RAFFLES INSTITUTION
2024 Preliminary Examination

PHYSICS **9749/01**
Higher 2

25 September 2024
Paper 1 Multiple Choice Questions **1 hour**

Additional Materials: OMR Form

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your index number, name and class on the OMR Form in the spaces provided. Shade the appropriate boxes.

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 OMR Form.

Read the instructions on the OMR Form 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 appropriate scientific calculator is expected, where necessary.

This document consists of **15** printed pages.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
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	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

1 The speed v of a liquid leaving a tube depends on the difference in pressure ΔP between the ends of the tube and the density ρ of the liquid according to the equation

$$v = k\left(\frac{\Delta P}{\rho}\right)^n$$

where k is a unitless constant.

What is the value of n?

A $\frac{1}{2}$ **B** 1 **C** $\frac{3}{2}$ **D** 2

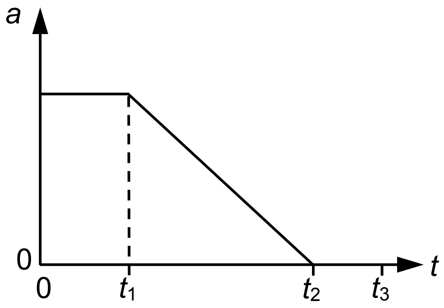
2 A micrometer screw gauge is used to measure the diameters of two cylinders. The measurements of the diameters, with their actual uncertainties, are given as follows:

$$\text{diameter of first cylinder } = (12.78 \pm 0.02) \text{ mm}$$
$$\text{diameter of second cylinder } = (16.24 \pm 0.03) \text{ mm}$$

What is the percentage uncertainty in the difference of the two diameters?

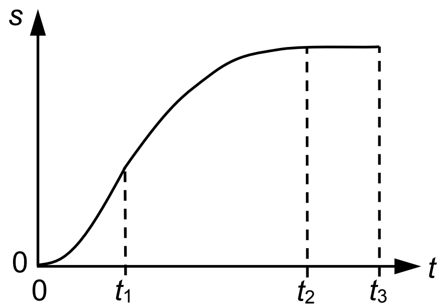
A 0.29% **B** 0.58% **C** 0.87% **D** 1.4%

3 A force is applied on a stationary object at time $t = 0$ s. The graph shows how the acceleration a of the object varies with time t.

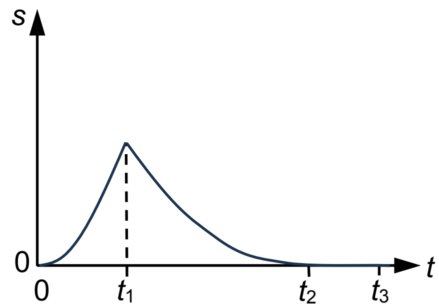


Which graph shows how the velocity v or displacement s of the object varies with t?

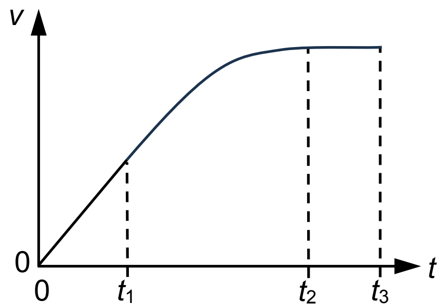
A



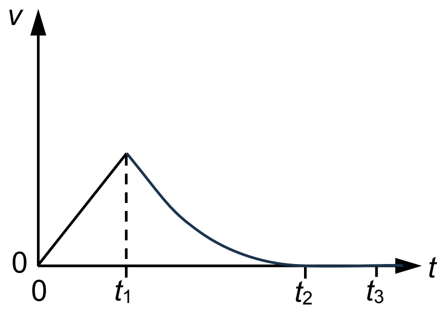
B



C



D



4 A student is standing on a weighing balance inside an ascending lift. The weighing balance gives a reading in newtons.

Which statement about the balance reading is correct?

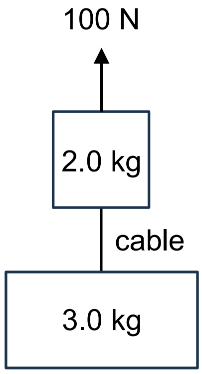
A The reading is less than the student's weight.

B The reading is equal to the student's weight.

C The reading is more than the student's weight.

D The reading can be less than, equal to or more than the student's weight.

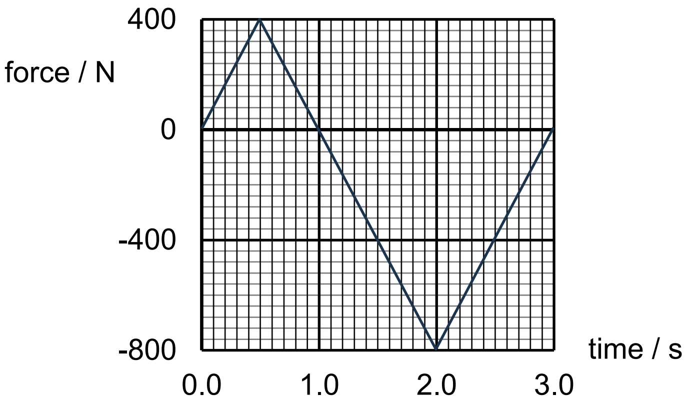
5 Two crates of masses 2.0 kg and 3.0 kg, connected by a cable, are lifted by a force of 100 N.



What is the tension in the cable between the crates?

A 40 N **B** 51 N **C** 60 N **D** 80 N

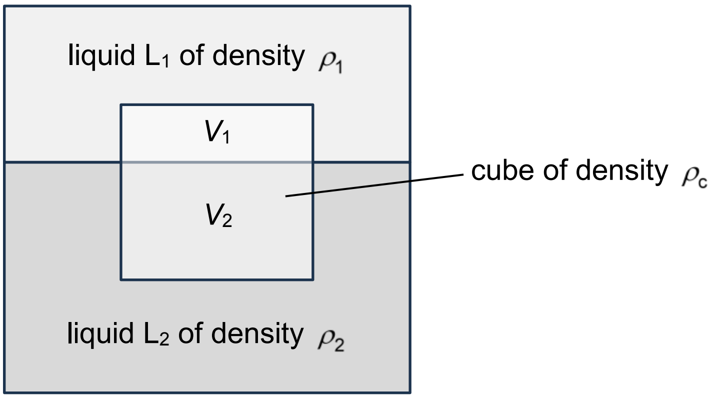
6 A motorcycle of mass 400 kg is travelling at a speed of 4.5 m s^{-1} when it experiences an accelerating force for 1.0 s, followed by a retarding force for 2.0 s as shown.



What is the speed of the motorcycle after 3.0 s?

A 1.5 m s^{-1} **B** 3.0 m s^{-1} **C** 4.5 m s^{-1} **D** 6.0 m s^{-1}

7 A cube of density ρ_c is floating in two liquids L_1 and L_2 of densities ρ_1 and ρ_2 respectively. Volume V_1 of the cube is immersed in L_1, and volume V_2 of the cube is immersed in L_2.

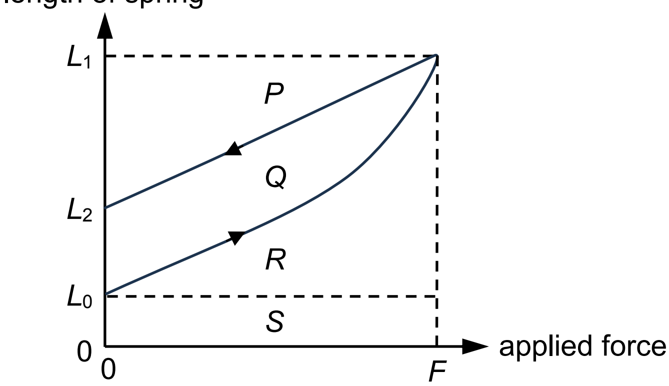


(not drawn to scale)

What is the ratio $\frac{V_1}{V_2}$, if $\rho_2 = 3\rho_1$ and $\rho_c = 2\rho_1$?

A $\frac{1}{3}$ **B** $\frac{1}{2}$ **C** $\frac{2}{3}$ **D** 1

8 A spring of unstretched length L_0 is extended to length L_1 by an applied force that is increased from zero until F. Upon removal of the force, the spring is damaged and has a new unstretched length L_2. The graph shows the variation of the length of the spring with the applied force.



Which combination of areas give the work done by the force to extend the spring from L_0 to L_1 and which area gives the increase in potential energy of the particles in the spring when its unstretched length is increased from L_0 to L_2?

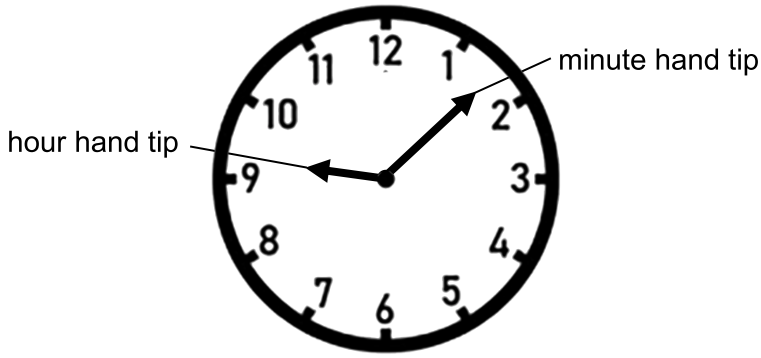
	work done by force from L_0 to L_1	increase in potential energy from L_0 to L_2
A	$P + Q$	Q
B	$R + S$	Q
C	$P + Q$	P
D	$R + S$	P

9 When a car is travelling along a straight road at a constant speed of 72 km h^{-1}, the power delivered by its engine is 12 kW. The efficiency of the engine is 30% and each kilogram of petrol produces 40 MJ of energy.

What is the total resistive force on the car and the mass of petrol required for a one-hour drive?

	total resistive force	mass of petrol
A	170 N	0.32 kg
B	600 N	0.32 kg
C	170 N	3.6 kg
D	600 N	3.6 kg

10 The minute hand on a clock is 1.5 times the length of its hour hand.



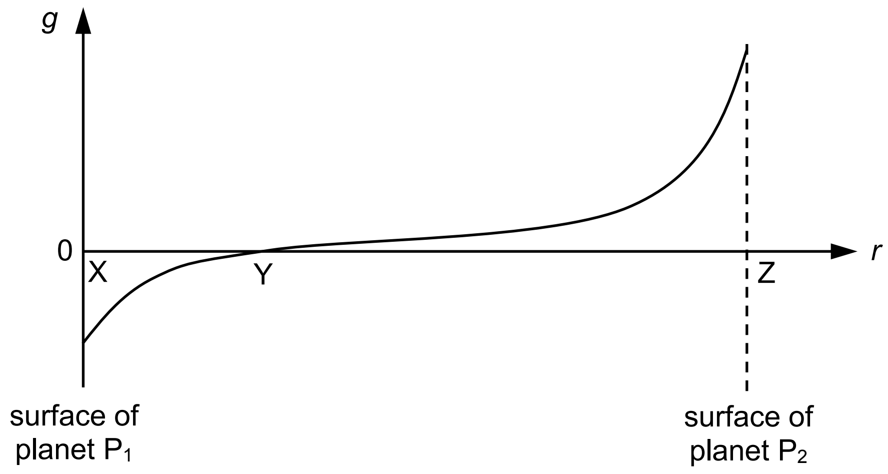
The average tangential speeds of the tips of the minute hand and the hour hand are v_m and v_h respectively.

What is the ratio $\frac{v_m}{v_h}$?

A 0.125 **B** 1.5 **C** 18 **D** 90

11 The graph shows the variation of the gravitational field strength g between the surface of planet P_1 and the surface of planet P_2 with distance r from the surface of planet P_1.

X, Y and Z are points along the line joining the centres of the planets.



Which statement about the gravitational potential between the two planets is correct?

A The gravitational potential at point Y is zero.

B The gravitational potential at point Z is positive.

