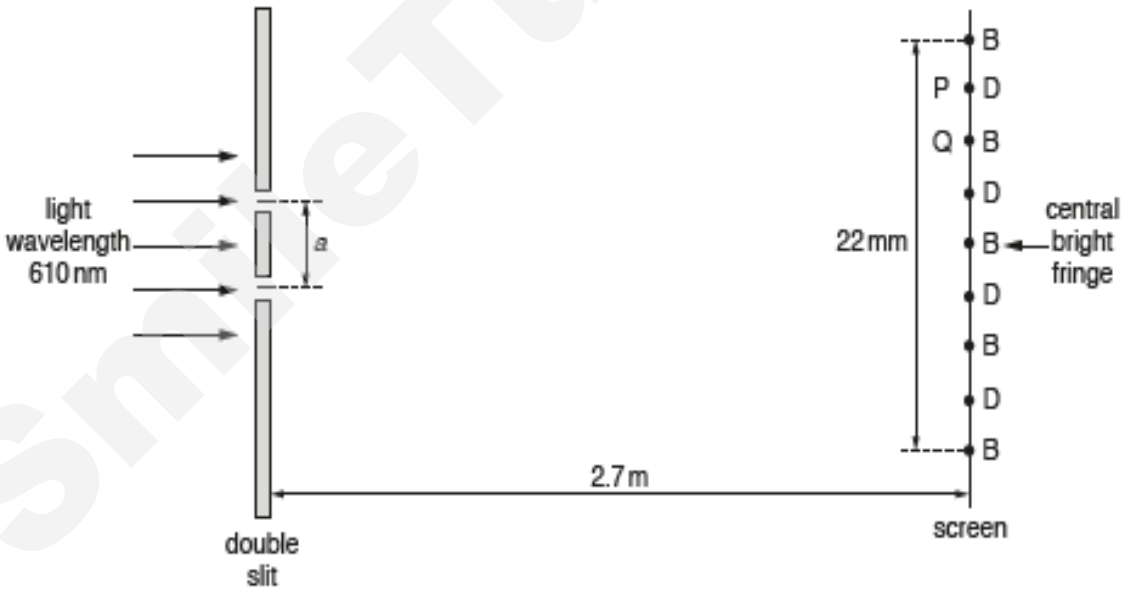


**Fig. 8.2** (not to scale)

The wavelength of the light is 610 nm. The distance between the double slit and the screen is 2.7 m.

An interference pattern of bright fringes and dark fringes is observed on the screen. The centres of the bright fringes are labelled B and centres of the dark fringes are labelled D. Point P is the centre of a particular dark fringe and point Q is the centre of a particular bright fringe, as shown in Fig. 8.2. The distance between five bright fringes is 22 mm.

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**(i)** The light waves leaving the two slits are coherent.

State what is meant by *coherent*.

……

……[1]

**(ii)** Calculate the path difference, in nm, of the waves meeting at P.

path difference = …… nm [1]

**(iii)** Determine the distance *a* between the two slits

*a* = …… m [2]

**(iv)** A higher frequency of visible light is now used. State and explain the change to the separation of the fringes.

……

……[1]

**(v)** The intensity of the light incident on the double slit is now increased without altering its frequency. Compare the appearance of the fringes after this change with their appearance before this change.

……

……

……

……[2]

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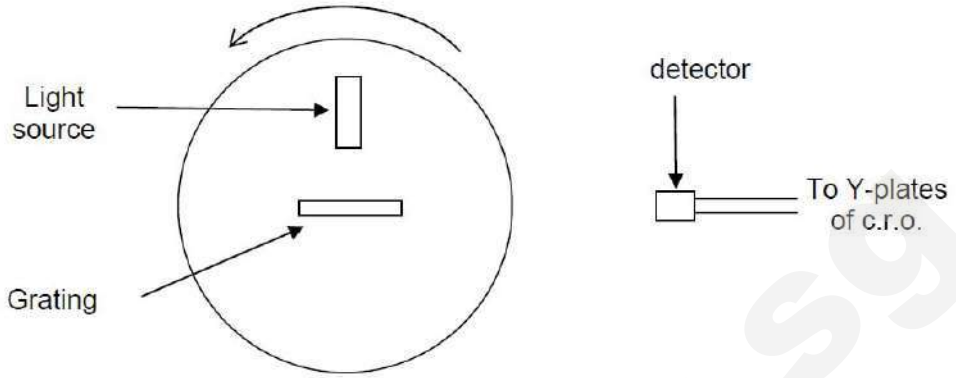
**(c)** A diffraction grating is set up at the centre of a rotating table which completes a revolution every 3.0 s. The grating is illuminated normally by monochromatic light of wavelength $\lambda$ from a source which is also mounted on the table as shown in Fig. 8.3.




Plan (top) view

**Fig. 8.3**

The emergent beams of light from the grating are monitored by means of a stationary opto-electrical detector. The output from the detector is displayed on a cathode ray oscilloscope (c.r.o.). With the timebase set at 0.10 s $cm^{-1}$, the trace obtained is shown in Fig. 8.4. The relative positions of the peaks are as indicated.

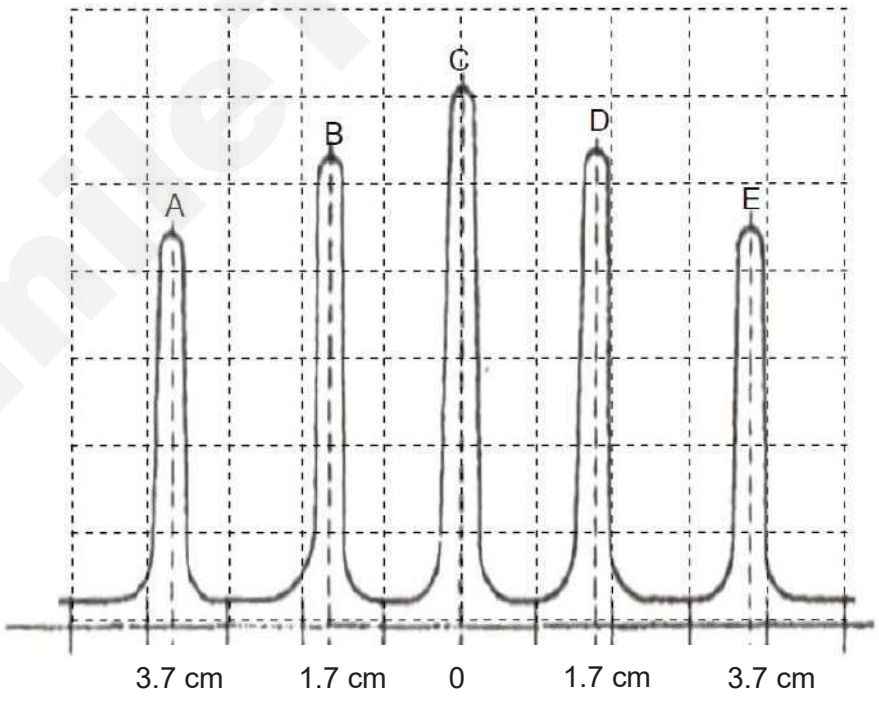



**Fig. 8.4**

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**(i)** Calculate the angular speed of rotation of the grating.

angular speed = ..... rad $s^{-1}$ [1]

**(ii)** Explain the appearance of the trace in Fig. 8.4.

.....

.....

.....

.....[2]

**(iii)** Using peak D, calculate the wavelength of the light if the grating has 550 lines per millimetre.

wavelength = ..... m [3]

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**(iv)** Sketch in Fig. 8.5, the c.r.o. display if the diffraction grating is replaced by a double slit of the same slit separation as the diffraction grating.

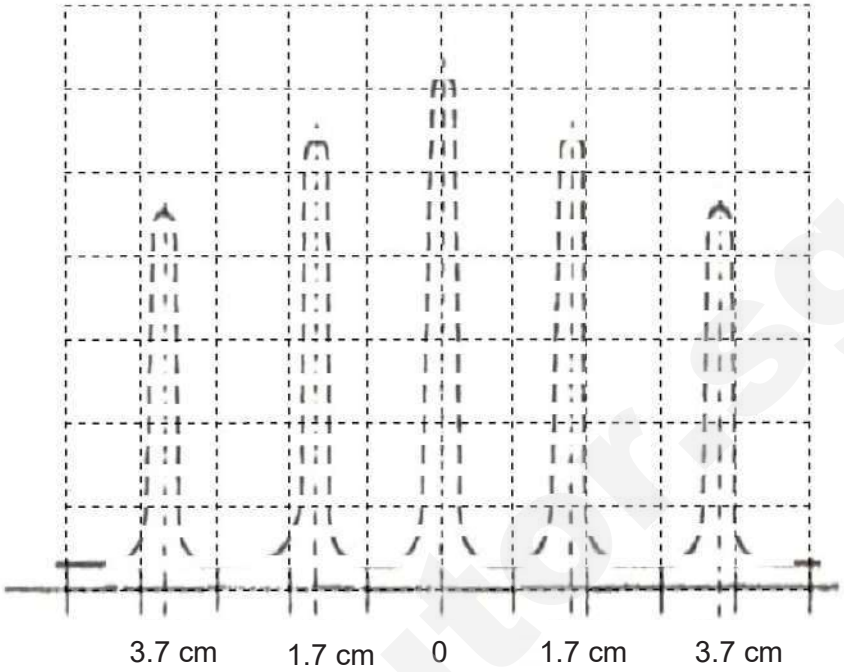


**Fig. 8.5**

(The original display from the grating is shown in dotted line) [2]

[Total: 20]

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# PHYSICS 9749/04

Paper 4 Practical

**27 August 2019**

**2 hours 30 minutes**

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

**READ THESE INSTRUCTIONS FIRST**

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

Answer **all** questions.

You will be allowed a maximum of one hour with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| 1 | /18 |
| 2 | /5 |
| 3 | /20 |
| 4 | /12 |
| Total | /55 |

This document consists of **19** printed pages and **1** blank page.

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

**(a)** **(i)** Measure and record the diameter $d$ of the short sample of wire that is placed in a transparent container.

$d$ = ..... [1]

**(ii)** Calculate the cross-sectional area A of the wire, using the formula

$$A = \frac{\pi d^2}{4}.$$

$A$ = ..... [1]

**(b)** **(i)** Use the wire attached to the metre rule, one of the voltmeters and one of the resistors to set up the partial circuit shown in Fig. 1.1.

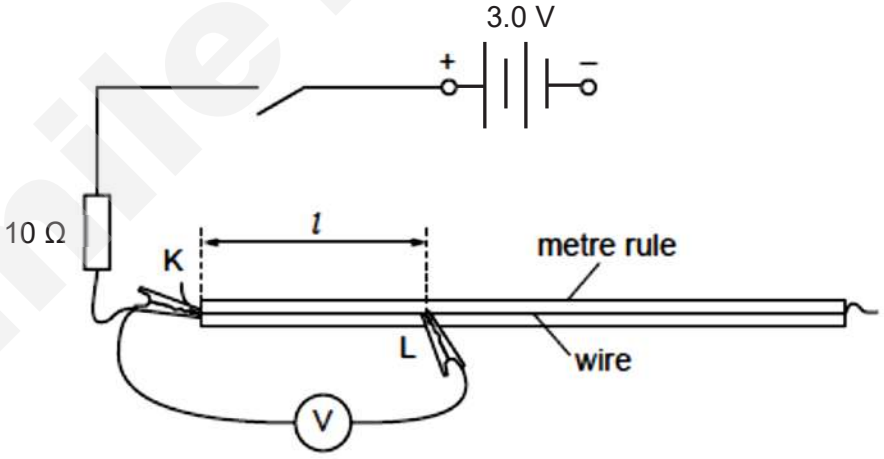


**Fig. 1.1**

There are two crocodile clips, one labelled K and the other labelled L.

Place K and L so that the distance $l$ between them is approximately 30 cm.

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

$l$ = .....

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**(iii)** Use the other resistor and the other voltmeter to complete the circuit shown in Fig. 1.2.

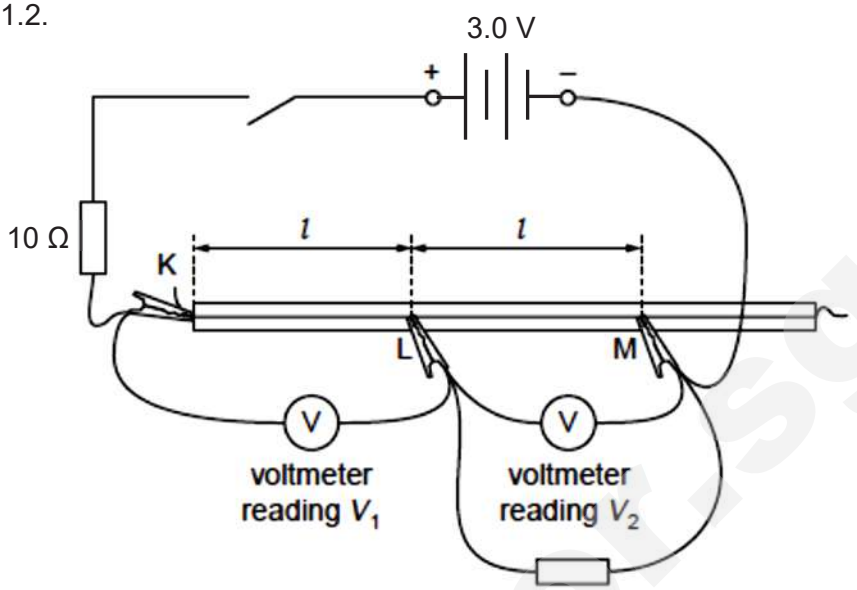


**Fig. 1.2**

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

**(c)** **(i)** Turn on the switch.

**(ii)** Record the voltmeter readings $V_1$ and $V_2$ as shown in Fig. 1.2.

$V_1$ = .....

$V_2$ = ..... [1]

**(iii)** Turn off the switch.

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

Include values of $\frac{V_1}{V_2}$ in your table.

[6]

**(e)** The quantities $V_1$, $V_2$ and $l$ are related by the equation

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

where $P$ and $Q$ are constants.

Plot a suitable graph to determine the values of $P$ and $Q$ with appropriate units.

$P$ = .....

$Q$ = ..... [6]

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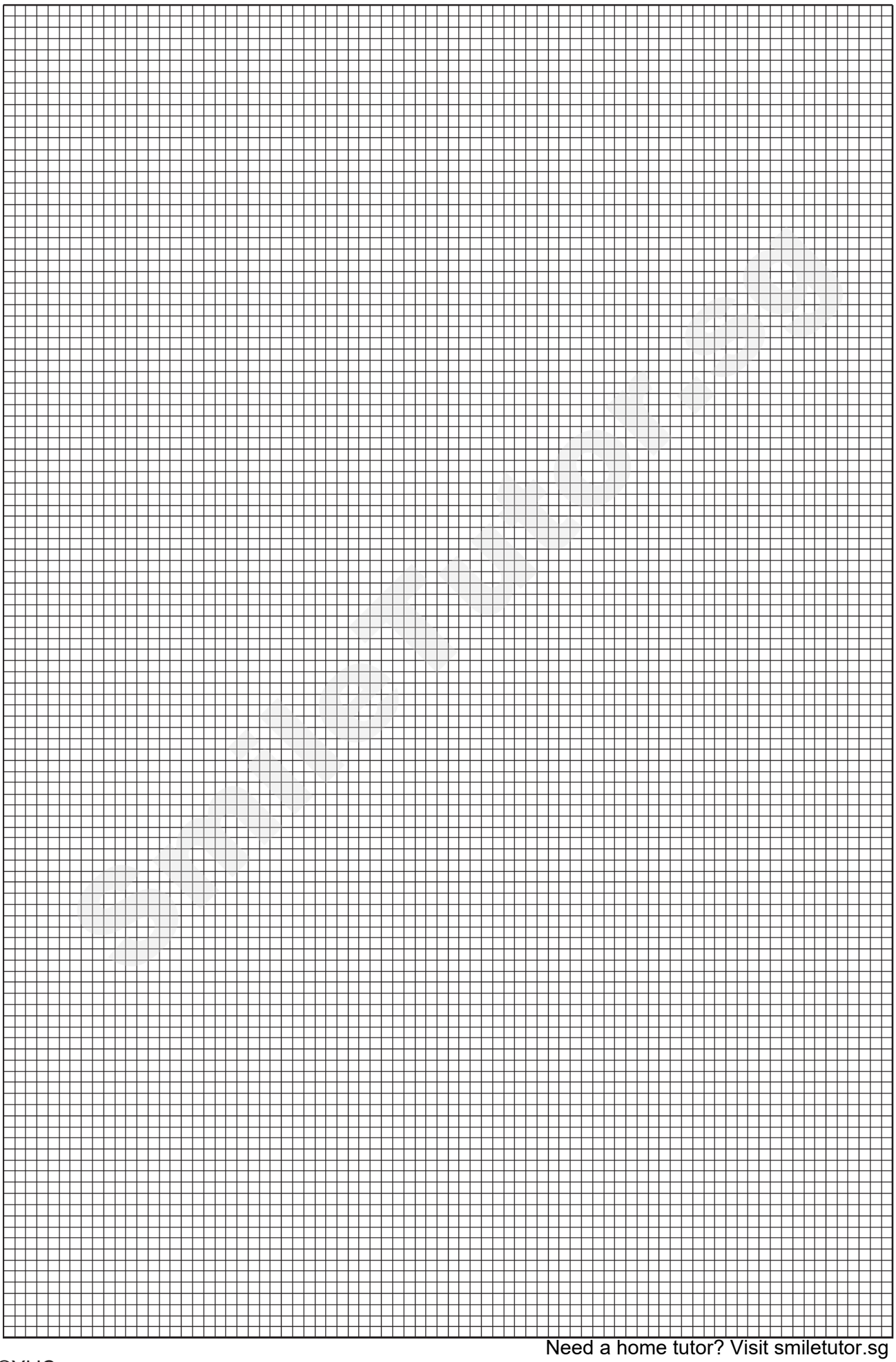

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**(f)** The resistivity $\rho$ of the material of the wire, in Ω m, can be found using the relationship

$$\rho = PAR$$

where $R$ = 10 Ω .

Use your answers in **(a)(ii)** and **(e)** to calculate a value for $\rho$.

$\rho$ = …… Ω m [1]

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

……..

……

…… [1]

**(h)** The experiment is repeated using the same resistance wire and a value of $R$ that is 20 Ω.

Assuming that $Q$ remains unchanged, on the same graph grid in **(e)**, sketch a second graph to represent the results. Label the graph, **Z**.

[1]

**[Total: 18 marks]**

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**2** In this experiment, you will investigate the balance of a ruler.

**(a)** **(i)** Record the length $L$ of the ruler as shown in Fig. 2.1.

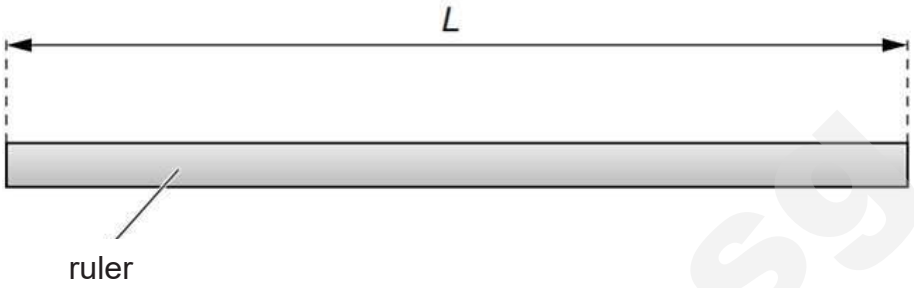


**Fig. 2.1**

$L$ = .....

**(ii)** Measure and record the mass $m$ of the ruler.

$m$ = ..... [1]

**(iii)** Calculate the mass per unit length $\rho$ of the ruler, where

$$\rho = \frac{m}{L} .$$

$\rho$ = ..... [1]

**(b)** **(i)** Record the mass $M$ of the slotted mass.

$M$ = .....

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**(ii)** Use the Blu-Tack to attach the slotted mass to the top of the ruler as shown in Fig. 2.2.

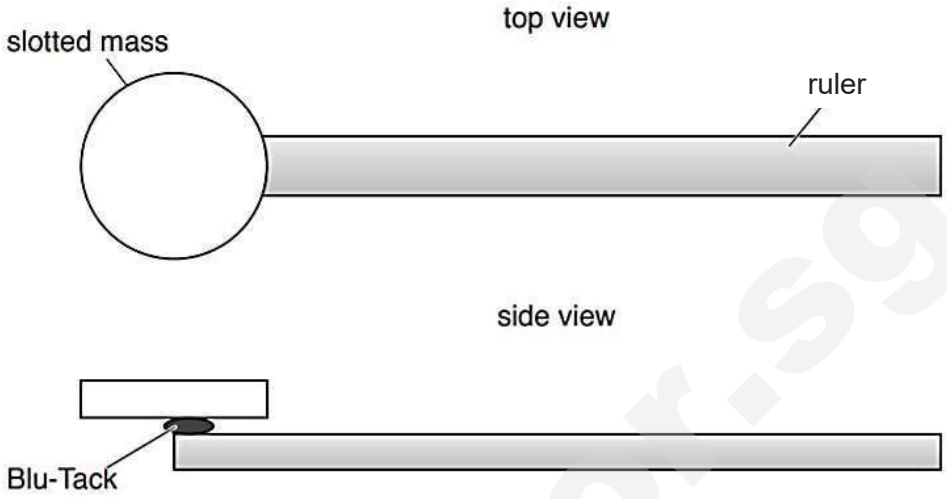


**Fig. 2.2**

The centre of the slotted mass should be positioned at the end of the ruler.

**(c)** **(i)** Balance the ruler on the pivot as shown in Fig. 2.3.

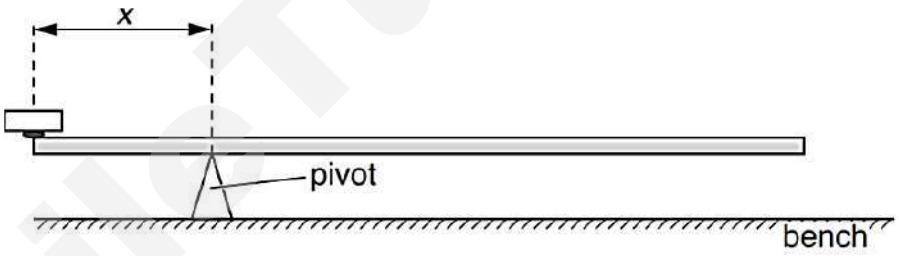


**Fig. 2.3**

**(ii)** Measure and record the distance *x* from the pivot to the end of the ruler as shown in Fig 2.3.

*x* = ..... [1]

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**(d)** Theory suggests that

$$x = \frac{kL^2}{2(M + L\rho)}$$

where $k$ is a constant.

**(i)** Using your data, calculate the value of $k$.

$k$ = ..... kg m$^{-1}$ [1]

**(ii)** If you were to repeat this experiment with rulers of different lengths $L$, each having the same mass per unit length $\rho$, describe the graph you would plot to determine $k$.

.....

.....

..... [1]

**[Total: 5 marks]**

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**3** In this experiment, you will investigate the motion of a Y-shaped pendulum.

**(a)** You have been provided with two loops of string.

Stretch one of the loops as shown in Fig. 3.1.

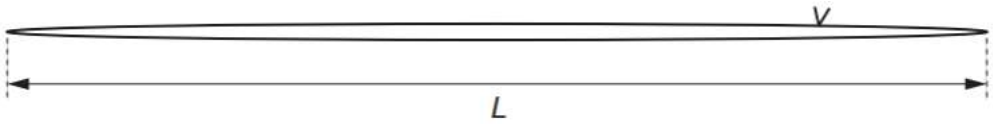


**Fig. 3.1**

Measure and record the length *L* as shown in Fig. 3.1.

*L* = …….. [1]

**(b)** **(i)** Set up the apparatus as shown in Fig. 3.2. Move the stands so that the distance between the centres of the rods of the clamps is 25.0 cm.

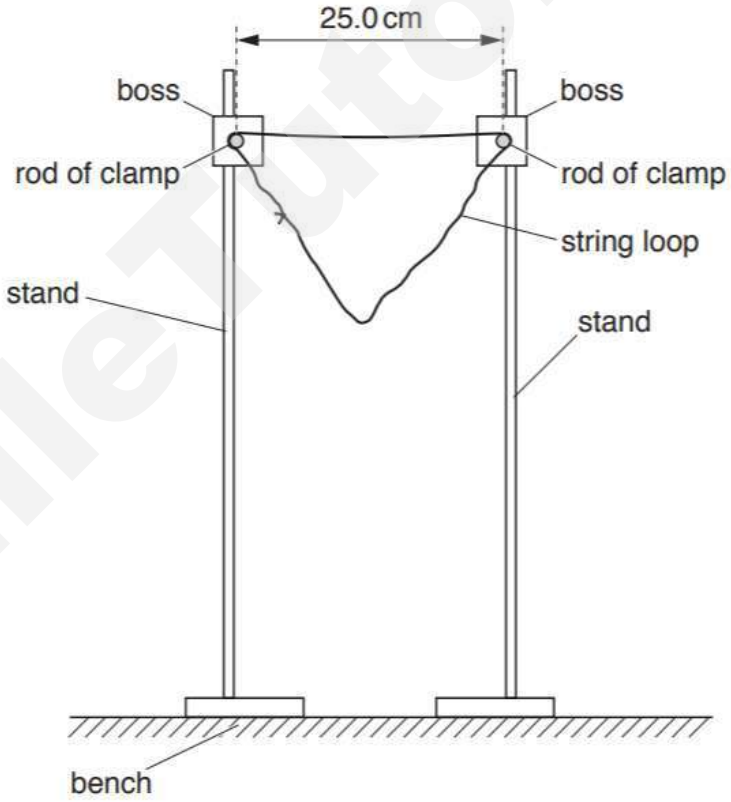


**Fig. 3.2**

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**(ii)** Pull down on the bottom of the loop until it is fully stretched as shown in Fig. 3.3.

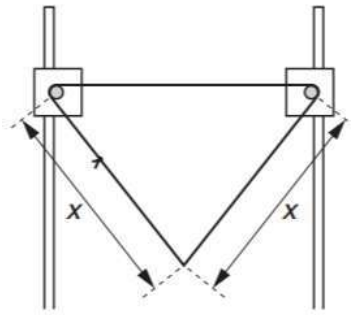


**Fig. 3.3**

The distance between the bottom of the loop and the centre of a rod is *x*.
Measure and record *x*.

*x* = …… [1]

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

percentage uncertainty = …… [1]

**(iv)** Calculate *G* where

$$G = \sqrt{L(2x - L)}\,.$$

*G* = …… [1]

**(v)** Justify the number of significant figures that you have given for your value of *G*.

……..

……..

…….. [1]

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**(c)** **(i)** You have been provided with two pendulum bobs tied to strings.

Tie the string attached to one of the bobs to the string loop so that the distance between the knot and the centre of the bob is equal to $x$, as shown in Fig. 3.4.

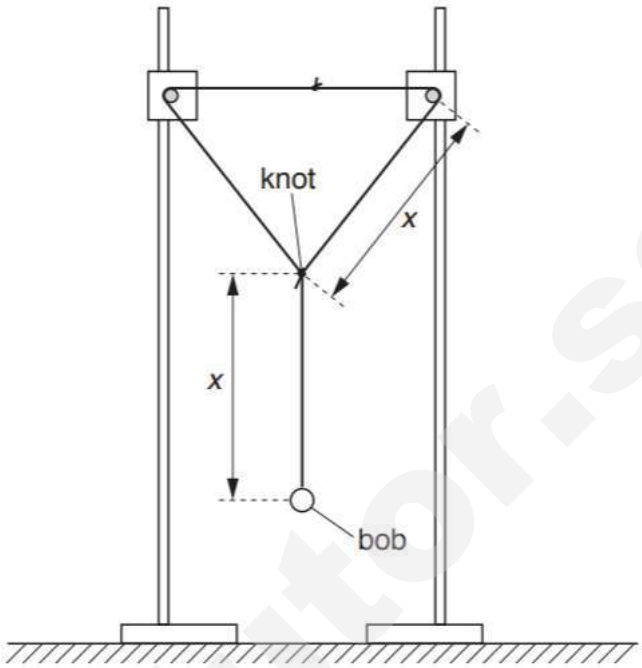


**Fig. 3.4**

**(ii)** Pull the bob a short distance towards you. Release the bob. The bob will oscillate.

Determine the period $T$ of these oscillations.

$T$ = ..... [1]

**(iii)** Estimate the percentage uncertainty in your value of $T$.

percentage uncertainty = ..... [1]

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**(d)** Move one of the stands until the distance between the centres of the rods of the clamps is 30 cm.

Using the second loop and bob, repeat **(a), (b)(ii), (b)(iv), (c)(i)** and **(c)(ii).**

$L$ = .....

$x$ = .....

$G$ = .....

$T$ = ..... [3]

**(e)** It is suggested that the relationship between $T$, $G$ and $x$ is

$$T^2 = k(G + x)$$

where $k$ is a constant.