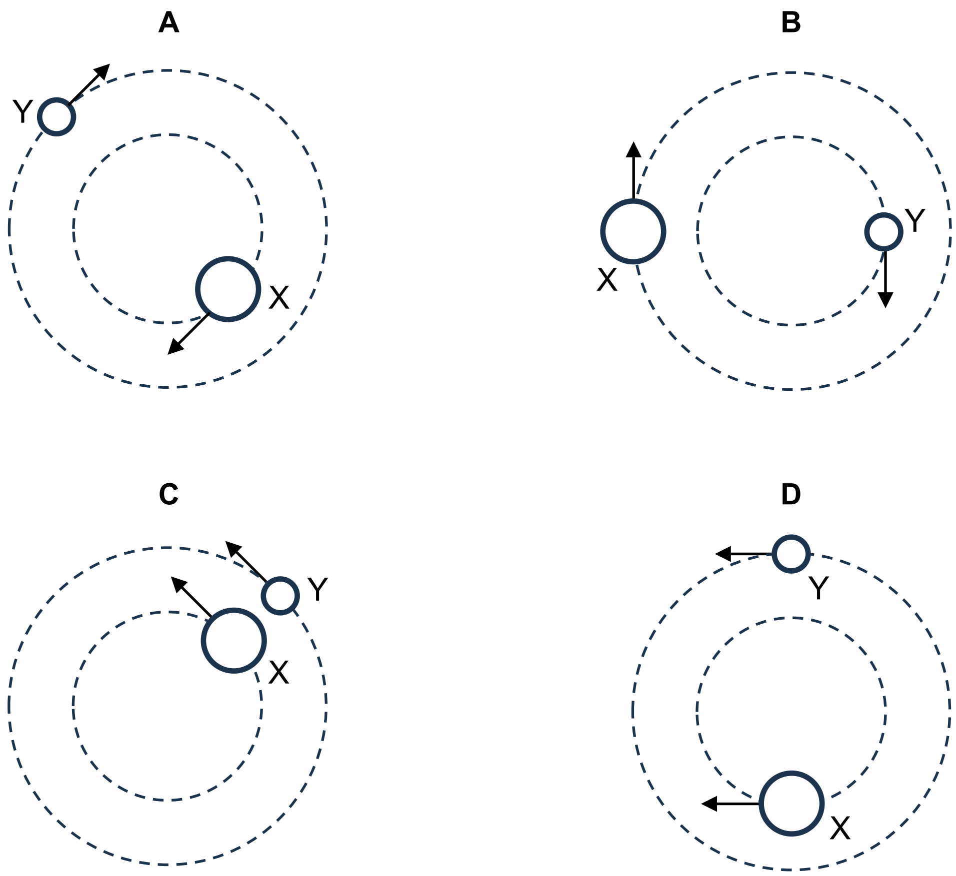
C The area under the graph gives the value of the change in gravitational potential when a test mass is brought from point X to point Z.

D The gradient of the tangent at any point on the graph gives the value of the gravitational potential at that point.

12 A binary star system consists of two stars X and Y orbiting about a common centre due to their mutual gravitational forces on each other.

The mass of star X is larger than the mass of star Y.

Which diagram shows the possible positions of stars X and Y and the directions of their velocities?



13 Two ideal gases X and Y are separately contained in two identical vessels. The absolute temperature and root-mean-square speed of the molecules of Y are 2 and 3 times that of X respectively.

What is the ratio $\dfrac{\text{molecular mass of X}}{\text{molecular mass of Y}}$?

A 0.22 **B** 1.5 **C** 2.3 **D** 4.5

14 In the continuous flow method for determining the specific heat capacity of a liquid, it is important to account for heat losses.

If the inlet temperature and room temperature are unchanged, which other quantity must also be kept constant in such experiments?

A electrical power input

B outlet temperature

C rate of liquid flow

D mass of liquid collected

15 A sphere of mass 20 g undergoes simple harmonic motion with a period of 9.0 s. The speed of the sphere 3.0 s after starting from the equilibrium is 4.0 m s^{-1}.

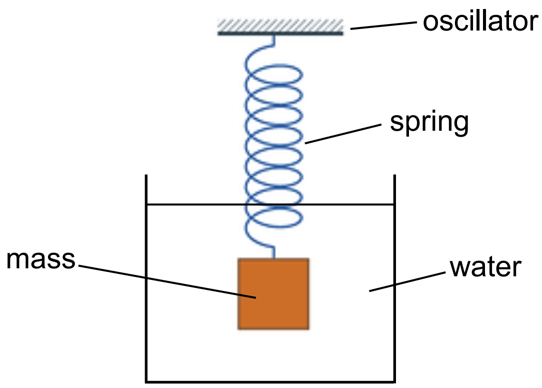
What is the kinetic energy of the sphere when it next passes the equilibrium position?

A 0 J **B** 0.16 J **C** 0.21 J **D** 0.64 J

16 A light spring hangs vertically from a driving oscillator. A mass is attached to the fee end of the spring and is submerged in water as shown.

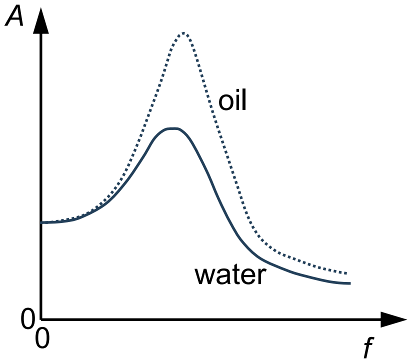
The mass is made to oscillate vertically at various frequencies of the oscillator. The oscillator has a constant amplitude at all frequencies.

The experiment is then repeated with the mass submerged in oil.

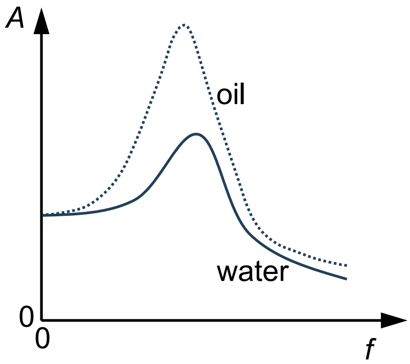


Which graph shows how the amplitude A of the oscillating mass varies with the frequency f at which it is driven when the mass is in water and oil?

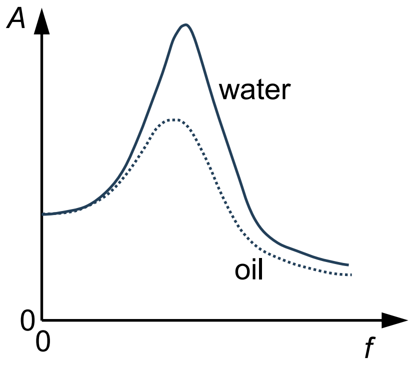
A



B



C



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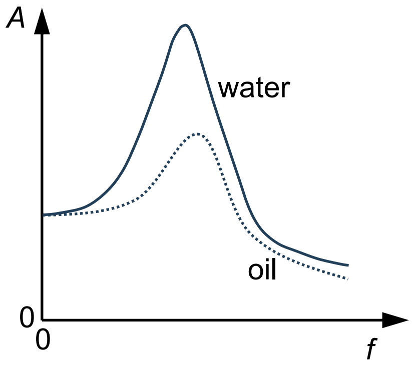


17 Transverse progressive sinusoidal waves of wavelength λ are passing vertically along a horizontal rope. P and Q are points on the rope $\frac{\lambda}{4}$ apart. The direction of energy transfer is from P to Q.

Which of the following describes the displacement and movement of Q at the instant when P is displaced downwards and moving upwards?

	displacement of Q	movement of Q
A	zero	upwards
B	downwards	downwards
C	upwards	downwards
D	upwards	upwards

18 An astronaut observes a point source of light from a distance in space. The diameter of the pupil of his eyes is 5.0 mm. The minimum power of light that a human eye can detect is 2.0×10^{-13} W.

If the power of the light emitted by the source is 10 W, which statement about the distance at which the astronaut can see the light source is correct?

A The astronaut can see the light source at a minimum distance of 8800 m.

B The astronaut can see the light source at a maximum distance of 8800 m.

C The astronaut can see the light source at a minimum distance of 17700 m.

D The astronaut can see the light source at a maximum distance of 17700 m.

19 A pillar in a concert hall can block the view of the audience but it does not disrupt their hearing.

What is the reason for this observation?

A Sound waves have a much longer wavelength compared to light waves.

B Sound waves are longitudinal whereas light waves are transverse.

C Sound travels at a much slower speed compared to light.

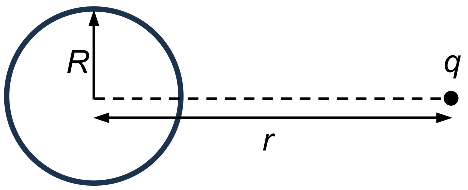
D Sound is a pressure wave whereas light is an electromagnetic wave.

20 Two point sources of light at a fixed distance apart emit monochromatic light of wavelength λ. An observer views the light sources with a telescope of aperture size *d* at a distance *D* from the light sources.

Which combination of λ, *d* and *D* would give the observer the best setting to resolve the light sources?

	λ	*d*	*D*
A	shorter	larger	nearer
B	shorter	smaller	nearer
C	shorter	larger	further
D	longer	smaller	further

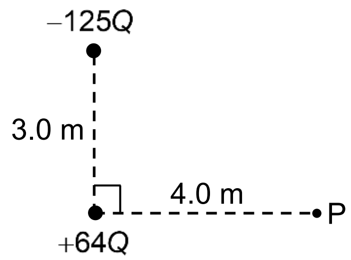
21 A charged conducting sphere of radius *R* has an electric potential *V*. A particle of charge *q* is at a distance *r* away from the centre of the charged sphere.



What is the magnitude of the electric force acting on the particle due to the charged sphere?

A $\dfrac{qV}{R}$ **B** $\dfrac{qV}{r}$ **C** $\dfrac{qVr}{R^2}$ **D** $\dfrac{qVR}{r^2}$

22 Two charged particles of charges $+64Q$ and $-125Q$ are separated by a distance of 3.0 m. Point P is at a distance 4.0 m to the right of the particle of charge $+64Q$.



What is the magnitude of the electric field strength at point P?

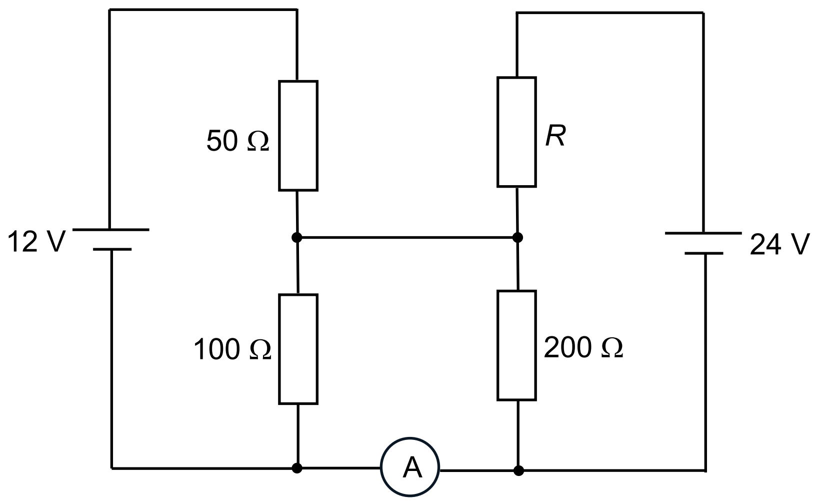
A $\dfrac{Q}{4\pi\varepsilon_0}$ **B** $\dfrac{3Q}{4\pi\varepsilon_0}$ **C** $\dfrac{9Q}{4\pi\varepsilon_0}$ **D** $\dfrac{41Q}{4\pi\varepsilon_0}$

23 Two wires X and Y are of the same length. The resistivity of wire X is half the resistivity of wire Y. The diameter of wire X is one quarter the diameter of wire Y. X and Y are connected in parallel to a battery with negligible internal resistance.

What fraction of the total current passes through wire X?

A $\frac{1}{9}$ **B** $\frac{1}{8}$ **C** $\frac{1}{3}$ **D** $\frac{1}{2}$

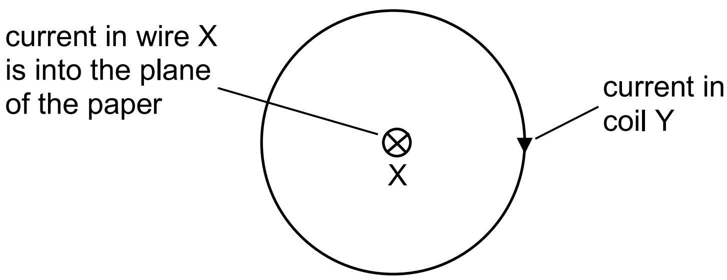
24 In the circuit shown, the ammeter reading is zero.



What is the value of resistance R?

A 40 Ω **B** 100 Ω **C** 200 Ω **D** 400 Ω

25 A long straight wire X is placed along the central axis of a flat circular coil Y. The wire and the coil each carry a current as shown.



Which statement about the force acting on each part of coil Y due to the current in wire X is correct?

A The force is towards wire X.

B The force is away from wire X.

C There is no force in all directions.

D The force is perpendicular to the plane of coil Y.

26 A straight wire of length 15 m is placed horizontally along the East-West direction. The wire is raised vertically through a height of 5.0 m in 150 ms.

The magnetic flux density due to the Earth's magnetic field at this location is 3.0×10^{-5} T at an angle of $50°$ below the horizontal.

What is the average e.m.f. induced across the ends of the wire?

A 0.0 mV **B** 9.6 mV **C** 11 mV **D** 15 mV

27 A generator produces a r.m.s. current of 50 A at a r.m.s. voltage of 240 V. The voltage is stepped up to 50 kV r.m.s. by an ideal transformer and transmitted through a power line with a total resistance of 100 Ω.

What is the percentage power lost in the transmission?

A 0.048% **B** 0.20% **C** 0.48% **D** 2.0%

28 An electron and a baseball have kinetic energies of 1.0 MeV and 100 J respectively. The percentage uncertainty in the measurement of their momenta is 1.0%.

What is the approximate ratio of the minimum uncertainty in the position of the electron to that of the baseball?

A 10^{7} **B** 10^{14} **C** 10^{22} **D** 10^{44}

29 Which series of radioactive decays will result in the formation of a different isotope of the parent nuclide?

A gamma decay

B one alpha decay and one beta decay

C one alpha decay and two beta decays

D two alpha decays and one beta decay

30 A sample consists of a radioactive nuclide X while another sample consists of a radioactive nuclide Y. After an interval of time, it is found that $\frac{7}{8}$ of the atoms of X and $\frac{3}{4}$ of the atoms of Y have decayed.

What is the ratio $\dfrac{\text{half life of X}}{\text{half life of Y}}$?

A 0.46 **B** 0.67 **C** 1.5 **D** 2.2

End of Paper 1

Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2024 Preliminary Examination

PHYSICS **9749/02**
Higher 2

11 September 2024

Paper 2 Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use 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	/ 8
2	/ 9
3	/ 5
4	/ 8
5	/ 10
6	/ 8
7	/ 10
8	/ 22
Deduction	
Total	/ 80

This document consists of **23** printed pages.

Data

speed of light in free space	c	=	$3.00 \times 10^{8}\ \text{m s}^{-1}$
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permittivity of free space	ε_0	=	$8.85 \times 10^{-12}\ \text{F m}^{-1}$
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elementary charge	e	=	$1.60 \times 10^{-19}\ \text{C}$
the Planck constant	h	=	$6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant	u	=	$1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron	m_e	=	$9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton	m_p	=	$1.67 \times 10^{-27}\ \text{kg}$
molar gas constant	R	=	$8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant	N_A	=	$6.02 \times 10^{23}\ \text{mol}^{-1}$
the Boltzmann constant	k	=	$1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant	G	=	$6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
acceleration of free fall	g	=	$9.81\ \text{m s}^{-2}$

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	$T/{}^\circ\text{C} + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
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	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

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

1 A small ball at the bottom of a frictionless slope is projected up the slope with speed u, as shown in Fig. 1.1.

The slope has a height of 4.0 m and makes an angle of 30° to the horizontal ground.

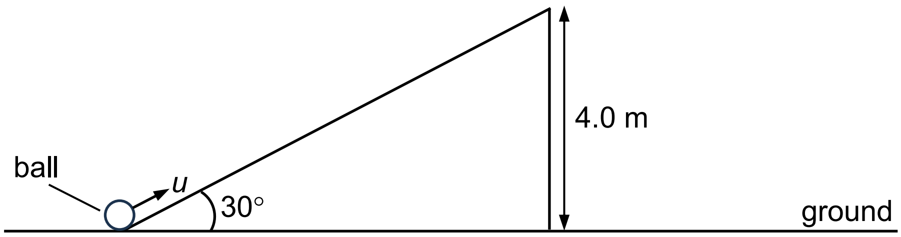

Fig. 1.1

(a) In one instance, $u = 7.0\text{ m s}^{-1}$.

(i) Calculate the maximum distance s_0 from the bottom of the slope that the ball reaches.

s_0 = ... m [2]

(ii) As the ball moves up the slope from the bottom, draw on Fig. 1.2 the variation with distance s travelled by the ball from the bottom of the slope of its

1. kinetic energy (label as E_K),

2. potential energy (label as E_P).

Potential energy at the bottom of the slope is zero.

[2]

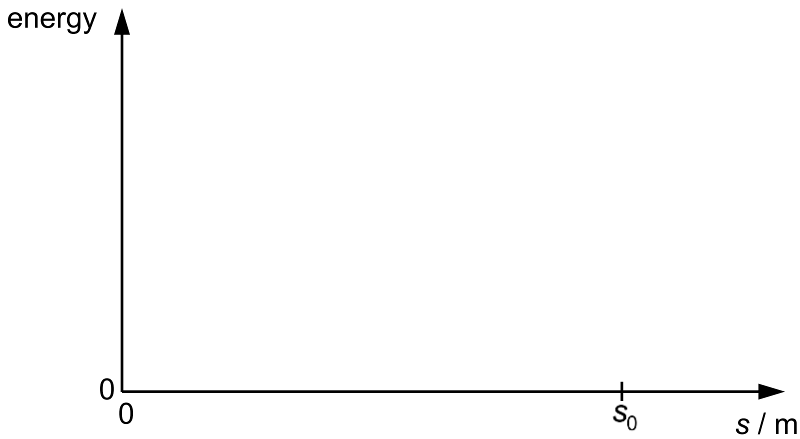

Fig. 1.2

(b) In another instance, $u = 14.0\ \text{m s}^{-1}$.

The ball travels to the top of the slope, leaves the slope and hits the ground.

(i) Show that the speed of the ball at the top of the slope is $10.8\ \text{m s}^{-1}$.

[1]

(ii) Calculate the horizontal distance travelled by the ball after it leaves the slope.

distance = ... m [3]

[Total: 8]

2 Two identical balls A and B approach each other along the same straight line on a smooth horizontal surface, as shown in Fig 2.1.

Fig. 2.1

At time $t = 0$ s, ball A moves towards ball B with a speed of 4.0 m s^{-1}, while ball B moves towards ball A with a speed of 1.0 m s^{-1}. Each ball has a mass of 0.50 kg.

At time $t = 0.50$ s, the balls undergo a head-on elastic collision and are in contact for a duration of 0.25 s.

After the collision, ball A moves with velocity v_A and ball B moves with velocity v_B.

(a) Explain whether both balls could be stationary at the same time during the collision.

....

....

....

....

.... [2]

(b) Show that v_B is 4.0 m s^{-1}.

[2]

(c) Calculate the magnitude of the average force on ball A during the collision. Explain your working.

force = ... N [3]

(d) Fig. 2.2 shows the variation with time t of the momentum p_A of ball A and momentum p_B of ball B before the collision.

On Fig. 2.2, complete the graphs for p_A and p_B from $t = 0.50$ s to $t = 1.5$ s .

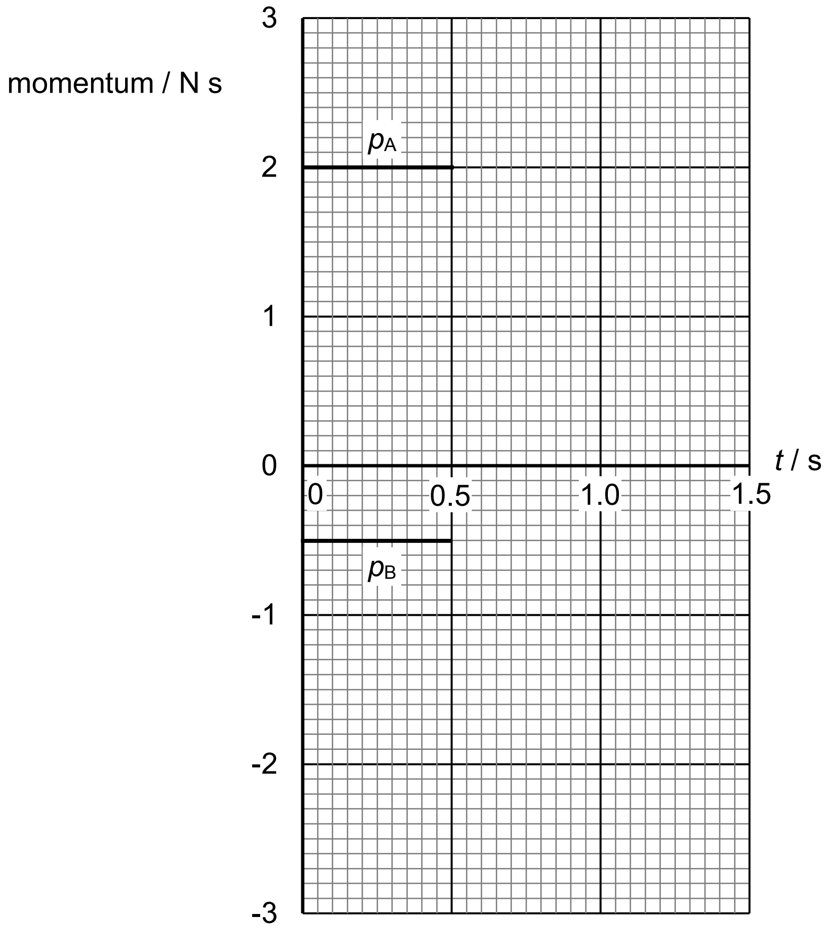

Fig. 2.2

[2]

[Total: 9]

3 A uniform circular disc of radius R and weight W is in contact with a smooth horizontal ground and the corner of a box of height $\frac{R}{2}$, as shown in Fig. 3.1.

A horizontal force F acts at the centre O of the disc to keep the disc in equilibrium.

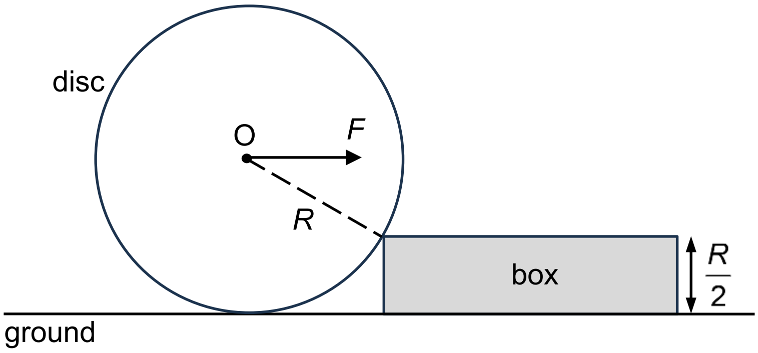

Fig. 3.1

(a) Force F is increased until the disc is just about to rotate about the corner of the box. Use the principle of moments to determine the ratio $\frac{F}{W}$. Explain your working.

$\frac{F}{W}$ = ... [3]

(b) The box is replaced with one of height R.

State and explain how the force F acting at the centre O would need to be changed for the disc to rotate about the corner of the box.