**(i)** Using your data, calculate two values of $k$.

first value of $k$ = ……..

second value of $k$ = …….. [1]

**(ii)** State whether the results of your experiment support the suggested relationship.

Justify your conclusion by referring to your values in **(b)(iii)** and **(c)(iii)**.

……

……

…… [1]

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**(f)** **(i)** State two significant sources of error in this experiment.

**1** ……..

……

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……

**2** ……..

……

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…… [2]

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

……

……

…… [1]

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**(g)** A student thinks that the behaviour of the oscillating system depends on the properties of the bob used.

He proposed that the volume $V$ of the bob affects the period $T$ of the system. He would like to determine the volume of the pendulum bob such that it would swing at 1 second for each oscillation.

Explain how you would be able to determine the volume of the pendulum bob that would give rise to an oscillation with a period of 1 second.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to determine the volume required

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…… [5]

**[Total: 20 marks]**

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**4** A student is investigating simple harmonic motion using an electric vibrator. A plate is attached to the top of the electric vibrator. A small mass is placed on the metal plate as shown in Fig. 4.1.

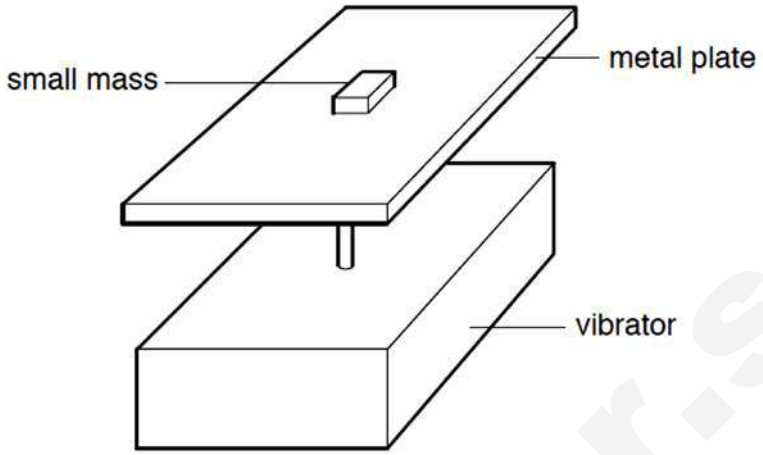


**Fig. 4.1**

An alternating potential difference (p.d.) is applied to the vibrator. 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 plate is lost when the frequency is greater than $f$.

It is suggested that the relationship between $f$ and $V$ is

$$k = \pi^2 f^2 V$$

where $k$ is a constant.

Design a laboratory experiment to test the relationship between $f$ and $V$. Explain how your results could be used to determine a value for $k$.

Draw a 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)** the measurements to be taken
**(d)** the control of variables
**(e)** the precautions that should be taken to improve the accuracy and safety of the experiment.

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**Diagram**

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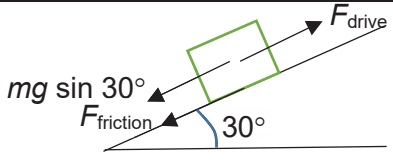
**2019 JC2 H2 Physics Preliminary Examination Paper 1 Suggested Solutions**

| S/N | Answer | Explanation |
|---|---|---|
| 1 | C | Frequency of ultraviolet light should be $10^{14}$ to $10^{16}$ Hz |
| 2 | A | The parachutist started from rest, hence, her speed at $t$ = 0 is zero. When she is falling, her acceleration starts to decrease more significantly due to increased air resistance. Once she opens the parachute, the tension force on her due to the parachute is larger than her weight causing her to decelerate and eventually reach a constant speed as the air resistance decreases. |
| 3 | B | $\Delta p$ = Area under $F$-$t$ graph<br>$= (20 \times 4) + (0.5 \times 2 \times 20)$<br>$= 100$ N s<br>$\Delta v = \Delta p / m = 50$ m s$^{-1}$ |
| 4 | B | In Fig. A,<br>$\Sigma F = ma$<br>$1.0\ (9.81) = 1.2\ a_1$<br>In Fig. B<br>$\Sigma F = ma$<br>$0.2\ (9.81) = 1.2\ a_2$<br>$a_1 : a_2 = 1.0 : 0.2 = 5 : 1$ |
| 5 | B | The board is in equilibrium. Net moment about point P is zero.<br>Let $x$ be the perpendicular distance between the line of action of force $2.5F$ at R to P.<br>$F\ (20) + 0.5F \sin 45° (x) = 2.5F\ (x) + 0.5F \cos 45° (20)$<br>$2.146\ (x) = 12.93$<br>$x = 6.0$ cm<br>Therefore, the area of the board = (40)(12) = 480 cm$^2$ |
| 6 | D | After the stone leaves the hand of the astronaut, it does not experience any horizontal forces anymore. The only force acting on the stone is its own weight acting vertically downwards to the surface of the Moon. This force is constant as there is no opposing air resistive force acting on the stone due to no atmosphere present. Hence, option D. |
| 7 | B | $P_{friction} = F_{friction}\ v$<br>$F_{friction} = (2000 / 0.75)$ N<br>  |

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| | | |
|---|---|---|
| | | $P_{drive} = F_{drive}\ v$<br>$= [\ (20)(60)(9.81)\ \sin 30° + (2000 / 0.75)\ ]\ 0.75$<br>$= 6415$ W |
| **8** | **B** | $KE_{Xi} + GPE_{Xi} + KE_{Yi} + GPE_{Yi} = KE_{Xf} + GPE_{Xf} + KE_{Yf} + GPE_{Yf}$<br>$0 + 0 + 0 + 5g(2) = KE_{Xf} + 4g(2\sin 30°) + KE_{Yf} + 0$<br>$KE_{Xf} + KE_{Yf} = 58.9$ J |
| **9** | **B** | The frictional force provides for the centripetal acceleration as the object undergoes circular motion:<br>$f = m\ r\ \omega^2$<br>Since the maximum friction is the same, and mass is the same,<br>$\frac{1}{r}\ \alpha\ \omega^2$ |
| **10** | **A** | $T\cos\theta = 0.020\ (9.81)$ ---- (1)<br>$T\sin\theta = 0.020\ (5.5)^2 / 12$ ---- (2)<br>(2) / (1)<br>$\tan\theta = 0.257$<br>$\theta = 14.4°$ |
| **11** | **C** | New GPE = 1.00 + $mgh$ = 1.00 + (0.200)(0.3) = 1.06 J |
| **12** | **D** | From $pV = 1/3\ Nm\ \langle c^2\rangle$,<br>$p = 1/3\ \rho\ \langle c^2\rangle$,<br>$(1.00 \times 10^5$ Pa) = 1/3 (1.60 kg m$^{-3}$) $\langle c^2\rangle$,<br>$\sqrt{\langle c^2\rangle}$ = 433 m s$^{-1}$ |
| **13** | **B** | Arrow from B to A is longer than from A to B. This means that more thermal energy is transferred from B to A, i.e. temperature of B is higher than A.<br>Arrow from A to C is longer than from C to A. This means that more thermal energy is transferred from A to C, i.e. temperature of A is higher than C. |
| **14** | **D** | Based on the definition of the terms and substitute them into the formula of $\Delta U = Q + W$,<br>$\Delta U = (-Q) + (-W)$,<br>$-\Delta U = Q + W$ |
| **15** | **C** | $v = \omega\sqrt{x_0^2 - x^2}$<br>$= \left(2\pi(1.0)\right)\sqrt{4^2 - 3^2}$<br>$= 16.6 \approx 17$ cm s$^{-1}$ |

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|---|---|---|
| **16** | **C** | By definition, amplitude is the maximum displacement of the particles from the equilibrium position (where the particles are at rest) |
| **17** | **C** | Diffraction occurs when microwaves spread around an obstacle, in this case, the edge of a metal plate. |
| **18** | **B** | P, R and Q are positions of nodes. The second mode of harmonics (first overtone) is formed in the string. Particles in adjacent loops have a phase difference of 180°. Since the distance of S and T from the node are equal, the two particles have the same amplitude. |
| **19** | **B** | Location of neutral point cannot be between the two charges as they have opposite sign.<br>It must also be nearer the charge with smaller magnitude.<br>Thus, the neutral point is on the left of the +1.0 μC charge.<br>  <br>Thus, $\frac{1}{4\pi\epsilon_o}\frac{1\mu}{x^2} = \frac{1}{4\pi\epsilon_o}\frac{3\mu}{(x+4)^2}$<br>$\Rightarrow$ x = 5.464 m ; the negative root is rejected |
| **20** | **A** | Force on nuclei is in the same plane as the field lines. Since the nuclei are positively-charged, they are deflected in the same direction as the field lines. |
| **21** | **D** | Let the original length, cross-sectional area and volume of cylinder be L, A and V respectively.<br>Originally, V = A L<br>After the length is doubled, the new cross-sectional area $A_1$ will be halved, or ½ A.<br>Let the new resistance be $R_1$.<br>$R = \frac{\rho l}{A}$<br>$\frac{R_1}{R} = \left(\frac{\rho(2L)}{(1/2\,A)}\right) \div \left(\frac{\rho L}{A}\right)$<br>$R_1 = 4R$ |
| **22** | **C** | Recall of definition of *n* i.e. the number density of the mobile charge carriers in the formula. |
| **23** | **B** | P.d. across 5.0 Ω resistor is proportional to the balanced length, i.e.<br>5.0 Ω = k (12.5 cm)<br>Resistor across Q and R is 10.0 Ω. Hence the balanced length should be doubled that of 5.0 Ω, or 25.0 cm. |

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| | | |
|---|---|---|
| | | Resistor across Q and S is (10.0 + 15.0 =) 25.0 Ω. Hence the balanced length should be 5 times that of 5.0 Ω, or 62.5 cm.<br>Resistor across P and R is (5.00 + 10.0 =) 15.0 Ω. Hence the balanced length should be 3 times that of 5.0 Ω, or 37.5 cm. |
| **24** | **A** | Magnetic force = $BIL$<br>1.0 = (0.50)($I$)(2.0)<br>$I$ = 1.0 A<br>Using Fleming's Left Hand Rule,<br>Since resulting force acts into the plane of the paper (thumb points into the plane) and magnetic field (first finger points to the right), current flows from R to S (upwards). |
| **25** | **B** | Initially, when the beam of electrons passes through without deviation, this means that the electric force (upward) is equal to the magnetic force (downwards).<br>For the second beam of protons, the electric force on protons is now downwards and magnetic force acts upwards. With a speed that is twice as large, the magnetic force on proton is now larger than the electric force, thus the beam of protons will be deflected upwards in the plane of the paper. |
| **26** | **C** | Average induced e.m.f. = (change in magnetic flux linkage)/time<br>= (final $\Phi$ - initial $\Phi$)/ $\Delta t$<br>= ($NBA$ – $N(-B)A$)/(60 × $10^{-3}$) taking the final $B$ as positive<br>= (2$NBA$)/(60 × $10^{-3}$)<br>= [2(500)(20 × $10^{-3}$)(π)(15 × $10^{-3}$)$^2$]/ (60 × $10^{-3}$)<br>= 0.24 V |
| **27** | **D** | r.m.s. current = $\sqrt{[(3^2 \times 4)+(9^2 \times 2)]/6}$ = 5.744 A<br>Mean power = $5.744^2$ x 3.5 = 115.5 W |
| **28** | **D** | The $K_\alpha$ lines have a higher probability of occurring hence its intensity should be higher than the $K_\beta$ lines. |
| **29** | **B** | Emission of one $\alpha$-particle ($^4_2\alpha$) causes the proton number to decrease by 2 and the neutron number to decrease by 2.<br>Emission of one $\beta$-particle ($^0_{-1}\beta$) causes the proton number to increase by 1 and the neutron number to decrease by 1. |
| **30** | **C** | Similar reasoning to why light emitted by an isolated atom reveals a line spectrum. |
| | | |

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**2019 JC2 H2 Physics Preliminary Examination Paper 2 Suggested Solutions**

| | | | | |
|---|---|---|---|---|
| **1** | **(a)** | **(i)** | Applying $v = u + at$ for vertical component,<br>$(-5.5\sin(33°)) = (5.5\sin(33°)) + (-9.81)t$<br>$t$ = 0.6107 = 0.61 s | 1<br>1 |
| | | **(ii)** | $d = (5.5\cos(33°)) \times 0.6107 = 2.817$ = 2.8 m | 1 |
| | | **(iii)** | $\frac{\Delta d}{d} = \frac{\Delta v}{v} + \frac{\Delta t}{t}$<br>$\frac{\Delta d}{d} = \frac{0.2}{5.5} + 0.02 = 0.056$<br>Therefore, percentage uncertainty = 5.6% | 1<br>1 |
| | | **(iv)** | $\Delta d$= 5.6% × 2.817 = 0.2 m (to 1 s.f.)<br>$d$ = (2.8 ± 0.2) m | 1 |
| | | **(v)** | $\frac{\text{kinetic energy of the car at its maximum height}}{\text{kinetic energy of the car as it leaves ramp P}}$<br>$= \frac{\frac{1}{2}m((5.5\cos(33°))^2}{\frac{1}{2}m(5.5)^2}$<br>= 0.703 | 1<br>1 |
| | | **(b)** | - Straight line from positive value of $v_y$ at $t$ = 0 to negative value of $v_y$<br>- Straight line ends at $t = T$ and final magnitude of $v_y$ greater than initial magnitude of $v_y$ | 1<br>1 |
| **2** | **(a)** | | Total momentum is constant<br>if net external force acting on the system is zero | **1**<br>**1** |
| | **(b)** | | $3mv + 2m(-v) = 3mv' + 2mv'$<br>$v' = 0.20\ v$<br>Deduct sf mark if student leaves answer in fraction. Allow 1 sf in this case. | **1**<br>**1** |
| | **(c)** | | Total initial momentum of the system is non-zero.<br>By principle of conservation of momentum, the total momentum of the system at any point in time should not be zero.<br>OR<br>If both stop at the same instant, the total momentum of the system will be zero, hence it violates the principle of conservation of momentum. | **1**<br>**1** |
| | **(d)** | | Taking rightwards as positive,<br>By conservation of momentum,<br>$3mv + 2m(-v) = 3m(v_T) + 2m(v_D)$<br>$v = 3v_T + 2v_D$<br><br>Relative speed of approach = relative speed of separation<br>$v - (-v) = v_D - v_T$<br>$v_T = v_D - 2v$ | **1**<br><br>**1** |