....

....

....

.... [2]

[Total: 5]

4 A ball of mass m is attached to one end of a light inextensible string of length L. The other end of the string is attached to a fixed point O.

(a) The ball is swung around in a vertical circle, as shown in Fig. 4.1. The speeds of the ball at the top and bottom of the vertical circle are v_T and v_B respectively.

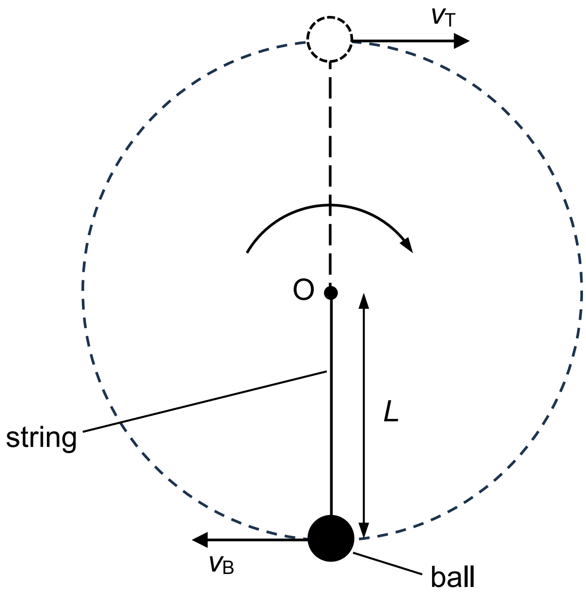

Fig. 4.1

(i) Show that for the ball to just complete the vertical circle, $v_T = \sqrt{gL}$.
Explain your working.

[2]

(ii) Explain why the ratio $\frac{v_B}{v_T}$ must be greater than 1 for the ball to complete the vertical circle.

....

....

.... [1]

(iii) A student wishes to swing the ball in a vertical circle such that $\frac{v_B}{v_T} = 3$.

With appropriate calculations, state and explain if this ratio is achievable.

....

....

.... [3]

(b) The ball is now swung in a horizontal circle around the fixed point O, as shown in Fig. 4.2.

When the ball is swinging around with angular velocity ω, the string is at an angle θ from the vertical and the tension in the string is T.

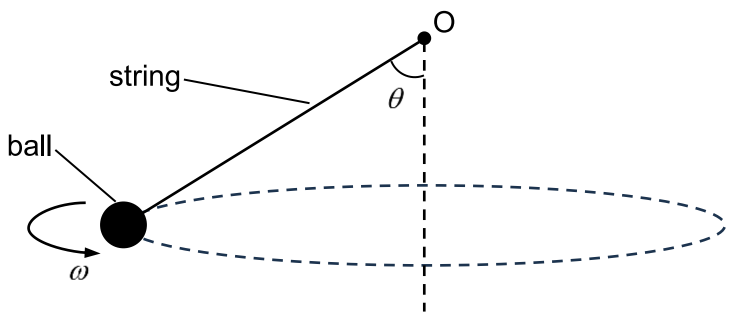

Fig. 4.2

Determine the tension in the string, in terms of T, when the angular velocity of the ball is doubled.

tension = ... [2]

[Total: 8]

5 **(a)** The value of the gravitational potential ϕ at a distance x from a point mass M is given by the expression

$$\phi = -\frac{GM}{x}$$

where G is the gravitational constant.

(i) Define *gravitational potential*.

....

....

.... [1]

(ii) Explain why gravitational potential is a negative quantity.

....

....

....

....

.... [2]

(b) A satellite is launched from the surface of the Earth.

(i) The Earth has a radius of 6400 km and a mass of 6.0×10^{24} kg. The mass of the satellite is 1600 kg.

Calculate the change in gravitational potential energy ΔE_P of the satellite as it moves from the surface of the Earth to a height of 2.1×10^{7} m above the surface of the Earth.

ΔE_P = ... J [2]

(ii) The satellite then orbits the Earth about the centre of the Earth.

1. Show that the speed v of the satellite in its orbit is given by the expression

$$v = \sqrt{\frac{GM_E}{r}}$$

where M_E is the mass of the Earth and r is the radius of orbit.

Explain your working.

[2]

2. While in orbit, the thruster of the satellite is fired. The satellite is given a boost such that it has just enough energy to travel out into space.

Determine the ratio

$$\frac{\text{kinetic energy of the satellite just after the boost}}{\text{kinetic energy of the satellite just before the boost}}.$$

ratio = ... [3]

[Total: 10]

6 A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected to resistors P and Q, a light dependent resistor (LDR) and ammeters A_1 and A_2, as shown in Fig. 6.1.

The resistance of P is $4.0\ \text{k}\Omega$ and the resistance of Q is $6.0\ \text{k}\Omega$.

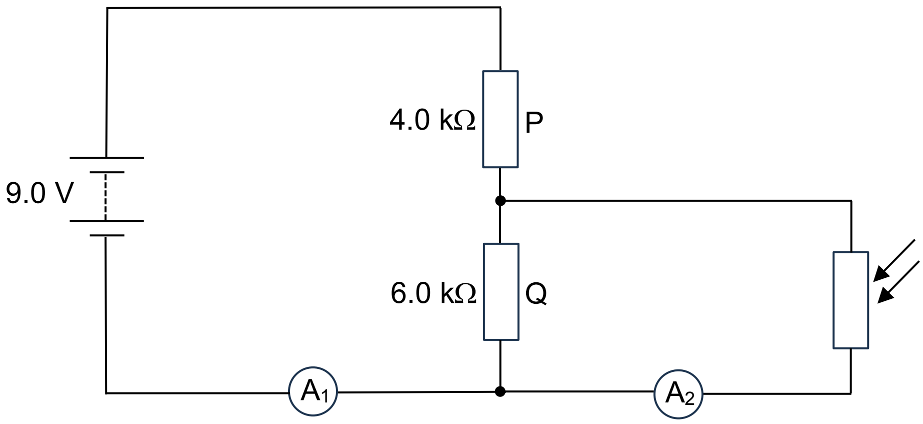

Fig. 6.1

(a) The intensity of the light incident on the LDR is such that the resistance of the LDR is $8.0\ \text{k}\Omega$.

Determine the current reading on

(i) ammeter A_1,

current = ... A [2]

(ii) ammeter A_2.

current = ... A [2]

(b) The intensity of the light incident on the LDR is lowered.

Explain the following changes:

(i) The potential difference across Q increases.

....

....

....

....

.... [2]

(ii) The current reading on ammeter A_2 decreases.

....

....

....

....

.... [2]

[Total: 8]

7 Hydrogen is the most abundant material in the universe and the most basic nuclear fusion reaction is the fusion of two hydrogen nuclei ($^{1}_{1}H$).

(a) State what is meant by *nuclear fusion*.

....

....

.... [1]

(b) Given that the radius of a hydrogen nucleus is 1.2×10^{-15} m, show that the minimum kinetic energy of each hydrogen nucleus needed to trigger a $^{1}_{1}H$ - $^{1}_{1}H$ fusion reaction is 0.30 MeV. Assume fusion occurs when the two nuclei touch each other.

[2]

(c) $^{1}_{1}H$ - $^{1}_{1}H$ fusion occurs naturally in the Sun and in most other stars because there is sufficient thermal energy to trigger the reaction.

By assuming that hydrogen behaves as an ideal gas, estimate the temperature of such an environment.

temperature = ... K [2]

(d) There are two possible outcomes of such a fusion reaction. In reaction (1), a helium isotope ${}^{2}_{2}\text{He}$ is formed. In reaction (2) a deuteron ${}^{2}_{1}\text{H}$ and an unknown elementary particle X is formed.

reaction (1): $${}^{1}_{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{2}_{2}\text{He}$$

reaction (2): $${}^{1}_{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{2}_{1}\text{H} + \text{X}$$

(i) State the nuclear notation for X.

$${}^{\boxed{}}_{\boxed{}}\text{X}$$

[1]

(ii) Deuteron ${}^{2}_{1}\text{H}$ is readily found on Earth, but not the helium isotope ${}^{2}_{2}\text{He}$.
Suggest a possible reason for this observation and hence deduce which reaction releases more energy.

....

....

.... [1]

(e) Data for the nuclei in reaction (2) are given in Fig. 7.1.

nucleus	mass / u
${}^{1}_{1}\text{H}$	1.007825
${}^{2}_{1}\text{H}$	2.014102
X	0.000549

Fig. 7.1

Calculate the energy released in reaction (2).

energy = ... J [2]

(f) Suggest one significant advantage in generating electrical power by a fission reaction compared to a fusion reaction.

....

....

.... [1]

[Total: 10]

8 Read the passage below and answer the questions that follow.

The Large Hadron Collider (LHC) is the world's largest and most powerful particle accelerator. It first started up on 10 September 2008 and is the crown jewel within the accelerator complex of the European Council for Nuclear Research (CERN).

Spanning across the Switzerland-France border, the LHC is a large horizontal ring in which high-energy particle beams, most commonly proton beams, are accelerated to speeds close to the speed of light in opposite directions. These proton beams circulate around the ring more than 11000 times a second as they are made to collide multiple times at different interaction points where the beams cross each other. By studying the fundamental particles produced in the aftermath of these proton-proton collisions, scientists hope to gain new insights and answers to some of the most important unsolved mysteries in Physics.

Inside the accelerator, the protons travel around the ring for hours along two separate beam pipes, both of which are kept at an ultrahigh vacuum. As the protons circulate around the LHC, they are repeatedly accelerated by strong electric fields along a short linear accelerator within the ring.

The protons are guided around the accelerator ring along the beam pipes by strong magnetic fields generated by thousands of electromagnets of different types and sizes, all of which need to be constantly kept at extremely low temperatures of about 1.9 K. This is why the LHC also houses the world's largest cryogenic system, using about 10000 tonnes of liquid nitrogen and 130 tonnes of liquid helium to maintain the operation of the magnets. (1 tonne = 1000 kg)

The most common type of these electromagnets is called dipole magnets, which help bend the protons' trajectories so that they travel successfully along the curved beam pipes. These dipole magnets consist of many coils of electric cables placed next to and at many different sections along the beam pipe, each carrying a large electric current. The dipole magnets are contained and fastened together with strong non-magnetic stainless-steel collars.

Fig. 8.1 shows the cross-section of one of the dipole magnet setups at a section of a beam pipe of the LHC. The large number of electric cables are grouped into two double-layered regions around the beam pipe, labelled as region 1 and region 2 in Fig. 8.1. These electric cables are arranged parallel to the beam pipe such that when a current is travelling along these cables, the magnetic flux density produced by these cables at the centre of the beam pipe helps bend the protons' trajectories so that they can travel along the curved beam pipe.

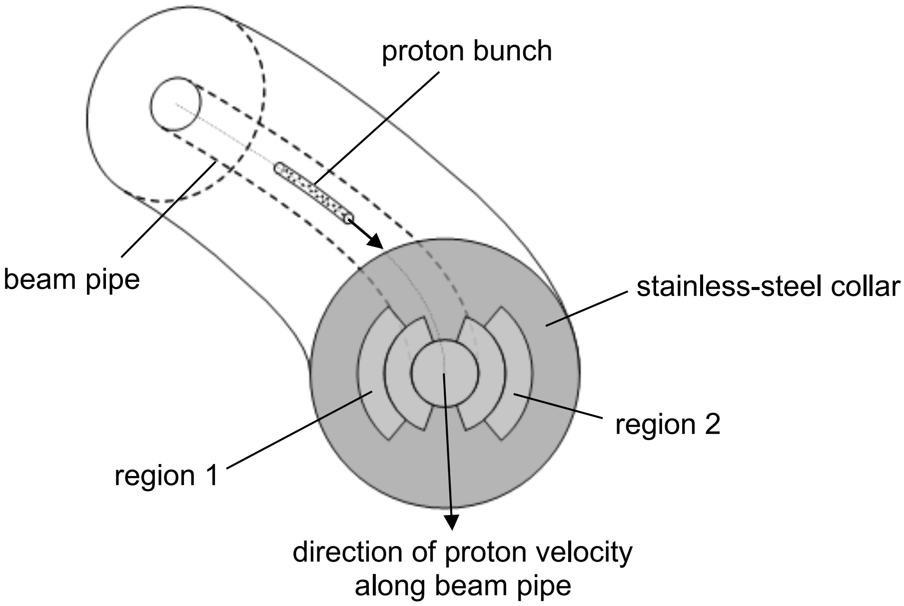

Fig. 8.1
(The electric cables parallel to the beam pipe are not shown for clarity.)

An important parameter in determining the functionality of a particle accelerator like the LHC is the beam current, which is defined as the average rate of flow of charge in the beam pipe. However, during normal operation, the protons do not travel in the beam pipe as a continuous beam. Instead, in each proton beam, the protons travel in groups called "bunches", which are approximately cylindrical in shape as shown in Fig. 8.1.

The LHC is built underground with a mean depth of 100 m for various reasons, including minimising the damage caused to the landscape and environment on the surface. In addition, protons travelling around the curved beam pipes accelerate to produce synchrotron radiation in the form of ultraviolet and X-ray photons, and interactions between the protons and the nuclei of any atoms around the beams in the beam pipes also produce ionising radiation. The Earth's crust therefore also provides natural shielding from these sources of radiation for anyone living on the surface near the LHC.

Table 8.1 shows some important data and parameters of the LHC under normal operating conditions.

Table 8.1

total circumference of LHC ring	26659 m
diameter of beam pipe	56 mm
proton energy	7.0 TeV
current in each cable of a dipole magnet setup	11850 A
length of a dipole magnet setup	14.3 m
peak dipole magnetic flux density at centre of beam pipe	8.33 T
beam current	0.58 A
number of bunches per proton beam	2808
length of one bunch	7.48 cm
cross-sectional area of one bunch	1.0 mm^2

(a) Suggest why the inside of the beam pipe needs to be maintained at an ultrahigh vacuum while the LHC is being operated.

....

....

.... [1]

(b) State and explain if an accelerator like the LHC can be used to study neutron-neutron collisions.

....

....

.... [1]

(c) **(i)** The relationship between the proton energy E and its speed v is given by

$$E = (\gamma - 1)m_0c^2$$

where $\gamma = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$, m_0 is the mass of a proton, and c is the speed of light in vacuum.

Show that the protons in the LHC beam pipe travel at a speed of 0.999999991 c.

[1]

(ii) Hence, by considering the beam current, show that the number of protons in each bunch within the proton beam is 1.15×10^{11}.

[3]

(d) The large number of cables in region 1 and region 2 in the dipole magnet setup in Fig. 8.1, can be modelled by combining the cables in each region into a single large cable carrying the total current in that region. The length of each single large cable is 14.3 m.

Fig. 8.2 shows a close-up of the cross section of the dipole magnet setup around the beam pipe in Fig. 8.1, where regions 1 and 2 are represented by combined cables 1 and 2 respectively. Each combined cable carries electric current of the same magnitude.

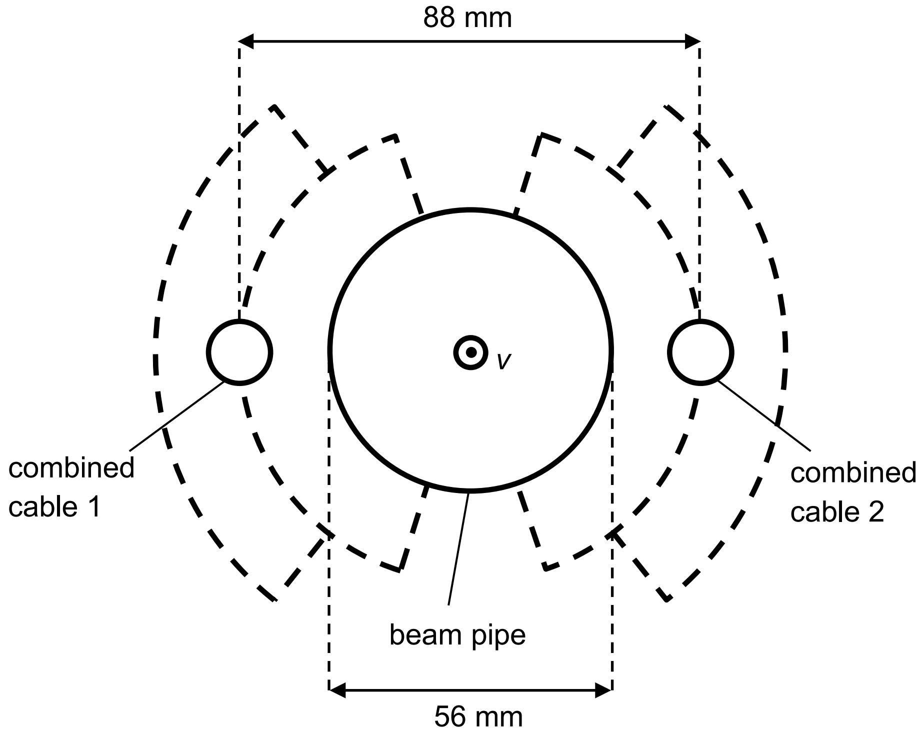

Fig. 8.2

In this model of the dipole magnet setup, the distance between the combined cables is 88 mm, while the diameter of the beam pipe is 56 mm.

The proton velocity v in the middle of the beam pipe is pointing out of the page, as shown in Fig. 8.2. The centre of the circular path of the proton's trajectory is on the side of combined cable 1.

(i) On Fig. 8.2, using appropriate symbols and labels, indicate the direction of

1. the magnetic flux density B at the centre of the beam pipe,

2. the currents I_1 and I_2 in the combined cables 1 and 2 respectively.

[2]

(ii) **1.** Determine the current required in each combined cable to produce the peak dipole magnetic flux density at the centre of the beam pipe.

current = ... A [2]

2. Hence, determine the number of cables in each region.

number of cables = ... [1]

3. Suggest a reason why the dipole magnets need to be contained and fastened together with strong stainless-steel collars.

Support your suggestion with appropriate calculations.

....

....

.... [3]

(e) Besides dipole magnets, another type of electromagnet used at the LHC are quadrupole magnets.

Quadrupole magnets help "squeeze" the travelling protons within each bunch closer together so that the protons stay travelling along the central axis of the beam pipe in a tightly focused beam. They do so by accounting for the electrostatic repulsion between the protons within each bunch.

(i) By approximating the average volume occupied by a proton in each bunch to be the volume of a cube, estimate the magnitude of the average repulsive force between two adjacent protons in a bunch.

force = ... N [2]

(ii) The quadrupole magnets also help to keep the protons in the proton beam on their intended path by accounting for the protons falling downwards due to their weight.

Determine the number of rounds a proton will be able to travel around the LHC accelerator ring before falling to the bottom of the beam pipe due to gravity, if there were no quadrupole magnets.

Assume that the acceleration due to gravity in the pipe is 9.81 m s^{-2}.

number of rounds = ... [2]

(iii) Suggest another reason why quadrupole magnets are needed to correct the proton's trajectory in the beam pipe.

....

....

....

....

.... [2]

(f) The International Linear Collider (ILC) is a proposed particle accelerator to be built in the future to further study the particles that have been discovered at the LHC.

Unlike the LHC, which is a circular particle accelerator, the ILC is a linear particle accelerator, in which two beams of particles travel down straight beam pipes and are made to collide with each other in the middle.

Suggest an advantage and a disadvantage of linear accelerators compared to circular accelerators.

advantage: ....

....

....

....

....

disadvantage: ....

....

....

....

.... [2]

[Total: 22]

End of Paper 2

Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2024 Preliminary Examination

PHYSICS **9749/03**
Higher 2

18 September 2024
Paper 3 Longer Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use 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 and **circle the question number** on the cover pages.

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.

***This booklet only contains Section A.**

For Examiner's Use		
Section A	1	/ 10
	2	/ 11
	3	/ 12
	4	/ 10
	5	/ 6
	6	/ 5
	7	/ 6
Section B (circle 1 question)	8	/ 20
	9	/ 20
Deduction		
Total		/ 80

This document consists of **20** printed pages.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/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	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin\omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\ln 2/t_{1/2}$

Section A

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

1 **(a)** State what is meant by the *internal energy* of an *ideal gas*.

....

....

....

....

.... [2]

(b) A fixed mass of an ideal monatomic gas has a volume of 2.0×10^{-2} m^3 at a pressure 1.0×10^5 Pa .

(i) To determine the specific heat capacity of the gas at constant volume, the gas is heated so that its pressure increases to 1.5×10^5 Pa without any change in volume.

1. Show that the heat supplied to the gas is 1500 J.

[1]

2. Determine the increase in temperature of the gas if the average translational kinetic energy of a gas molecule is 6.2×10^{-21} J just before the gas is heated.

increase in temperature = ... °C [3]

(ii) To determine the specific heat capacity of the gas at constant pressure, the gas is heated from its initial state without any change in pressure.

State the first law of thermodynamics and use it to explain why the specific heat capacity of the ideal gas determined at constant volume is different to the specific heat capacity when determined at constant pressure.

....

....

....

....

....

....

....

.... [4]

[Total: 10]

2 A light spring of force constant k hangs vertically from a fixed point. A block of mass m is attached to the free end of the spring, as shown in Fig. 2.1.

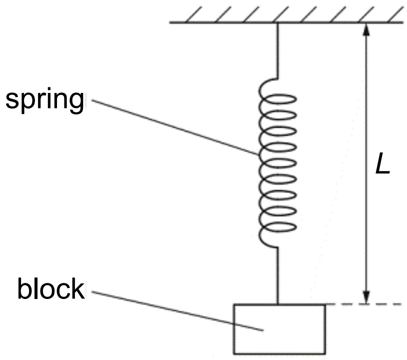

Fig. 2.1

The block is displaced downwards from its equilibrium position and then released at time $t = 0$ s.

(a) The acceleration a of the block is related to its displacement x from the equilibrium position by the equation

$$a = -\frac{k}{m}x.$$

Explain why the equation leads to the conclusion that the block is performing simple harmonic motion.

....

....

....

....

.... [2]

(b) The variation with time t of the length L of the spring is shown in Fig. 2.2.

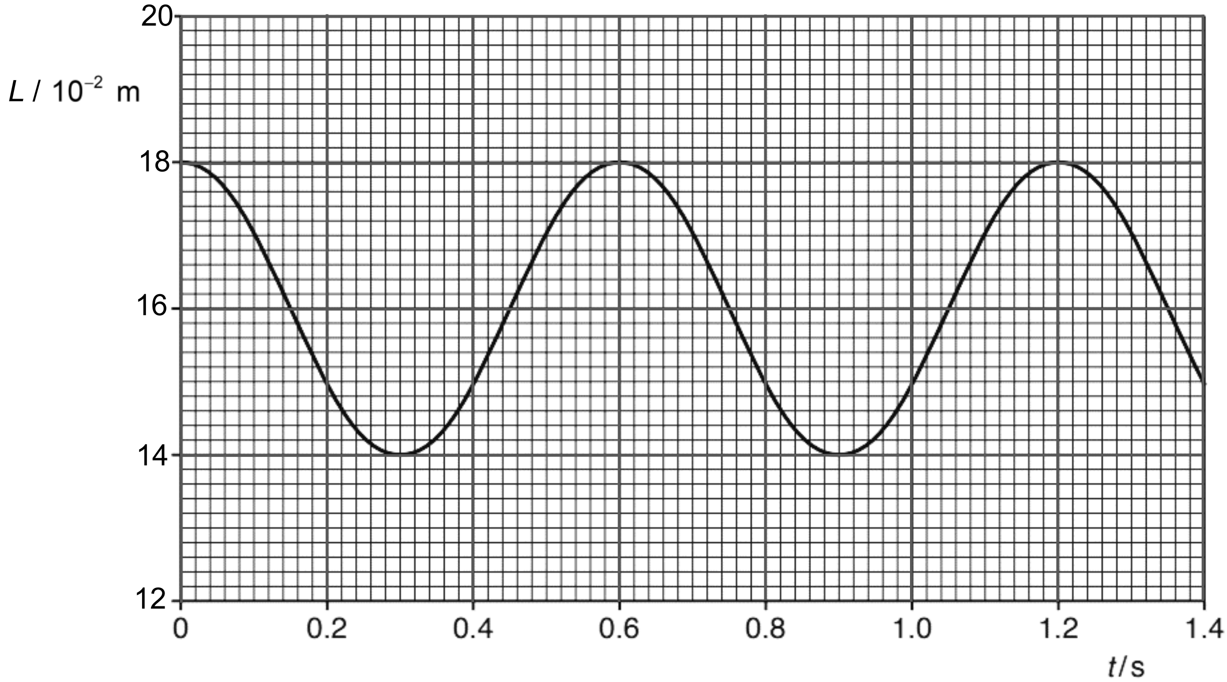

Fig. 2.2

(i) Determine the maximum speed of the block.