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| | | | | |
|---|---|---|---|---|
| | | | Substituting,<br>$v = 3(v_D - 2v) + 2\ v_D$<br>$v_D = 1.4\ v$<br>$v_T = -\ 0.6\ v$ | <br>1<br>1 |
| | | | | |
| 3 | (a) | The current in the battery is the sum of the currents through P and Q.<br>The p.d. across P and Q must be the same as they are in parallel circuit arrangement.<br>From the graph, the value of p.d. of P for 0.15 A is 2.7 V.<br>From the graph, the value of current of Q for 2.7 V is 0.090 A.<br>Hence the total current is 0.15 + 0.09 = 0.24 A | | <br><br><br>1<br>1 |
| | (b) (i) | P.d. across R is 4.5 – 2.7 = 1.8 V<br>Resistance of R = 1.8 V / 0.24 A<br>= 7.5 Ω | | 1<br><br>1 |
| | (b) (ii) | Straight line passing through the points (0,0) and (1.5 V, 0.20 A) | | 1 |
| | (c) | Resistance of P = $V / I$ = 2.7 V / 0.15 A = 18 Ω<br>Resistance of Q = 2.7 V / 0.09 A = 30 Ω<br>Given that<br>$R = \frac{\rho l}{A} \quad \rightarrow R = \frac{4\rho l}{\pi d^2}$<br>$l = \frac{R\pi d^2}{4\rho}$<br>$\frac{l_P}{l_Q} = \frac{R_P d_P^2}{R_Q d_Q^2} \quad \rightarrow \frac{l_P}{l_Q} = \frac{18}{30} \times \left(\frac{2}{1}\right)^2 = 2.4$ | | <br>1<br><br><br><br>1<br><br>1 |
| | (d) | The effective resistance of P and Q will be larger as Q stops conducting.<br>The p.d. across P increases (due to the potential divider method), or the current through P has increased.<br>From the graph, the ratio of current to voltage is smaller, hence the resistance of P increases. | | <br>1<br><br>1 |
| | | | | |
| 4 | (a) | (i) | A decrease in the reading on the top pan balance implies that the net force acting on the balance is now smaller than before. Thus, the force on the magnet due to the current carrying wire is upwards. [B1]<br>By Newton's third law, the force on the wire by the magnet is equal and opposite to the force on the magnet by the wire. [B1]<br>Hence, the force on the wire is downwards. [B1] | 1<br><br>1<br><br>1 |

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| | | | | |
|---|---|---|---|---|
| | | **(ii)** | Using Fleming's left hand rule (thumb points downwards, first finger points from North to South) [M1], (second finger points from B to A)<br>current flows from B to A. [A1] | **1**<br>**1** |
| | **(b)** | Sinuisoial wave with 2 cycles. [B1]<br>Peaks at + 6.4 mN and –6.4 mN [B1]<br>Time period 25 ms [B1] | | **1**<br>**1**<br>**1** |
| | | | | |
| **5** | **(a)** | Faraday's law of electromagnetic induction states the induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage. | | **1** |
| | **(b)** | **(i)** | Induced e.m.f. = $(\Delta B)AN/(\Delta t)$<br>$= (2.0 \times 0.19 \times 1.5 \times 10^{-4} \times 120)/(0.13)$ [C1]<br>= 0.053 V [A1] | **1**<br>**1** |
| | | **(ii)** | Reading on voltmeter connected to coil C/ V: 0 0.053 0 [A1]<br>(all three values required)<br>Reading on voltmeter connected to Hall probe/ V:<br>Zero in middle column [B1]<br>Final column correct sign {positive} [B1]<br>Final column correct magnitude (0.20) [B1] | **1**<br><br><br>**1**<br>**1**<br>**1** |
| | | | | |
| **6** | **(a)** | **(i)** | Area under graph from 0 to 5.0 m<br>= ½ (5) (200 + 160)<br>= 900 J (correct substitution + final answer) | <br><br>**1** |
| | | **(ii)** | Gain in KE of child = Net work done<br>= Work done by driving force – work done by friction<br>$\frac{1}{2} m v^2 = 900 - (160 \times 5)$<br>$v = \sqrt{100\ (2)\ /\ 30.5} = 2.56$ m s$^{-1}$<br>(correct substitution + final answer)<br><br>Alternative:<br>$KE_i + E_{supplied} = KE_f + E_{dissipated}$ | <br>**1**<br><br>**1** |
| | **(b)** | | $(2m)\ c^2 = 3.38 \times 10^{-11}$ (correct expression)<br>$m = 1.88 \times 10^{-28}$ kg (correct final answer, 3 s.f.) | **1**<br>**1** |
| | **(c)** | | $^{1}_{0}\mathrm{n} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{1}\mathrm{H}$ (accept $^{3}_{1}\mathrm{X}$)<br><br>$^{3}_{1}\mathrm{H} \rightarrow {}^{0}_{-1}\mathrm{e} + {}^{3}_{2}\mathrm{He}$ (do not accept $^{3}_{2}\mathrm{X}$)<br><br>Final isotope : $^{3}_{2}\mathrm{He}$ or He-3 | **1**<br><br>**1** |

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| | | | | |
|---|---|---|---|---|
| | **(d)** | | Difference in mass between parent and products is fixed. Thus, the corresponding energy released, which is mainly in the form of KE of the beta particle should also be a constant.<br>The continuous spread of energy values seemed to violate the principle of conservation of energy. | **1**<br>**1** |
| | **(e)** | **(i)** | $\frac{N_K}{N_{Ar}} = \frac{1}{6} \Rightarrow \frac{N_K}{N_{Ar}+N_K} = \frac{1}{7}$<br>$\Rightarrow \frac{N_K}{N_{K_0}} = \frac{1}{7}$<br>$\Rightarrow e^{-0.693/(1.37 \times 10^9)\,t} = \frac{1}{7}$ (correct expression, substitution)<br>$\Rightarrow t = 3.85 \times 10^9$ years (correct final answer, 3 s.f.) | <br><br><br>**1**<br>**1** |
| | | **(ii)** | If the escaped argon was accounted for, the ratio will be smaller than 1/6.<br>Thus time elapsed is actually greater than $3.85 \times 10^9$ years. Thus, the answer in **(e)(i)** is an underestimate. | **1**<br>**1** |

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| | | | | |
|---|---|---|---|---|
| **7** | **(a)** | | The pressure-drop <u>increases</u> as volume flow rate <u>increases</u>.<br>The <u>rate</u> of increase in pressure-drop <u>decreases</u> as volume flow rate increases. | [1]<br>[1] |
| | **(b)** | | Due to the orifice plate, the <u>speed of water at upstream position is lower</u> than the speed of water at downstream position. OR The <u>speed of water at downstream position is higher</u> as it passes through a smaller cross section.<br><u>At lower speed, the pressure becomes higher</u> at the upstream position which results in the pressure difference. | [1]<br>[1] |
| | **(c)** | | In a vertical position, there is a <u>change in gravitational potential energy</u> between the upstream and downstream positions.<br>This will <u>affect the speed of water</u>, which in turns <u>affect the pressure difference</u>. | [1]<br>[1] |
| | **(d)** | **(i)** | At $Q = 8.0\ m^3\ s^{-1}$, $\Delta p = 38.5 \times 10^3$ Pa (allow $38.0 \times 10^3$ Pa)<br>lg $\Delta p$ = 4.59 (or 4.58)<br>(lg $Q$ = 0.90) | [1]<br>[1] |

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**(ii)**

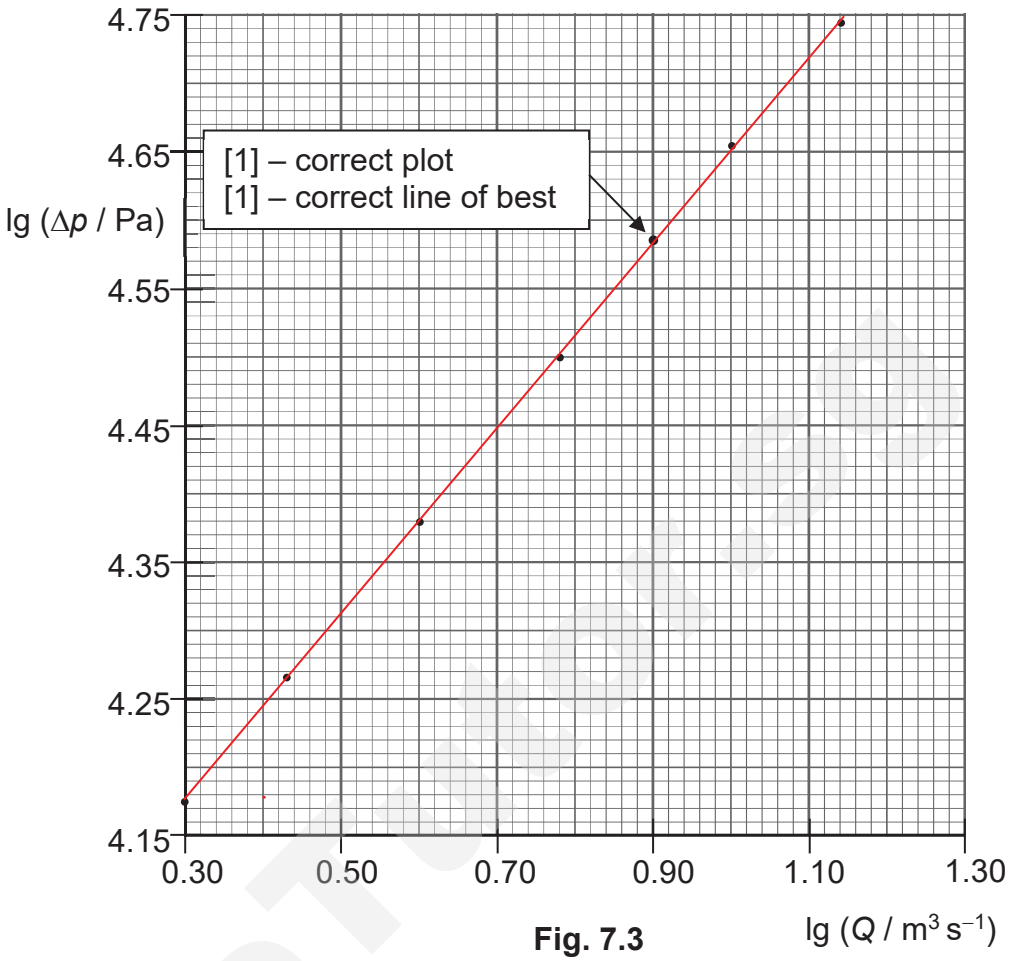


**Fig. 7.3**

**(iii)**

Gradient $n = \dfrac{4.650 - 4.300}{1.00 - 0.48}$ (must be > ½ line, correct coord & dp) [1]

$= \dfrac{0.350}{0.52}$

$= 0.673$ or $0.67$ [1]

**(iv)**

Linearising, lg $\Delta p$ = lg $k$ + n lg $Q$.

Using (1.00,4.650), lg $k$ = 4.650 – 0.673(1.00) = 3.977 [1]

$\therefore$ $k$ = 9483 = 9500 or 9480 (allow ecf) [1]

**(v)**

Unit of $\Delta p$ $= \dfrac{\text{unit of force}}{\text{unit of area}} = \dfrac{\text{kg m s}^{-2}}{\text{m}^2} = \text{kg m}^{-1}\ \text{s}^{-2}$ [1]

Unit of $k$ $= \dfrac{\text{unit of } \Delta p}{\text{unit of } Q^n}$

$= \dfrac{\text{kg m}^{-1}\ \text{s}^{-2}}{\left(\text{m}^3\ \text{s}^{-1}\right)^{0.67}}$

$= \text{kg m}^{-3.0}\ \text{s}^{-1.3}$ [1]

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**(e) (i)**

From $k = \dfrac{\rho}{1.2\,A_o^2} \Rightarrow A_o = \sqrt{\dfrac{\rho}{1.2k}} \Rightarrow r^2 = \dfrac{1}{\pi}\sqrt{\dfrac{\rho}{1.2k}}$

$$r = \frac{1}{\sqrt{\pi}}\left(\frac{\rho}{1.2k}\right)^{\frac{1}{4}} = \frac{1}{\sqrt{\pi}}\left(\frac{1000}{1.2\times 9483}\right)^{\frac{1}{4}}$$

$= 0.307$ m (allow ecf)

[M 1]

[A 1]

**(ii)**

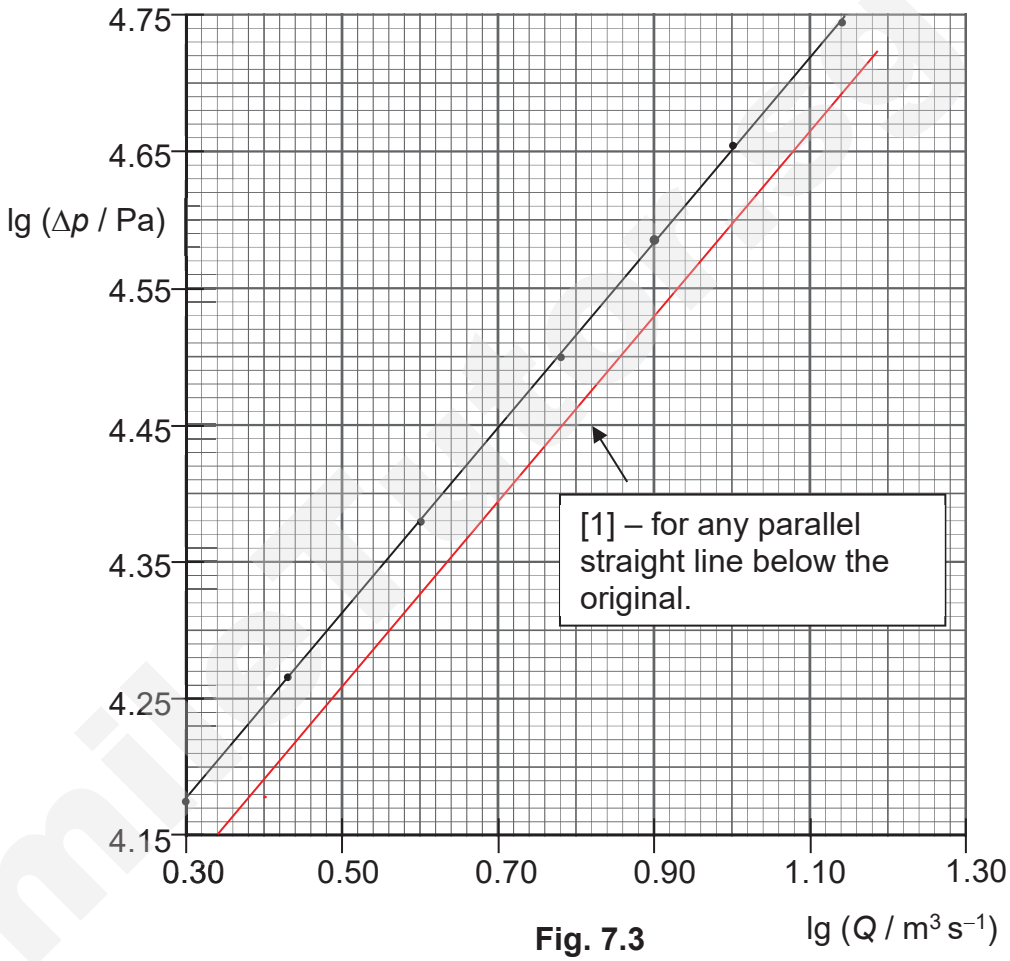


**Fig. 7.3**

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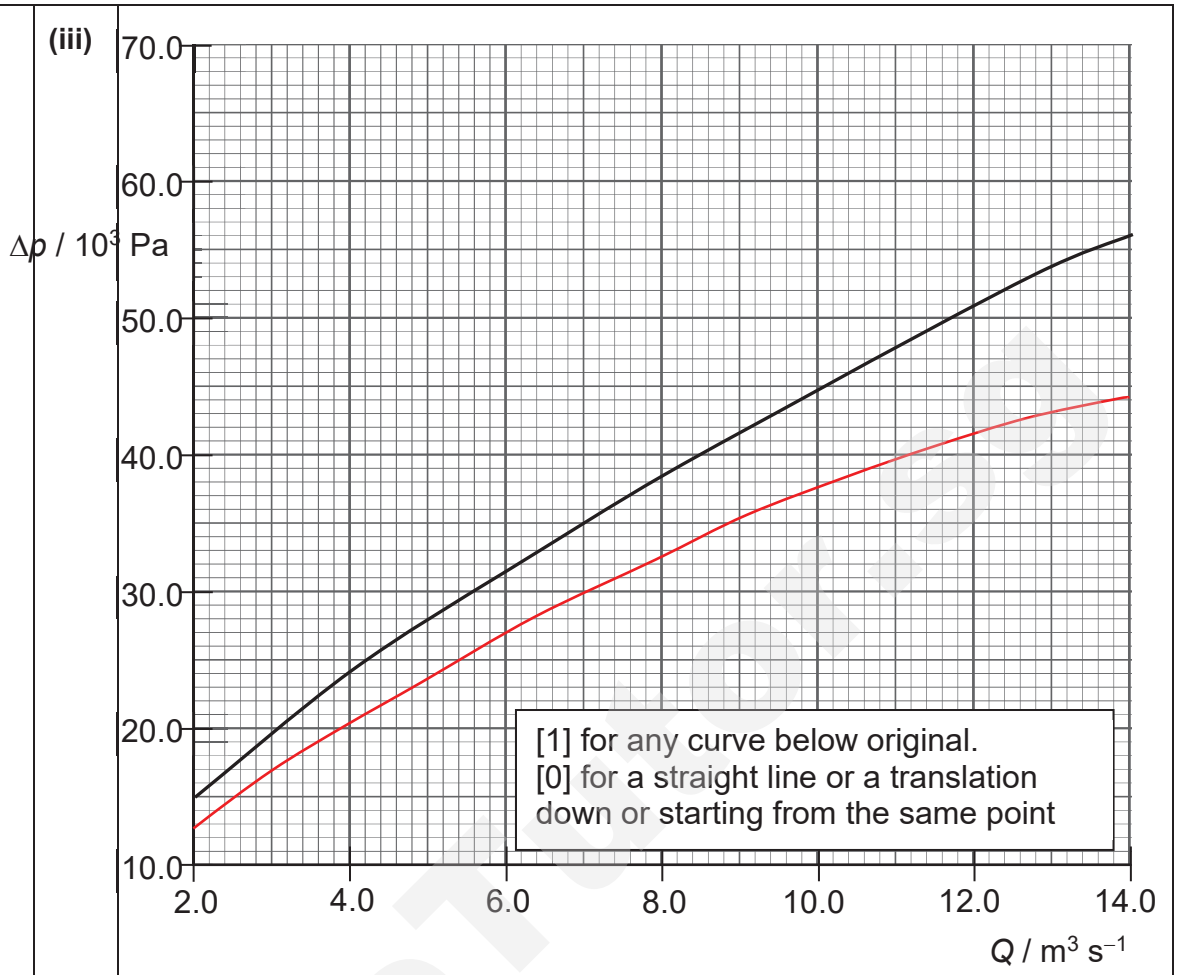
| | | | | |
|---|---|---|---|---|
| | | (iii) |  | |
| | | (iv) | Since the density of oil is lower than water, the $k$ value will be lower which leads a lower pressure difference for the same volume flow rate.<br><br>In order to ensure a more observable height difference in the liquid of the manometer, the diameter of the orifice plate opening should be decreased / the fluid in manometer should be of lower density. | [1]<br><br>[1] |

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**2019 JC2 H2 Physics Preliminary Examination Paper 3 Suggested Solutions**

| | | | | |
|---|---|---|---|---|
| **1** | **(a)** | | Upthrust is the weight of the oil displaced by cylinder X.<br>Cylinder X is fully submerged in oil at position X. Hence volume of oil displaced is equal to the volume of the cylinder.<br>Upthrust = (density of oil) × (volume of cylinder) × 9.81<br>$U = 940 \times 0.018 \times 1.2 \times 9.81$<br>$U = 200$ N | **2** |
| | **(b)** | **(i)** | Since velocity is constant throughout the lifting process, net force on cylinder X is zero.<br>Tension + Upthrust = Weight of cylinder<br>$T = 560 - 200$<br>$T = 360$ N | **2** |
| | | **(ii)** | Power output of motor = $T\,v$<br>$= 360 \times 0.020$<br>$= 7.2$ W | **2** |
| | **(c)** | | As the cylinder is raised the volume of the liquid displaced decreases. Hence, upthrust acting on the cylinder decreases **[B1].** With the weight of the cylinder unchanged, the tension in the wire increases **[B1].** Therefore, the power output of the motor increases. | **2** |
| **2** | **(a)** | | FBD at the top<br>$N + W = mv^2 / r$<br>$N = mv^2 / r - mg$<br>$= 800(17)^2 / 7.2 - 800\,(9.81)$<br>$= 24200$ N<br>[Zero marks if student simply calculated centripetal force.] | **1**<br>**1** |
| | **(b)** | | The direction of the centripetal acceleration changes such that it is always pointing towards the centre of the circle.<br>The magnitude of the centripetal acceleration decreases.<br>Because the speed of the carriage decreases. | **1**<br>**1**<br>**1** |
| | **(c)** | **(i)** | Difference in height = $h - (2 \times 7.2) = h - 14.4$<br>Loss in GPE = Gain in KE<br>$mg\,(h - 14.4) = ½\ m\ v^2$<br>$9.81\,(h - 14.4) = ½\,(17)^2$<br>$h = 29.1$ m<br>[0 mark if student did not use the correct difference in height] | **1**<br>**1** |
| | | **(ii)** | $h$ should remain the same. [based on the calculation in (i), the $h$ required is independent of the mass.] | **1** |

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<table>
<tr><td>3</td><td>(a)</td><td>(i)</td><td>It is the <u>sum of potential and kinetic energies</u><br>(of molecules/atoms/particles) <u>in random motion.</u></td><td>1<br>1</td></tr>
<tr><td></td><td>(a)</td><td>(ii)</td><td>There is (in ideal gas) <u>no intermolecular forces so no potential energy.</u><br>Hence, <u>internal energy is (solely) kinetic energy</u> (of particles)<br>The (mean) <u>kinetic energy (of particles) proportional to (thermodynamic) temperature of gas.</u></td><td>1<br>1<br>1</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>Mean KE = 3/2 kT = 1.5 x 1.38 x $10^{-23}$ x (25 + 273)<br>= 6.17 x $10^{-21}$ J</td><td><br>1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Using the formula, pV = NkT<br>(6.4 x $10^{6}$ Pa)( 1.8 x $10^{4}$ x $10^{-6}$ $m^3$) = N (1.38 x $10^{-23}$ J $K^{-1}$) (25 + 273.15 K)<br>N = 2.80 x $10^{25}$.</td><td>1<br><br>1</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>Total internal energy = total kinetic energy of the gas<br>= (6.17 x $10^{-21}$ J)(2.80 x $10^{25}$) = 1.73 x $10^{5}$ J</td><td><br>1</td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td>Sections AB and CD (isothermal gradient is smaller than adiabatic)<br>Adiabatic process will result in temperature change, i.e. the curve will be from one isothermal curve to another isothermal curve. Hence the adiabatic curve will be steeper than isothermal curves.</td><td>1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>1.6 = 160 / WD<br>WD = + 100 J</td><td><br>1</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>
<table>
<tr><th>Sections</th><th>Increase in internal energy / J</th><th>Work done on gas / J</th><th>Heat supplied to gas / J</th></tr>
<tr><td>A → B</td><td>(1) 0</td><td>(7) + 100</td><td>(7) – 100</td></tr>
<tr><td>B → C</td><td>+ 70</td><td>(4) + 70</td><td>(2) 0</td></tr>
<tr><td>C → D</td><td>(1) 0</td><td>(5) – 160</td><td>(0) + 160</td></tr>
<tr><td>D → A</td><td>(3) – 70</td><td>(6) – 70</td><td>(2) 0</td></tr>
</table>
Mark scheme<br>B1 for answers (1)<br>B1 for answers (2)<br>B1 for answers (3)<br>B1 for answers (4 to 6)<br>B1 for answers (7).<br>No mark will be awarded for (0) as it is given in the question in (ii)</td><td>[5]</td></tr>
<tr><td>4</td><td>(a)</td><td></td><td>$T$ = 0.75 s<br>$\omega = 2\pi / T$</td><td></td></tr>
</table>

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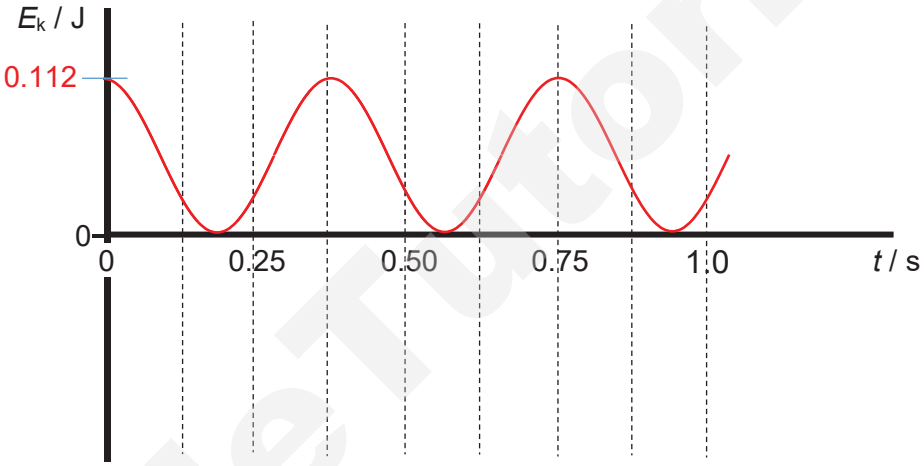
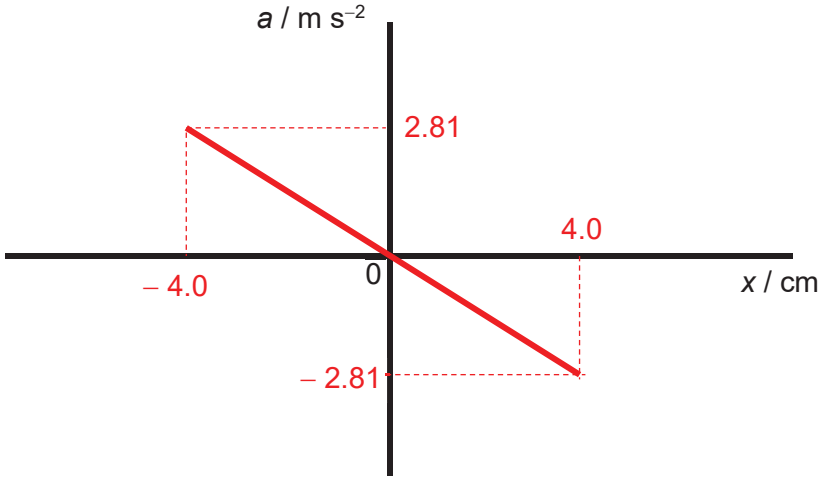
| | | | | |
|---|---|---|---|---|
| | | | $= 8.38 \text{ rad s}^{-1}$ | 1 |
| | (b) | | $a_o = \omega^2 x_o$<br>$= 8.38^2 (4.0 \times 10^{-2})$<br>$= 2.81 \text{ m s}^{-2}$ | <br><br>1 |
| | (c) | | At the lowest point of oscillation<br>$\Sigma F = ma_o$<br>$T - mg = ma_o$<br>$25 - m(9.81) = m(2.81)$<br>$m = 1.98 \text{ kg}$<br>  | <br><br>1<br>1 |
| | (d) | |  <br>Max $E_K = \frac{1}{2} m (x_o \omega)^2$<br>$= \frac{1}{2} (2.0)(0.04)^2(8.38)^2$<br>$= 0.112 \text{ J}$<br>Labelling of the correct maximum $E_k$ [1]<br>Correct positions of maximum $E_k$ and shape of the graph [1] | 2 |
| | (e) | |  <br>Correct straight line with negative gradient passing through origin [1]<br>Correct labelling of the critical values and no exceeding of line beyond 4.0 cm [1] | 2 |