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

(ii) On Fig. 2.3, show the variation with time t of the velocity v of the block from $t = 0$ s to $t = 1.4$ s.

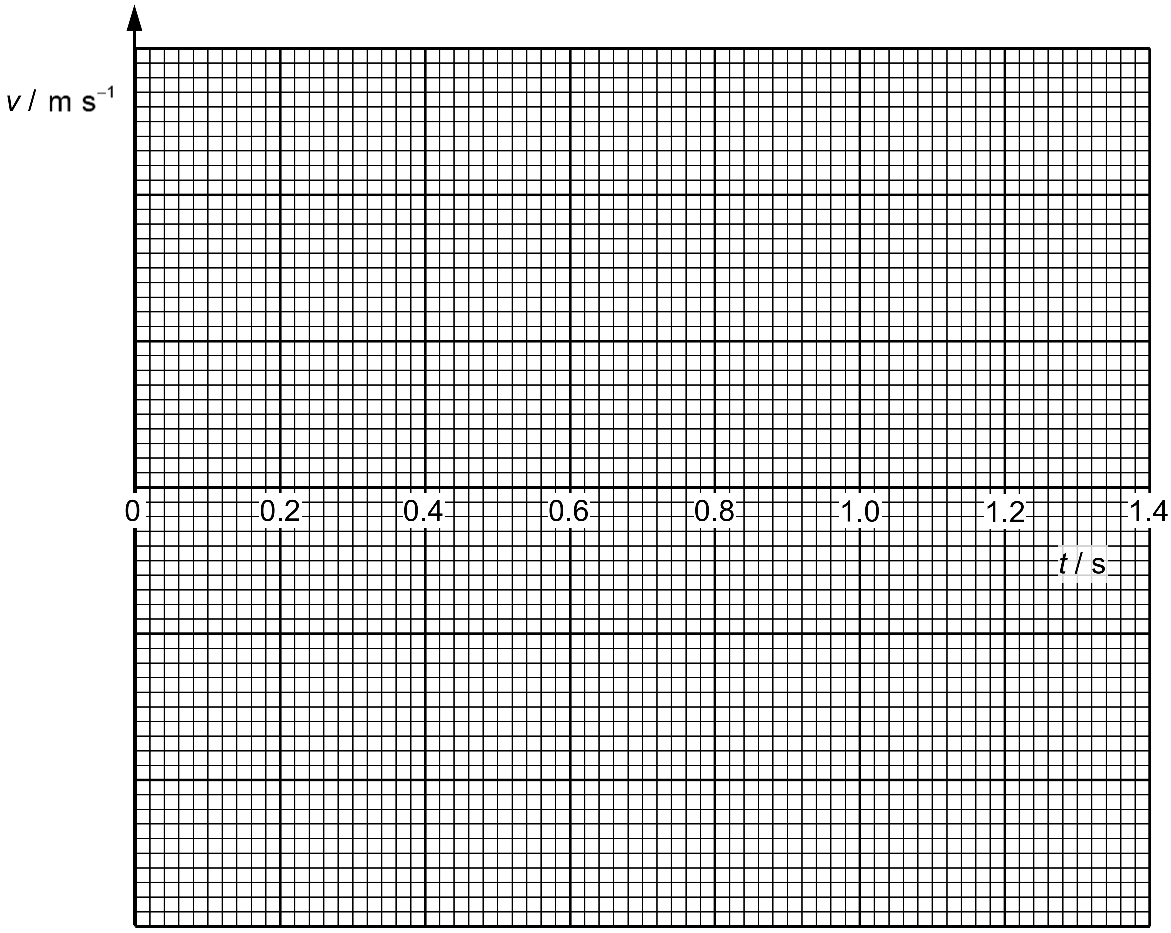

Fig. 2.3

[2]

(iii) Determine a value of L at which the potential energy and kinetic energy of the oscillating system are equal.

The total potential energy of the oscillating system at equilibrium is taken to be zero.

L = ... cm [2]

(c) The same block is suspended from two springs as shown in Fig. 2.4. Both springs are identical to that used in Fig. 2.1.

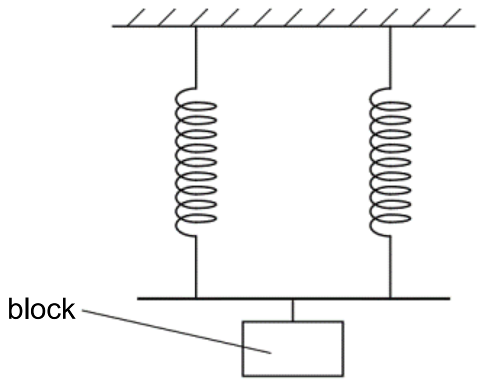

Fig. 2.4

The block is pulled down a small distance and released so that it oscillates.

By considering the extension at equilibrium of the spring combination in Fig. 2.4, state and explain how the period of these oscillations compares with the period of oscillations in **(a)**.

....

....

....

....

....

.... [3]

[Total: 11]

3 Fig. 3.1 shows, at time t_0 , the positions x of the air particles where a progressive sound wave passes through the air towards a reflector.

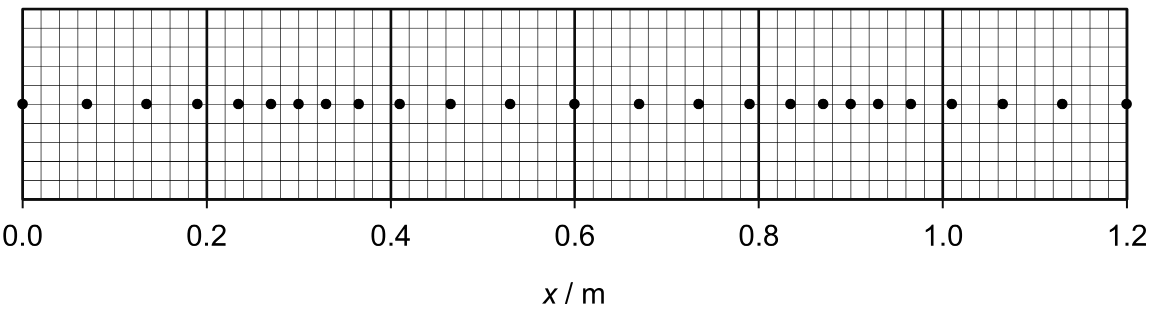

Fig. 3.1

Fig. 3.2 shows, at a later time t_1, the positions x of the same air particles when the reflected sound wave is superposed with the original sound wave to form a stationary wave.

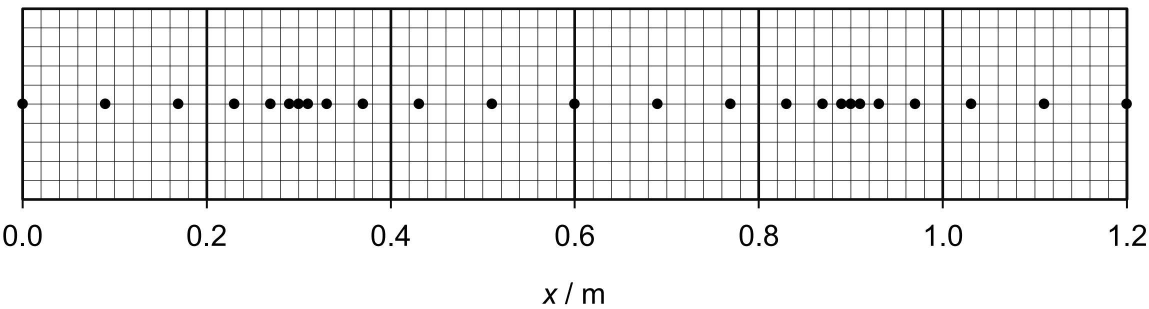

Fig. 3.2

(a) Distinguish between progressive and stationary waves in terms of the amplitudes and the phases of oscillations of the particles.

amplitudes: ....

....

....

....

phases: ....

....

....

.... [2]

(b) Use Fig. 3.1 to deduce, with an explanation,

(i) the wavelength of the sound wave,

wavelength = ... m

....

....

.... [1]

(ii) the amplitude of the oscillations of the particles.

amplitude = ... m

....

....

....

.... [2]

(c) **(i)** On Fig. 3.2, indicate all the positions of the displacement nodes (label as N) and displacement antinodes (label as A).

[1]

(ii) By considering the positions of the particles in Fig. 3.2, draw on Fig. 3.3, the variation with position x of the pressure p of the air when a stationary wave is set up

1. at time t_1 (label as Y), [1]

2. at time $t_1 + \frac{T}{8}$ (label as Z), where T is the period of the wave. [1]

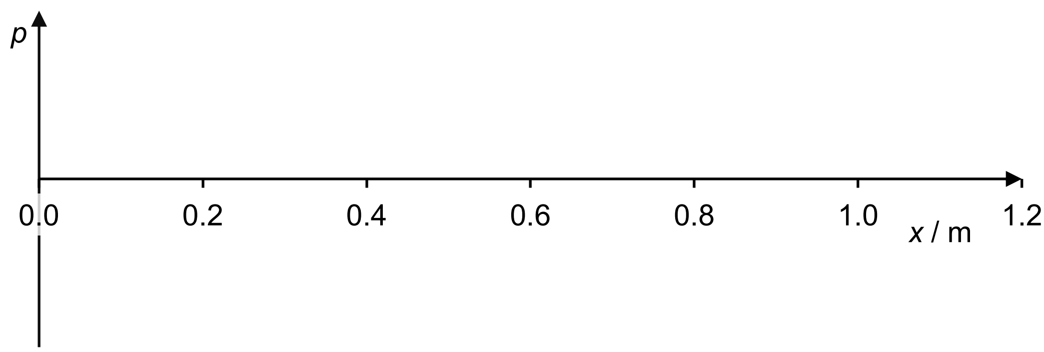

Fig. 3.3

(d) The sound wave represented in Fig. 3.1 is now continuously projected along a vertical tube that is initially fully immersed in water.

As the tube is raised vertically, it was found that the first loud note was heard when the air column has a length of 14.4 cm.

Determine

(i) the end correction of the tube,

end correction = ... m [2]

(ii) the length of the air column when the next loud note is heard.

length = ... m [2]

[Total: 12]

4 **(a)** Two charged particles, A and B, are isolated in space and separated by a distance *x*, as shown in Fig. 4.1.

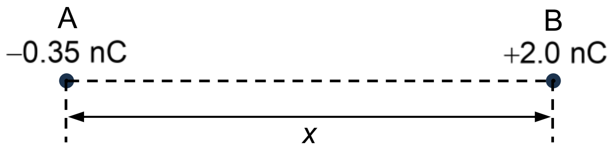

Fig. 4.1

Particle A has a charge of −0.35 nC and particle B has a charge of +2.0 nC .

(i) Explain whether the electric field strength is zero at any point along the straight line between the two charged particles.

....

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....

.... [1]

(ii) Explain whether the electric potential is zero at any point along the straight line between the two charged particles.

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....

.... [1]

(b) Two long parallel metal plates, X and Y, are separated by a distance 3.6 cm in a vacuum. Plate X is at potential *V* and plate Y is earthed. The potential difference between the plates gives rise to a uniform electric field in the region between the plates.

A particle of charge -3.2×10^{-19} C and mass 6.6×10^{-27} kg is projected into the uniform electric field midway between plates. It enters the electric field with speed 4.1×10^{5} m s^{-1} at an angle 32° from the vertical and hits plate Y at point P with speed 6.5×10^{5} m s^{-1}. Point P is a vertical distance *d* from the top of the plate.

Fig. 4.2 shows the path of the particle. Ignore gravitational effects.

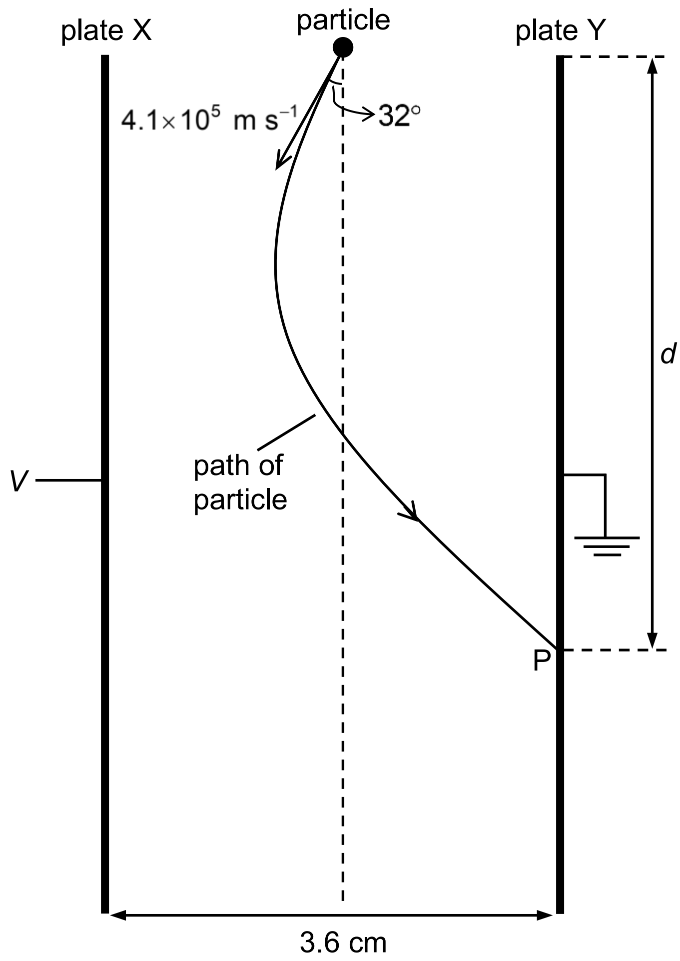

Fig. 4.2

Determine

(i) the potential V,

$V =$ .... V [3]

(ii) the magnitude of the acceleration a of the particle,

$a =$ .... $m\ s^{-2}$ [2]

(iii) the distance d.

$d =$ .... m [3]

[Total: 10]

5 A model for a braking system is shown in Fig. 5.1. A large thin horizontal aluminium disc spinning about a vertical axle through its centre slows down as the poles of two magnets are brought near to it.

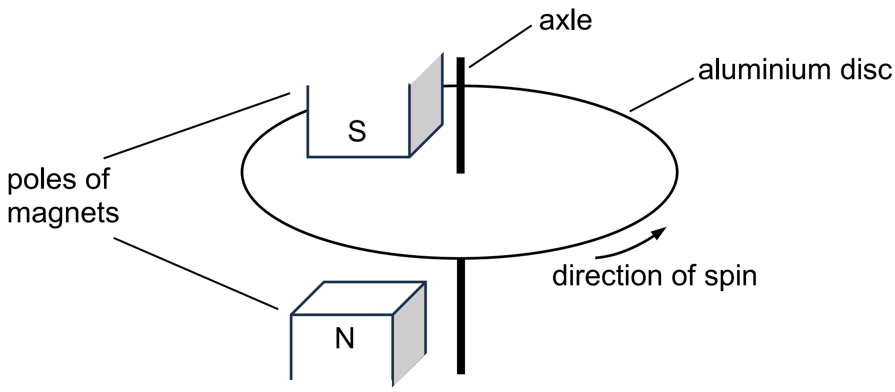

Fig. 5.1

(a) Explain how the model of the braking system shows that Lenz's law is an example of the law of conservation of energy.

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.... [2]

(b) Fig. 5.2 shows the top view of the disc.

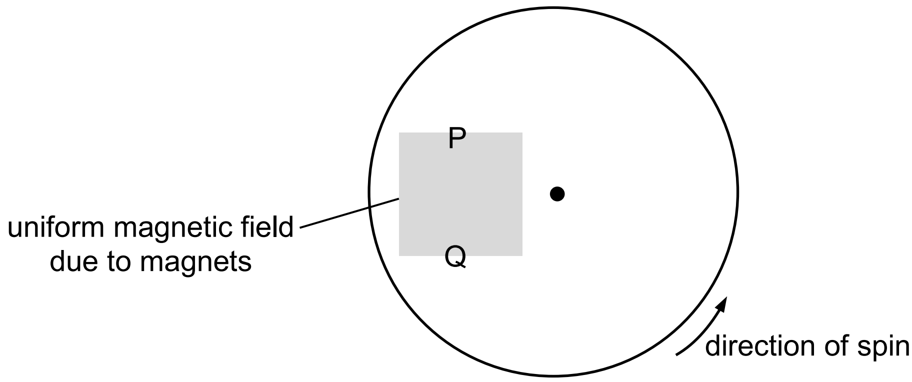

Fig. 5.2

On Fig. 5.2, draw the directions of the eddy currents induced at regions P and Q of the disc.

[1]

(c) Explain why the angular velocity of the disc does not decrease linearly with time.

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....

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....

.... [3]

[Total: 6]

6 **(a)** By reference to heating effect, state what is meant by the *root-mean-square* value of an alternating current.

....

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.... [1]

(b) An alternating power supply is connected to a switch S, an ideal diode and two identical resistors R_1 and R_2, as shown in Fig. 6.1. Each resistor has a resistance of 18 Ω.

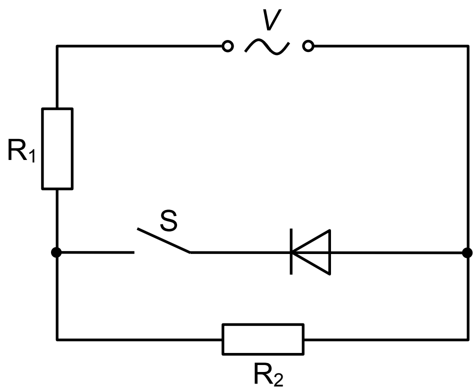

Fig. 6.1

The variation with time *t* of the potential difference *V* of the alternating supply is given by the expression

$$V = 24 \sin 314\, t$$

where *V* is in volts and *t* is in seconds.

(i) Switch S is closed.

On Fig. 6.2, show the variation with time t of the potential difference V_1 across R_1 for two periods of the alternating voltage.

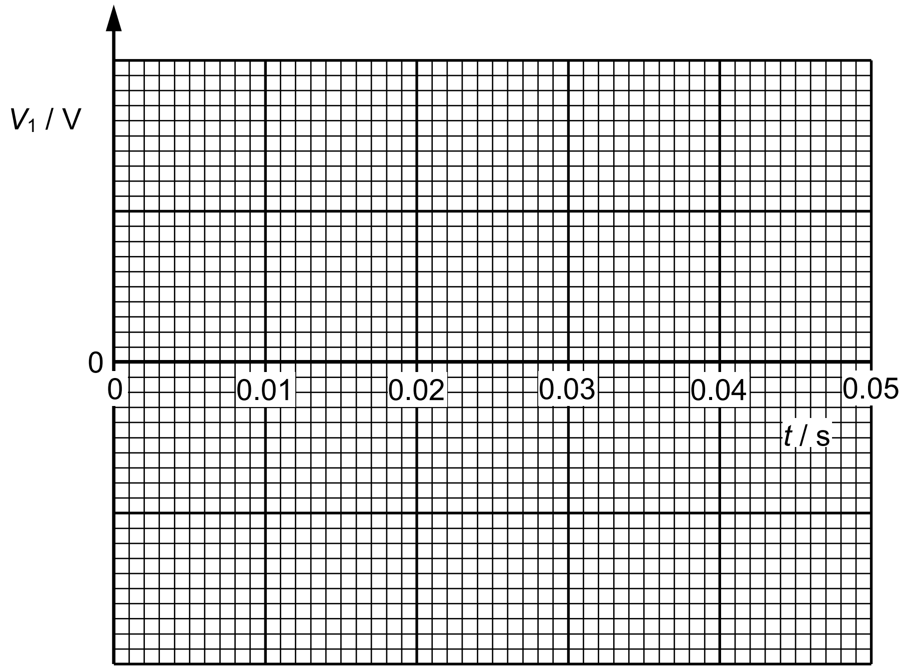

Fig. 6.2

[2]

(ii) Switch S is opened.

On Fig. 6.3, draw the variation with time t of the power P_1 transferred in R_1 for two periods of the alternating voltage.

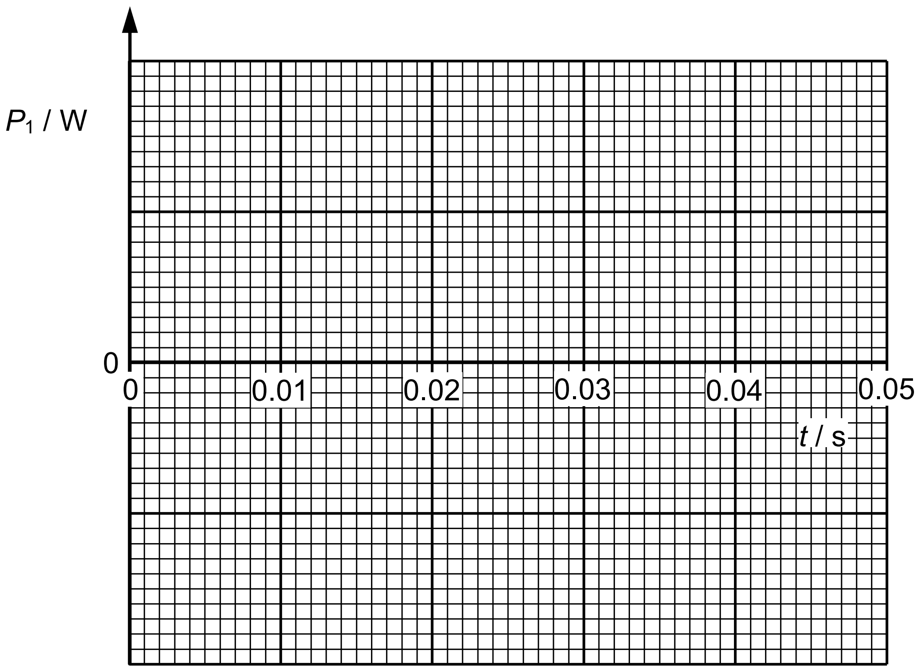

Fig. 6.3

[2]

[Total: 5]

7 **(a)** Explain how emission line spectra provide evidence for discrete electron energy levels in isolated atoms.

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.... [2]

(b) X-rays are produced when high speed electrons collide with a metal target.

Fig. 7.1 shows how the intensity of the X-rays varies with their wavelength.

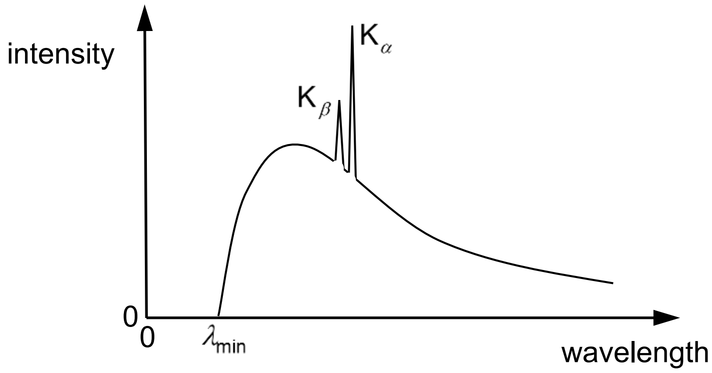

Fig. 7.1

Explain the origins of the following features in Fig. 7.1:

(i) The wavelength of the characteristic line K_α is greater than the wavelength of K_β.