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| | | | | |
|---|---|---|---|---|
| **5** | **(a)** | | Current = Power / pd = $3 \times 10^6$ / $125 \times 10^3$ = 24 A<br>Power lost = $I^2 R$ = $(24)^2$ (80) = $4.6 \times 10^4$ W | **1**<br>**1** |
| | **(b)** | | Energy lost = (46 kW) (24 h) = 1104 kWh<br>Money lost = (1104) ($0.25) = $276 | **1**<br>**1** |
| | **(c)** | | No power lost in transformer due to eddy currents in the core/windings<br>No leakage of magnetic flux | **1**<br>**1** |
| | | | | |

| | | |
|---|---|---|
| **6(a)** | • Electrons in the gas atoms interact with the photons and the photon energy causes the electron to move to higher energy level/to be excited<br>• Since the energy of the electron energy level is discrete, the difference in the energy will be discrete<br>• Only photon energy equivalent to the difference of energy of the electron energy levels will cause this excitation<br>• When the electrons de-excite, photons are emitted in all directions and hence they appear to be dark lines<br>[point 1 and point 3 are compulsory], [3 out of 4 points] | 1<br>1<br>1<br>1 |
| **(b)(i)** | 6 | 1 |
| **(ii)1.** | Maximum photon energy = 13.6 – 0.85<br>= 12.75<br>Maximum *KE*= 12.75 – 5.6<br>= 7.2 (7.15) eV | 1<br>1 |
| **2.** | Wavelength = $(6.63 \times 10^{-34})(3 \times 10^8)$ / $(12.75 \times 1.6 \times 10^{-19})$<br>= $9.75 \times 10^{-8}$ m | 1 |
| **3.** | Velocity of electron = $\sqrt{\frac{2(7.2\times(1.6\times10^{-19}))}{9.11\times10^{-31}}} = 1.59\times10^6$<br>Uncertainty of momentum = $(9.11 \times 10^{-31})(0.15 \times 1.59 \times 10^6) = 2.17 \times 10^{-25}$<br>Uncertainty of position = $(6.63 \times 10^{-34})$ / $(2.17 \times 10^{-25}) = 3.06 \times 10^{-9}$ m | 1<br>1<br>1 |
| **(c)(i)** | Either:<br>If waves (or light) passes through suitable aperture size,<br>Diffraction would occur and similar pattern would be observed<br>Or:<br>Concentric circles are evidence of diffraction<br>And diffraction is a wave property | 1<br>1<br>1<br>1 |
| **(ii)** | (speed increases so) momentum increases<br>Since λ=h/p so λ decreases, hence radii decreases | 1<br>1 |
| | | |

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| | | | | |
|---|---|---|---|---|
| 7 | (a) | (i) | $F_A = \frac{GM_1M_2}{(R_1+R_2)^2}$ (correct expression) | 1 |
| | | (ii) | $F_B = M_2 R_2 \omega^2$ (correct expression)<br>OR same expression as (a)(i) | 1 |
| | (b) | | $\omega = 2\pi / T = 2\pi / (1.26 \times 10^8)$ (correct expression + substitution)<br>$= 4.99 \times 10^{-8}$ rad s$^{-1}$ (correct final answer, 3 s.f.) | 1<br>1 |
| | (c) | (i) | Both stars experience the same centripetal force because they experience the same gravitational force (which provides the centripetal force)<br>Thus, $M_2 R_2 \omega^2 = M_1 R_1 \omega^2$<br>$\Rightarrow \frac{M_2}{M_1} = \frac{R_1}{R_2}$ (shown) | 1<br>1 |
| | | (ii) | $\frac{1}{3} = \frac{R_1}{3.2 \times 10^{11} - R_1}$<br>(correct substitution)<br>$\Rightarrow 3R_1 = 3.2 \times 10^{11} - R_1$<br>$\Rightarrow R_1 = 8.0 \times 10^{10}$ m and $R_2 = 2.4 \times 10^{11}$ m (correct final answers, 2/3 s.f.) | 1<br>1 |
| | (d) | | Both stars are orbiting in a plane containing Earth's line of sight. So at two instances in one oscillation, one star will block the other star from our view. That is the reason for the reduction in intensity.<br>AND EITHER<br>(Addresses difference in dip) One star is brighter than the other star. That is why the reduction in intensity is different.<br>OR<br>(Addresses why shape of dip is V) Both stars are of similar size. That is why the dip in intensity is V-shaped (as opposed to U-shaped) | 1<br>1<br>1 |
| | (e) | | A point charge may be positive or negative / the electric potential can either be positive or negative<br>So if it is positive, when distance increases, the electric potential decreases. This is different from gravitational potential.<br>If the charge is negative, when distance increases, the electric potential increases, which is the same as gravitational potential. | 1<br>1 |
| | (f) | (i) | $U = \frac{1}{4\pi\epsilon_0}\frac{Q_1Q_2}{r} = \frac{1}{4\pi\epsilon_0}\frac{(3\times1.6\times10^{-19})(1.6\times10^{-19})}{(2.3+1.2)(10^{-15})}$<br>(correct expression)<br>(correct substitution)<br>$= 1.97 \times 10^{-13}$ J (correct answer, 2/3 s.f.) | 1<br>1<br>1 |

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| | | | | |
|---|---|---|---|---|
| | | (ii) | For the proton to travel from infinity and just make contact with the lithium nucleus, it must have possessed an initial kinetic energy of $1.97 \times 10^{-13}$ J,<br>which means it had an initial speed of about 5% the speed of light.<br><br>Thus, the kinetic energy is of a high amount. | 1<br>1 |
| | (g) | | Work done on $e^-$ by p.d. between plates = Gain in KE of $e^-$<br>$\Rightarrow q\Delta V = \frac{1}{2} m v_Y^2 - \frac{1}{2} m v_X^2$ ($2.04975 \times 10^{-17}$ J)<br>$\Rightarrow (1.6 \times 10^{-19})\ \Delta V = \frac{1}{2}(9.11 \times 10^{-31})[(9 \times 10^6)^2 - (6 \times 10^6)^2]$<br>$\Rightarrow \Delta V = 128.109$ V (correct expression + substitution)<br><br>Since $E = \Delta V / s$, we have<br>$s = \frac{128.109}{1.4 \times 10^5} = 9.15 \times 10^{-4}$ m (correct answer, 2/3 s.f) | 1<br><br>1<br><br>1 |
| | | | | |
| 8 | (a) | (i) | Wavelength = speed × time for 1 cycle<br>= 20 × 0.60<br>= 12 cm [A1] | 1 |
| | | (ii) | Phase difference = (0.20/0.60) × 360° = 120° [A1]<br>Or<br>Phase difference = (0.40/0.60) × 360° = 240° | 1 |
| | | (iii) | Intensity $I \propto A^2$ [C1]<br>$I_Q / I_P = A_Q^2 / A_P^2$<br>$= 2.0^2 / 3.0^2$<br>= 0.44 [A1] | 1<br><br><br>1 |
| | | (iv) | Displacement = 1.00 – 3.00 = – 2.00 mm [A1] | 1 |
| | (b) | (i) | It means the two waves have constant phase difference. [A1] | 1 |
| | | (ii) | P is the second minima from the central bright fringe,<br>Path difference = $1.5\lambda = 1.5 \times 610$<br>= 920 nm [A1] | <br><br>1 |
| | | (iii) | $\lambda = ax / D$<br>$x = (22 / 4) = 5.5$. mm [C1]<br>$a = (610 \times 10^{-7})(2.7) / (5.5 \times 10^{-3})$<br>$= 3.0 \times 10^{-4}$ m [A1] | 1<br><br>1 |

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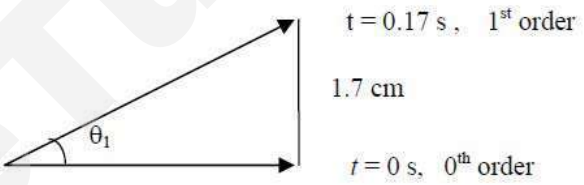
| | | | | |
|---|---|---|---|---|
| | | **(iv)** | When visible light of higher frequency is used, the wavelength becomes shorter. Since fringe separation is directly proportional to wavelength for the same slit separation and distance D, the fringe separation decreases. [B1] | **1** |
| | | **(v)** | No change to fringe separation / fringe width / number of fringes [B1]<br>Bright fringes are brighter, Dark fringes unchanged. [B1] | **2** |
| | **(c)** | **(i)** | Angular speed of grating $\omega = 2\pi/T = 2\pi/3.0 = 2.1$ rad $s^{-1}$ | **1** |
| | | **(ii)** | When the turntable rotates, the second order of the diffraction pattern will be registered first by the detector, forming peak A. As the turntable continues rotating, the first order of the diffraction pattern (peak B) was detected and then the central maximum (peak C) was observed.<br>Since the turntable rotates at constant angular speed, the other half of the peaks (D and E) appear at same separation away from the central maximum as peaks B and A respectively. | **1**<br>**1** |
| | | **(iii)** | Time to shift from zeroth order to peak D through 1.7 cm on the screen is $1.7 \times 0.10 = 0.17$ s [C1]<br>  <br>$\theta_1 = \omega t = (2\pi/3.0)\,(0.17) = 0.356$ rad<br>$d\sin\theta_1 = n\lambda$<br>$\sin(0.356) = (1)(5.5 \times 10^5)(\lambda)$ [C1]<br>$\lambda = 6.34 \times 10^{-7}$ m [A1] | **1**<br>**1**<br>**1** |

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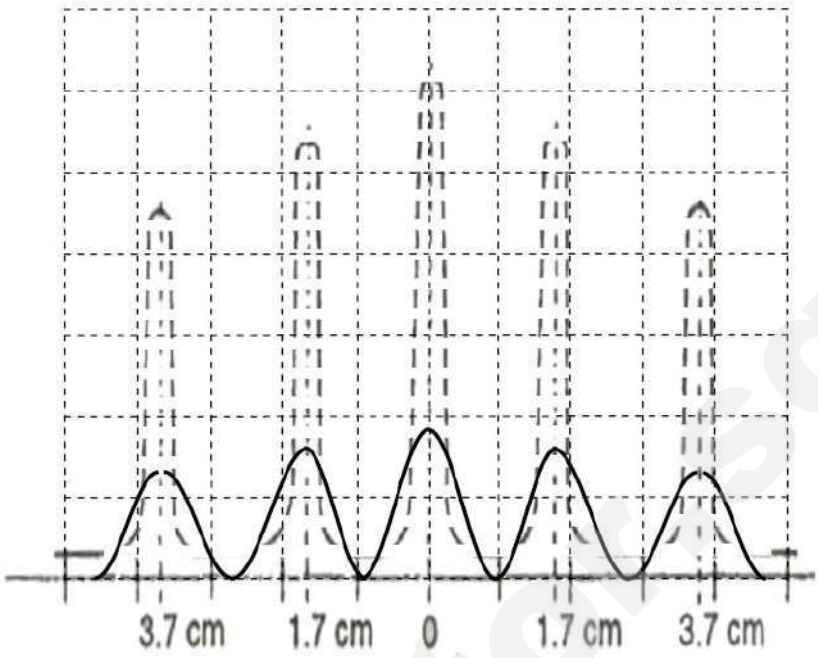
| | | | | |
|---|---|---|---|---|
| | | (iv) |  <br>Since the slit separation remain the same, the fringe separation remains the same. [B1]<br>However, the peaks are less intense (less contrast between the bright and dark fringes) and less sharp (broader and less defined) [B1] | **1**<br>**1** |
| | | | | |

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# PHYSICS 9749/04

Paper 4 Practical

**27 August 2019**

**2 hours 30 minutes**

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

**READ THESE INSTRUCTIONS FIRST**

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

Answer **all** questions.

You will be allowed a maximum of one hour with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

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

| Shift |
|---|
| |
| **Laboratory** |
| |

| For Examiner's Use | |
|---|---|
| 1 | /18 |
| 2 | /5 |
| 3 | /20 |
| 4 | /12 |
| Total | /55 |

This document consists of **19** printed pages and **1** blank page.

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

**(a) (i)** Measure and record the diameter $d$ of the short sample of wire that is placed in a transparent container.

$d_1$ = 0.18 mm
$d_2$ = 0.18 mm
Average reading, $d$ = ½ ($d_1$ + $d_2$)
= ½ (0.18 + 0.18)
= 0.18 mm

$d$ = ..... [1]

**(ii)** Calculate the cross-sectional area A of the wire, using the formula

$$A = \frac{\pi d^2}{4}.$$

$A = \pi d^2 / 4$
$= \pi(0.18 \times 10^{-3})^2 / 4$
$= 2.5 \times 10^{-8}$ m$^2$

$A$ = 2.5 x 10$^{-8}$ m$^2$ ..... [1]

**(b) (i)** Use the wire attached to the metre rule, one of the voltmeters and one of the resistors to set up the partial circuit shown in Fig. 1.1.

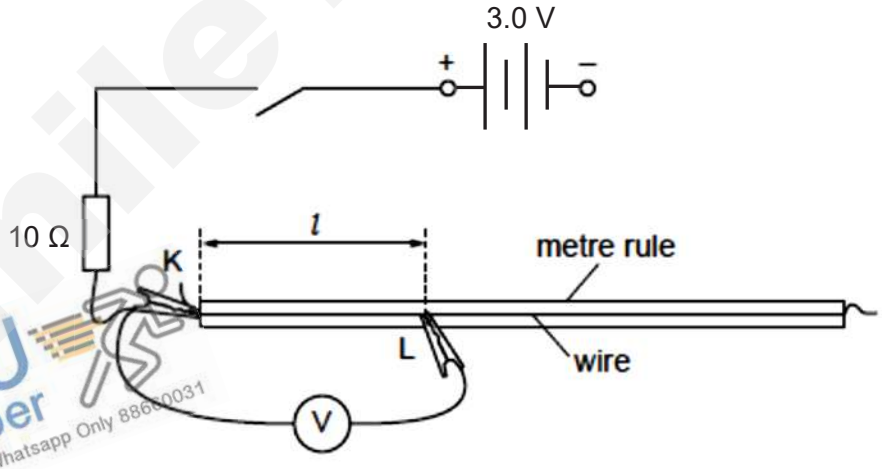


**Fig. 1.1**

There are two crocodile clips, one labelled K and the other labelled L.

Place K and L so that the distance $l$ between them is approximately 30 cm.

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

300 mm or 30.0 cm or 0.300 m

$l$ = .....

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**(iii)** Use the other resistor and the other voltmeter to complete the circuit shown in Fig. 1.2.

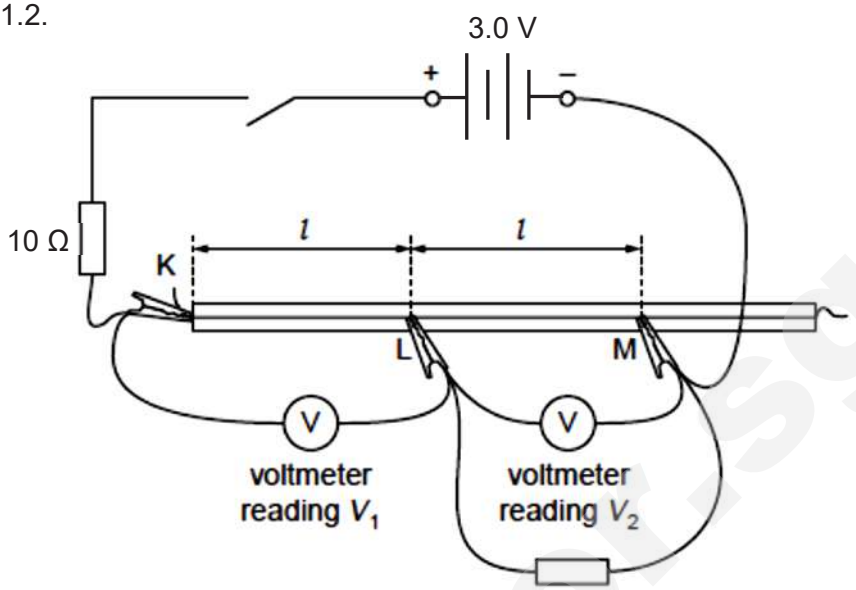


**Fig. 1.2**

**(iv)** Place the crocodile clip M at a distance $l$ from L.

The value of $l$ should be the same as in **(b)(ii)**.

**(c)** **(i)** Turn on the switch.

**(ii)** Record the voltmeter readings $V_1$ and $V_2$ as shown in Fig. 1.2.

$V_1$ = 775 mV or 0.775 V

$V_2$ = 518 mV or 0.518 V [1]

**(iii)** Turn off the switch.

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

Include values of $\frac{V_1}{V_2}$ in your table.

| $l$ / m | $V_1$ / V | $V_2$ / V | $V_1 / V_2$ |
|---|---|---|---|
| 0.100 | 0.372 | 0.346 | 1.08 |
| 0.150 | 0.494 | 0.467 | 1.06 |
| 0.200 | 0.600 | 0.450 | 1.33 |
| 0.300 | 0.775 | 0.518 | 1.50 |
| 0.400 | 0.931 | 0.557 | 1.67 |
| 0.450 | 0.983 | 0.560 | 1.76 |

[6]

**(e)** The quantities $V_1$, $V_2$ and $l$ are related by the equation

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

where $P$ and $Q$ are constants.

Plot a suitable graph to determine the values of $P$ and $Q$ with appropriate units.

$P$ = 1.89 $m^{-1}$

$Q$ = 0.921 [6]

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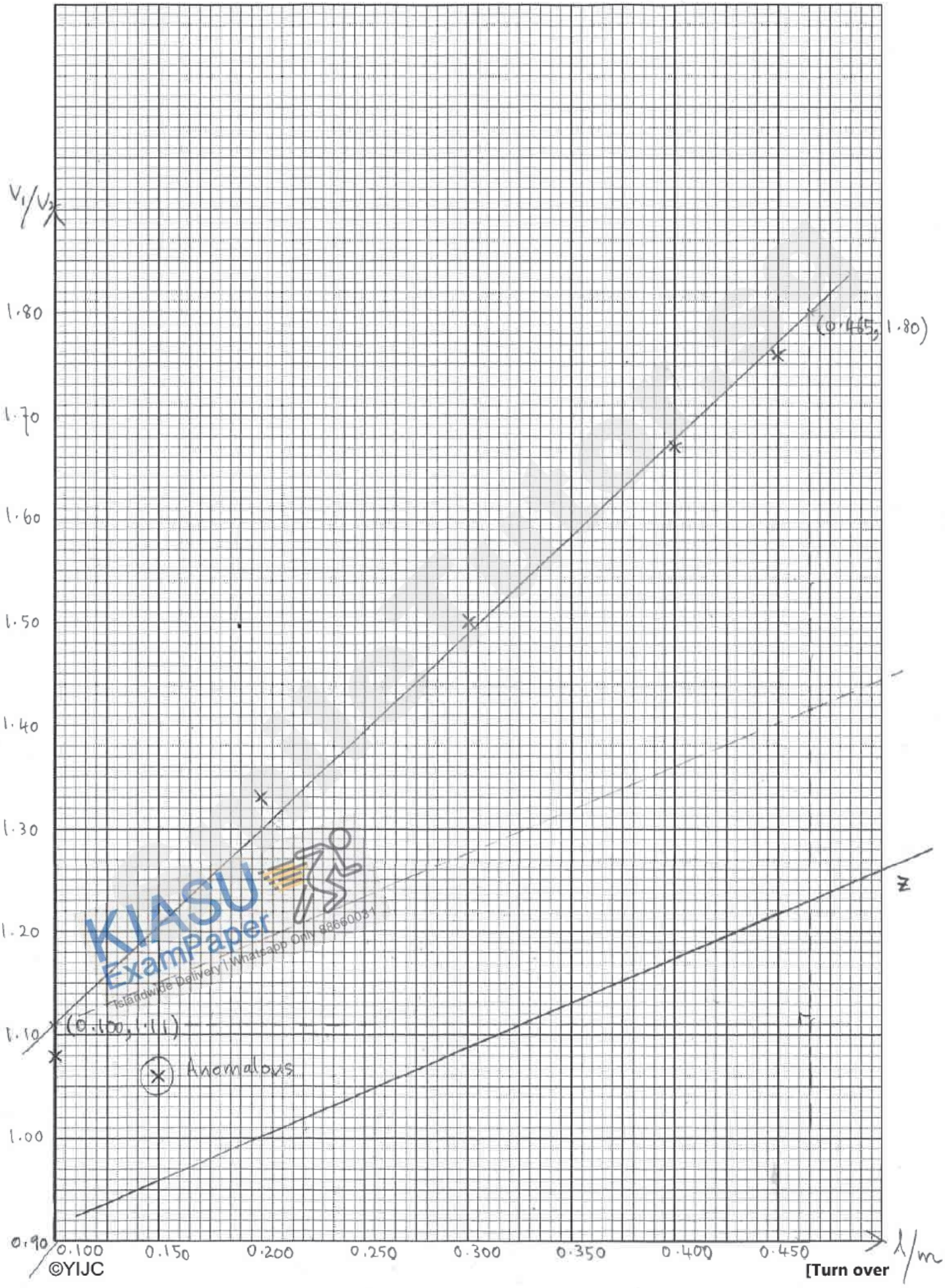


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| | | | |
|---|---|---|---|
| | **(f)** | The resistivity $\rho$ of the material of the wire, in Ω m, can be found using the relationship<br>$\rho = PAR$<br>where $R$ = 10 Ω .<br>Use your answers in **(a)(ii)** and **(e)** to calculate a value for $\rho$.<br>$\rho = PAR$<br>$= 1.89\ (2.6 \times 10^{-8})(10)$<br>$= 4.9 \times 10^{-7}$ Ω m | |
| | | $\rho$ = ..... Ω m | [1] |
| | **(g)** | Comment on any anomalous data or results that you may have obtained. Explain your answer. | |
| | | .....<br>.....<br>..... | [1] |
| | **(h)** | The experiment is repeated using the same resistance wire and a value of $R$ that is 20 Ω.<br>Assuming that $Q$ remains unchanged, on the same graph grid in **(e)**, sketch a second graph to represent the results. Label the graph, **Z**. | |
| | | | [1] |

**[Total: 18 marks]**

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**2** In this experiment, you will investigate the balance of a ruler.

**(a) (i)** Record the length $L$ of the ruler as shown in Fig. 2.1.

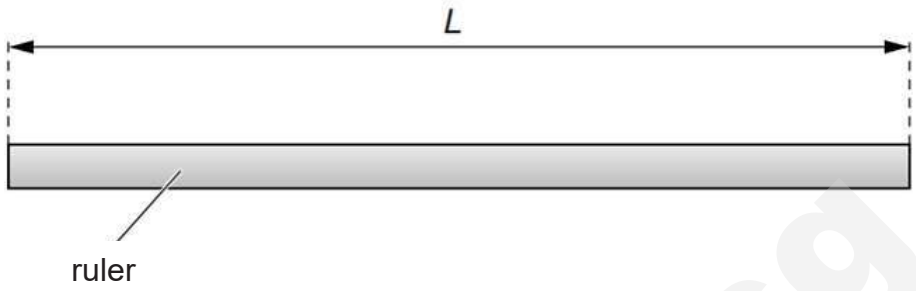


**Fig. 2.1**

$L$ = 50.0 cm

**(ii)** Measure and record the mass $m$ of the ruler.

$m$ = 63.9 g [1]

**(iii)** Calculate the mass per unit length $\rho$ of the ruler, where

$$\rho = \frac{m}{L}$$

$\rho$ = 1.28 g cm$^{-1}$ [1]

**(b) (i)** Record the mass $M$ of the slotted mass.

$M$ = 100 g

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| | | | |
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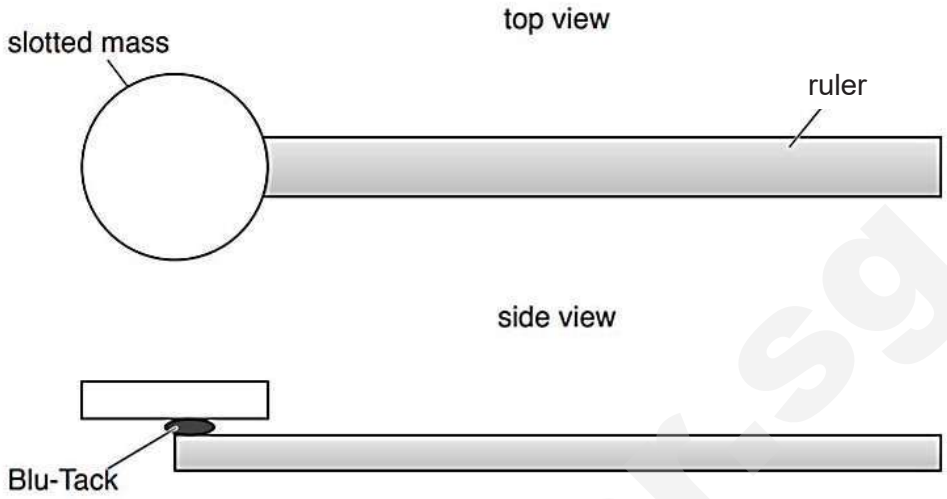
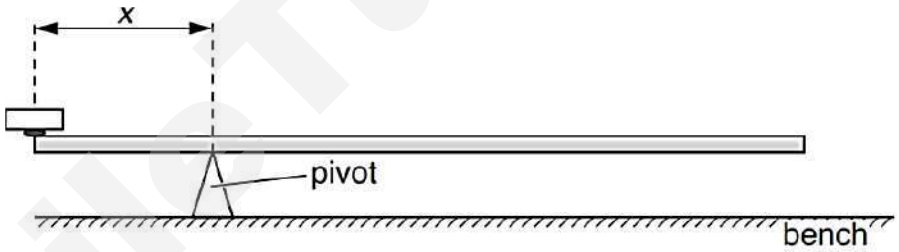
| | | **(ii)** | Use the Blu-Tack to attach the sloted mass to the top of the ruler as shown in Fig. 2.2.<br>  <br><br>**Fig. 2.2**<br>The centre of the slotted mass shold be positioned at the end of the ruler. |
| | **(c)** | **(i)** | Balance the ruler on the pivot as shown in Fig. 2.3.<br>  <br><br>**Fig. 2.3** |
| | | **(ii)** | Measure and record the distance *x* from the pivot to the end of the ruler as shown in Fig 2.3. |
| | | | *x* = 9.9 cm ..... [1] |
| | | | |

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**(d)** Theory suggests that

$$x = \frac{kL^2}{2(M + L\rho)}$$

where $k$ is a constant.

**(i)** Using your data, calculate the value of $k$.

$k$ = 0.13 kg m$^{-1}$ [1]

**(ii)** If you were to repeat this experiment with rulers of different lengths $L$, each having the same mass per unit length $\rho$, describe the graph you would plot to determine $k$.

I would plot $x$ against $\frac{L^2}{2(M + L\rho)}$ and the gradient will be expected to be $k$. [1]

**[Total: 5 marks]**

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**3** In this experiment, you will investigate the motion of a Y-shaped pendulum.

**(a)** You have been provided with two loops of string.

Stretch one of the loops as shown in Fig. 3.1.

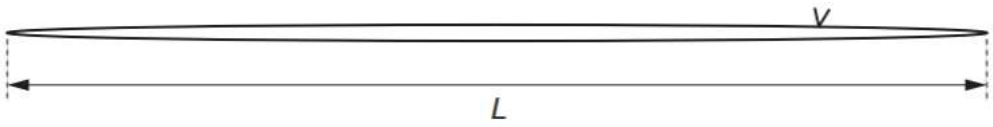


**Fig. 3.1**

Measure and record the length *L* as shown in Fig. 3.1.

*L* = 38.3 cm ..... [1]

**(b)** **(i)** Set up the apparatus as shown in Fig. 3.2. Move the stands so that the distance between the centres of the rods of the clamps is 25.0 cm.

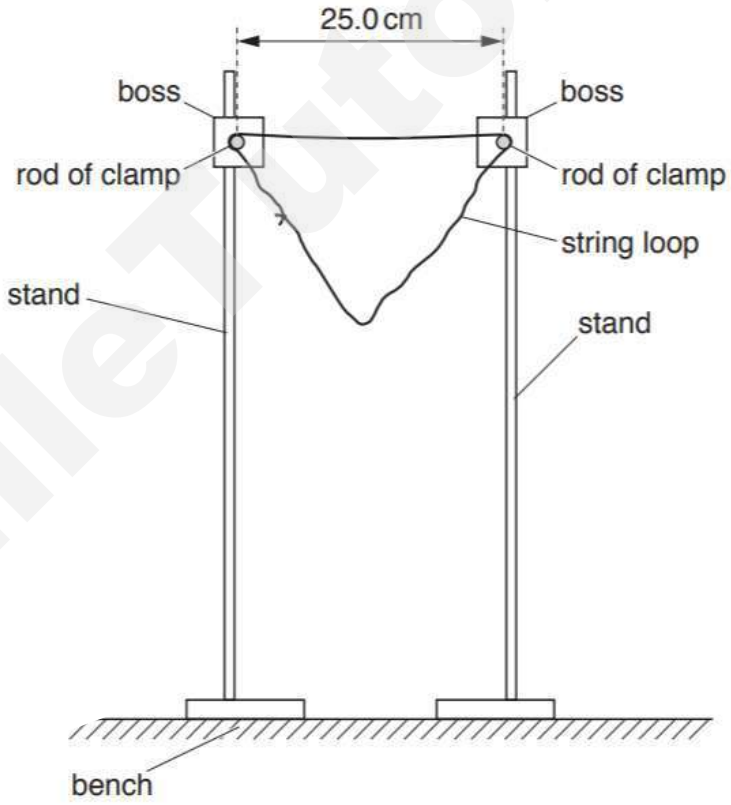


**Fig. 3.2**

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**(ii)** Pull down on the bottom of the loop until it is fully stretched as shown in Fig. 3.3

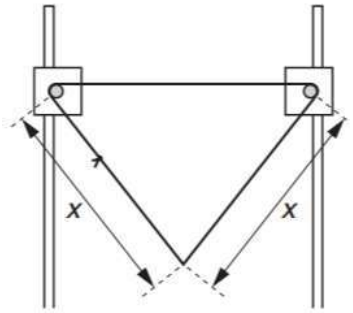


**Fig. 3.3**

The distance between the bottom of the loop and the centre of a rod is *x*.
Measure and record *x*.

*x* = 25.4 cm ..... [1]

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

percentage uncertainty = 0.78% ..... [1]

**(iv)** Calculate *G* where

$$G = \sqrt{L(2x - L)}$$

*G* = 21.9 cm ..... [1]

**(v)** Justify the number of significant figures that you have given for your value of *G*.

The significant figures of *G* should follow the least significant figures of the data used to calculate it. Given that the least significant figure of the data used is 3 s.f hence *G* is 3 s.f. ..... [1]

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**(c) (i)** You have been provided with two pendulum bobs tied to strings.

Tie the string attached to one of the bobs to the string loop so that the distance between the knot and the centre of the bob is equal to *x*, as shown in Fig. 3.4.

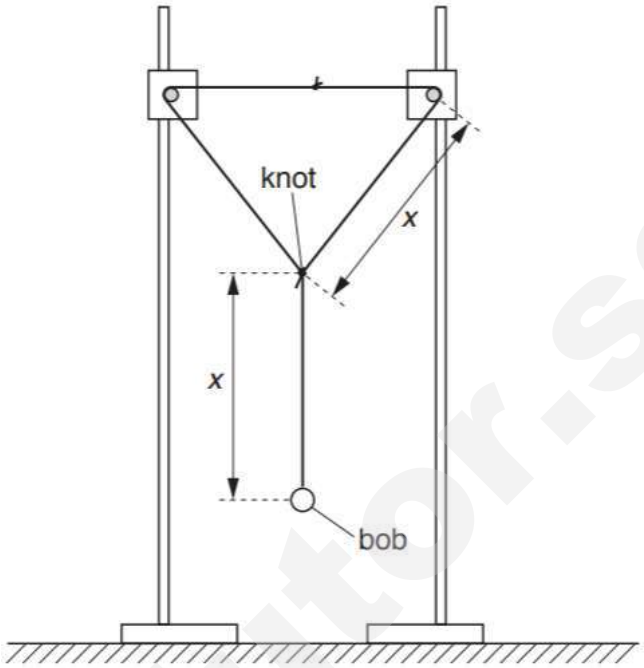


**Fig. 3.4**

**(ii)** Pull the bob a short distance towards you. Release the bob. The bob will oscillate.

Determine the period *T* of these oscillations.

Number of oscillations = 18
First reading for 18 oscillations = 25.61 s
Second reading for 18 oscillations = 25.78 s
*T* = (25.61+25.78) / 36 = 1.428 s

*T* = 1.428 s ..... [1]

**(iii)** Estimate the percentage uncertainty in your value of *T*.

percentage uncertainty = 1.4% ..... [1]

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**(d)** Move one of the stands until the distance between the centres of the rods of the clamps is 30 cm.

Using the second loop and bob, repeat **(a), (b)(ii), (b)(iv)** and **(c)(ii).**

$L$ = 38.2 cm

$x$ = 22.4 cm

$G$ = 15.8 cm

$T$ = 1.301 s [3]

**(e)** It is suggested that the relationship between $T$, $G$ and $x$ is

$$T^2 = k(G + x)$$

where $k$ is a constant.

**(i)** Using your data, calculate two values of $k$.

First $k = \frac{1.428^2}{(21.9+25.4)} = 0.0431$ s$^2$ cm$^{-1}$

Second $k = \frac{1.301^2}{(15.8+22.4)} = 0.0443$ s$^2$ cm$^{-1}$

first value of $k$ = ……..

second value of $k$ = …….. [1]

**(ii)** State whether the results of your experiment support the suggested relationship.

Justify your conclusion by referring to your values in **(b)(iii)** and **(c)(ii)**.

Percentage difference = (0.0443 – 0.0431) / 0.0431 x100% = 2.8%

Since the percentage difference is less than the sum of 2 times percentage uncertainty of $T$ and percentage uncertainty of $x$ [(2 x 1.4) + 0.78 = 3.6%]
Hence the percentage difference of the two $k$ values are insignificant and the suggested relationship is supported [1]

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| | | | | |
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| | **(f)** | **(i)** | State two significant sources of error in this experiment.<br>**1** .....<br>.....<br>.....<br>.....<br>**2** .....<br>.....<br>.....<br>..... | [2] |
| | | **(ii)** | Suggest an improvement that could be made to the experiment to address one of the errors identified in **(f)(i)**. You may suggest the use of other apparatus or a different procedure. | |
| | | | .....<br>.....<br>..... | [1] |

Error:

- Difficult to measure *x* with a reason e.g. holding ruler and pulling down on loop at the same time/holding string and rule/measuring at an angle/holding rule steady/stands move or tilt when loop pulled/judging end points.
- Difficulty linked to the length of the pendulum e.g. knot slips/tying a knot/measuring to the centre of the bob.
- Difficult to measure *L* with a reason e.g. finger gets in the way/thickness of string.
- Difficulty linked to oscillation e.g. strings on rods move/stands move as the pendulum oscillates **or** difficult to judge the end of an oscillation.

Improvement:

- Improved method to measure *x* e.g. clamp rule/clamp stands/hang mass on loop.
- Use glue (not knots)/mark the string/attach hook or loop to pendulum/measure string and add radius to length.
- Improved method to measure *L* e.g. use pins/nails/tape to table.
- Clamp stands/use tape to fix strings to rods/idea of a groove **or** film/video camera with timer/frame by frame/marker at centre of oscillation.

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**(g)** A student thinks that the behaviour of the oscillating system depends on the properties of the bob used.

He proposed that the volume of the bob *V* affects the period of the system *T*. He would like to determine the volume of the pendulum bob such that it would swing at 1 second for each oscillation.

Explain how you would be able to determine the volume of the pendulum bob that would give rise to an oscillation with a period of 1 second.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to determine the volume required

1. Set up the apparatus as shown in Fig 3.4,
2. keep *L* to be constant at 25.0 cm by using a ruler to measure whenever repeating the steps
3. Measure the diameter *d* of the bob used with a vernier caliper.
4. Calculate the volume *V* of the bob by using the formula $V = 4/3\pi\ (d/2)^3$
5. Measure the total time *t*1 for *N* oscillations using a stopwatch.
6. Determine the period $T = t1 / N$ for the pendulum.
7. Repeat step 1 to 4, 5 more times by using pendulum bob of different diameter

8. Plot a graph of *T* against *V* and draw a best fit line / curve through the points.
9. From the line / curve, determine the volume *V* which will provide the *T* to be 1 s.

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[5]

**[Total: 20 marks]**

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**4** A student is investigating simple harmonic motion using an electric vibrator. A plate is attached to the top of the electric vibrator. A small mass is placed on the metal plate as shown in Fig. 4.1.

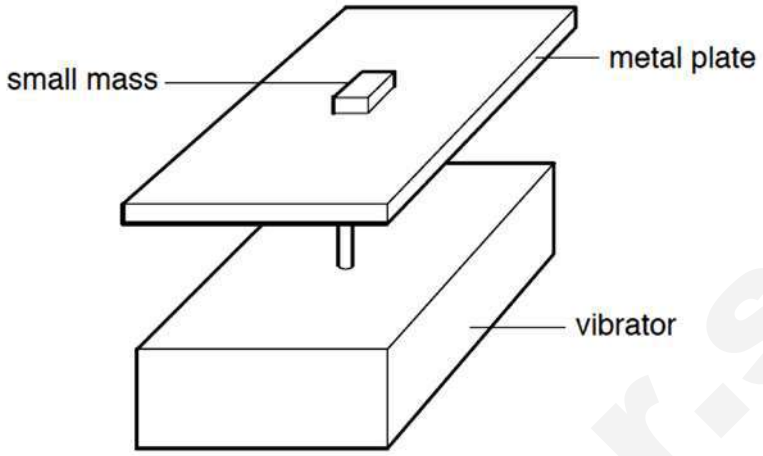


**Fig. 4.1**

An alternating potential difference (p.d.) is applied to the vibrator. 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 plate is lost when the frequency is greater than $f$.

It is suggested that the relationship between $f$ and $V$ is

$$k = \pi^2 f^2 V$$

where $k$ is a constant.

Design a laboratory experiment to test the relationship between $f$ and $V$. Explain how your results could be used to determine a value for $k$.

Draw a 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)** the measurements to be taken
**(d)** the control of variables
**(e)** the precautions that should be taken to improve the accuracy and safety of the experiment.

**[Total: 12 marks]**

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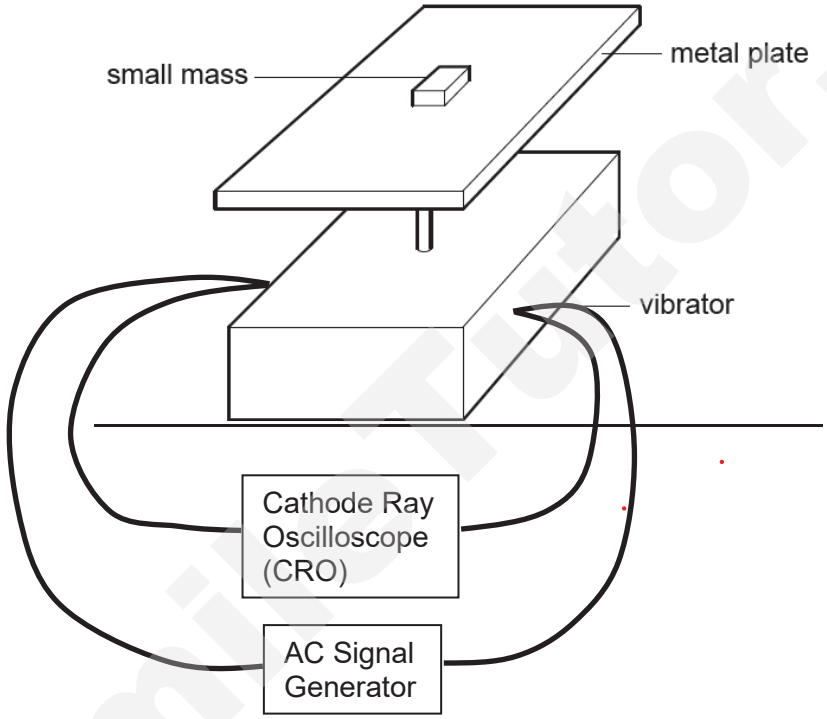
**Suggested mark scheme for Q4**

| | | |
|---|---|---|
| 1 | **Answer Scheme (12 marks)**<br><br>**D – Labelled diagram of a workable circuit [1]**<br>**A – Defining the problem, Identification of variables [1]**<br>**P – General procedure marks [1]**<br>**M – Method to measure dependent, independent variable and keeping controlled variable constant [4]**<br>**A – Analysis marks [2]**<br>**AD – Safety precautions or steps to improve reliability. [3]**<br><br>**DIAGRAM - 1 x [D1]**<br>  <br><br>• Diagram to minimally show an AC signal generator and a CRO connected in parallel to the vibrator with 2 wires.<br><br>**AIM – 1x [A1]**<br><br>Independent variable: Peak AC input potential difference, *V*<br>Dependant variable: Maximum frequency before mass loses contact with the plate, *f*<br>Controlled variable: Position of mass on the plate. (Do not allow mass)<br><br>**PROCEDURE - 1x [P1], 4x [M1]**<br><br>(a) Set up the apparatus as shown above.<br><br>(b) The position of the small mass should be kept constant roughly in the middle of the plate by marking an X in the middle of the plate and observing that the mass doesn't shift off the centre. **[M1]** | D1 - labelled diagram of a workable circuit<br><br>M1 – Any suitable method to monitor that mass doesn't shift |

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| | | |
|---|---|---|
| | (c) Adjust the peak p.d, *V* of the ac signal generator to a certain low value. V is obtained from the amplitude (height) x y-gain of the CRO. **[M1]** | M1 – Method of recording V |
| | (d) Adjust the frequency, *f* of the signal generator until the small mass just begins to lift off the surface of the plate. Observe the formation of a small air gap between the mass and the plate when this happens. **[M1]** | M1 – Method to varying *f*. Criteria used to stop *f* adj. impt. |
| | (e) Obtain the period, *T* of the oscillation of the plate from at least 2 waveforms on the CRO. Period *T* is given by (two time period x time base) / 2. | M1 – for both steps (e) and (f). Method of measuring *f* |
| | (f) The maximum frequency *f* before the mass starts to lift off the surface of the plate, *f* is calculated as $f = 1 / T$ **[M1]** | |
| | (g) Repeat steps (d) to (f) to obtain 5 more sets of *f* each time by increasing the value of the peak p.d. *V* of the signal generator. **[P1]** | P1 – Method of varying *V* |
| | **ANALYSIS - 2x [N1]** | |
| | (h) Plot a graph of $f^2$ against $1 / V$. (Or other possible linearization method) | N1 – for both steps (h) and (i). |
| | (i) The given relationship of $k = \pi^2 f^2 V$ is valid if the plotted points follow a trend of best fit line that passes through the origin. (If log – log graph was used, method to proof validity of relationship lies in the correct determination of the gradient of the proposed graph, either -2 or -0.5) **[N1]** | |
| | (j) The value of *k* is obtain from $\pi^2$ x gradient of the straight line graph. **[N1]** | N1 – Method of determining *k* (important to make *k* the subject) |
| | **ADDITIONAL DETAILS - 3x [AD1]** | |
| | **Safety considerations – 1x [S1]**<br>S1: Be careful of the small mass that may suddenly fly off the plate if the frequency is too high. Make sure it does not hit the experimenter. Wear safety goggles or face shield to protect the face.<br>S2: Avoid handling the electrical circuit with wet hands in case of short circuit. | S1<br>Maximum 1 safety mark<br><br>R1<br>Maximum 2 reliability marks |
| | **Reliability considerations – 2x [R1]**<br>R1: Clean the surfaces of the small mass and the vibrating plate so that the interface is clean and mass does not 'stick' to the plate. This will ensure that the frequency *f* calculated is unaffected.<br>R2: A spirit level may be used to make sure that the vibrating plate is horizontal so that the frequency *f* at which the mass lifts off the plate could be accurately determined.<br>R3: Ensure that the position of the eye is levelled to the plate to observe the formation of a small air gap, so that the minumum frequency *f* before the mass lifts off from the plate could be accurately determined. | |

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| | R4: Take slow-motion video of the mass and view the playback to determine if the mass has truly lifted off the plate for each *f* determined. Fine tune *f* if necessary.<br>R5: Adjust the frequency gradually to ensure that the lowest possible frequency to cause the mass to lift off from the plate surface is obtained | |

**END OF PAPER**

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