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.... [2]

(ii) There is a minimum wavelength λ_{min} for the X-rays.

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.... [2]

[Total: 6]

End of Paper 3 Section A

Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2024 Preliminary Examination

PHYSICS **9749/03**
Higher 2

18 September 2024
Paper 3 Longer Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use 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 and **circle the question number** on the cover pages.

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 booklet only contains Section B.**

For Examiner's Use		
Section B (circle 1 question)	8	/ 20
	9	/ 20
Deduction		

This document consists of **12** printed pages.

Section B

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

8 A research facility located in the northern hemisphere is used to study the effects of the solar wind from the Sun. At its location, the Earth's magnetic field is found to have a magnetic flux density of 5.2×10^{-5} T at an angle of $70°$ below the horizontal.

(a) A vertical window at the research facility has an aluminium frame ABCD with length 80 cm and width 55 cm, as shown in Fig. 8.1.

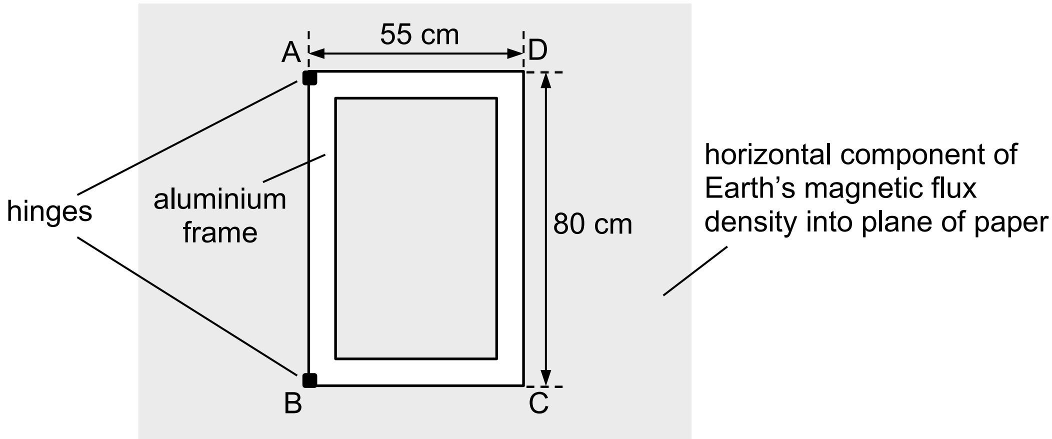

Fig. 8.1

The window is hinged along the side AB. When the window is closed as in Fig. 8.1, the horizontal component of the Earth's magnetic flux density is directed normally into the plane of the window.

(i) Calculate the magnetic flux through the window when it is closed.

magnetic flux = ... Wb [2]

(ii) The window is opened by pushing it into the plane of the paper in a time of 0.30 s. When fully opened, the plane of the window is parallel to the horizontal component of the Earth's magnetic flux density.

During the opening of the window,

1. use the laws of electromagnetic induction to explain why there is a current induced in the aluminium frame,

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.... [3]

2. determine the change in the magnetic flux through the window,

magnetic flux = ... Wb [1]

3. calculate the magnitude of the average e.m.f. induced in side CD of the frame.

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

(b) An electron and an alpha particle from the solar wind enter a region of uniform magnetic field. Both particles are travelling along the same path with the same speed just before they enter the uniform magnetic field, as shown in Fig. 8.2.

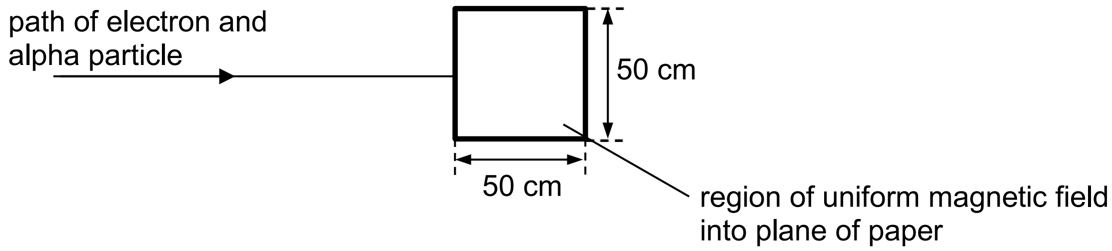

Fig. 8.2

The direction of the magnetic field is into the plane of the paper.

The particles enter the region of the magnetic field at right angles to the edge of the region. Both particles follow circular paths in the magnetic field.

(i) Explain why the charged particles follow circular paths in the magnetic field.

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.... [2]

(ii) Show that the radius r_α of the circular path of the alpha particle is related to the radius r_e of the circular path of the electron by the equation

$$r_\alpha = 3.6 \times 10^3 r_e .$$

Explain your working.

[2]

(iii) The radius of the circular path of the electron is observed to be about 7 mm.

On Fig. 8.2, draw a possible path for the alpha particle as it passes through and beyond the region of the magnetic field.

[1]

(iv) The uniform magnetic field in Fig. 8.2 is now replaced with a varying magnetic field. The variation with time *t* of the magnetic flux density *B* of this new magnetic field is shown in Fig. 8.3.

Positive values of *B* indicate that the magnetic field is directed into the plane of the paper.

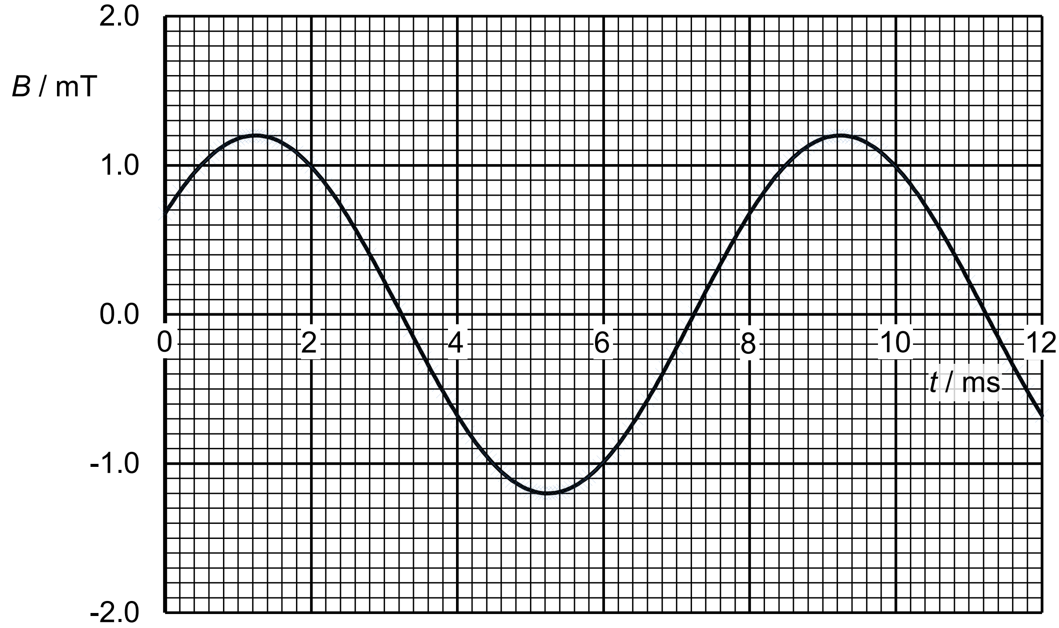

Fig. 8.3

Another electron travelling perpendicularly to the magnetic field and at a speed of 1.2×10^{6} m s^{-1} enters the centre of the magnetic field at time $t = 0$ ms.

From Fig. 8.3, at $t = 0$ ms, $B = 0.70$ mT.

1. Show that the radius of curvature of the electron's path is 9.8 mm at $B = 0.70$ mT.

[1]

2. Calculate the period of the electron's motion at $B = 0.70$ mT.

T = ... s [2]

3. Describe the path of the electron in the magnetic field for the first 4.0 ms, assuming it stays in the magnetic field for the whole of this duration.

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.... [3]

4. In reality, the electron leaves the magnetic field before 4.0 ms.

Without any calculations, state a possible time when this occurs.

Explain your answer.

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.... [1]

[Total: 20]

9 **(a)** Photoelectrons are emitted with insignificant time lag when electromagnetic radiation of a certain frequency is incident on a metal plate.

State and explain one other observation from the photoelectric effect that provides evidence for the particulate nature of electromagnetic radiation.

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.... [4]

(b) Two parallel zinc plates placed a distance d apart are used to investigate the photoelectric effect, as shown in Fig. 9.1. Zinc has a work function of 4.33 eV.

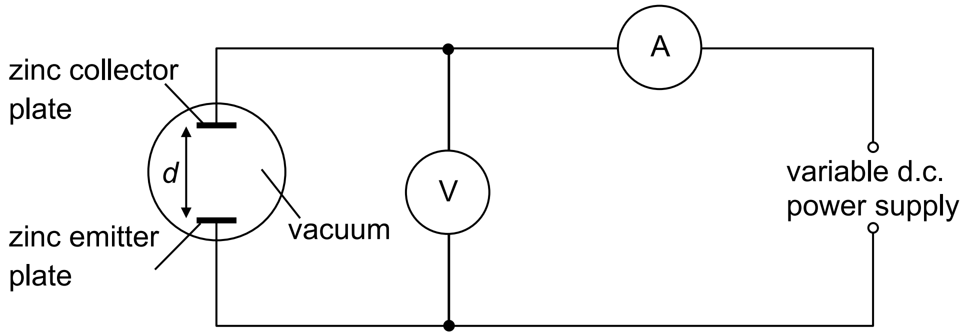

Fig. 9.1

Electromagnetic radiation of wavelength 210 nm is incident on the zinc emitter plate. The potential of the zinc collector plate is varied from –3.0 V to +3.0 V with respect to the zinc emitter plate.

The variation of the current I with the potential difference V is shown in Fig. 9.2.

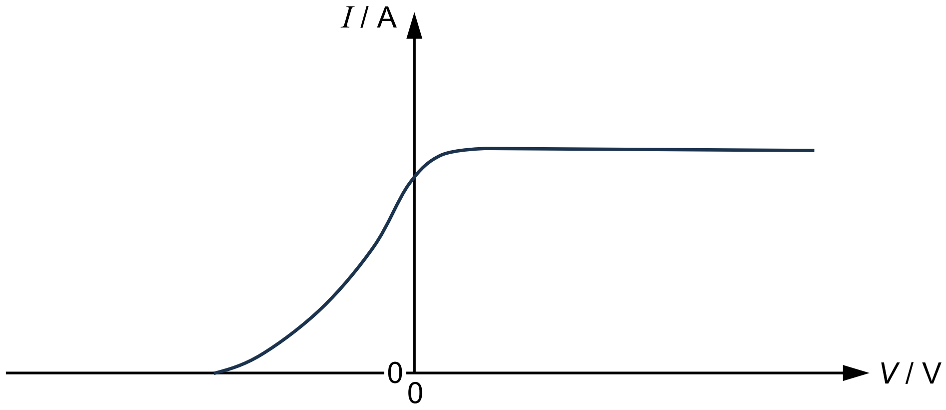

Fig. 9.2

(i) Calculate the threshold wavelength for the zinc plate.

wavelength = ... nm [2]

(ii) Calculate the maximum speed of the emitted photoelectrons.

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

(iii) Photoelectrons in **(b)** are emitted perpendicularly to the zinc emitter plate.

Explain why the subsequent motion of the emitted photoelectrons is different when $V = 0$ V and $V = +3.0$ V .

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.... [3]

(iv) On Fig 9.2, draw the variation of I with V if the zinc emitter plate is now illuminated with radiation of a shorter wavelength but the same intensity as in **(b)**.

[2]

(c) Electrons are accelerated in a vacuum before passing through a graphite film, as shown in Fig. 9.3. The electrons are then incident on a fluorescent screen.

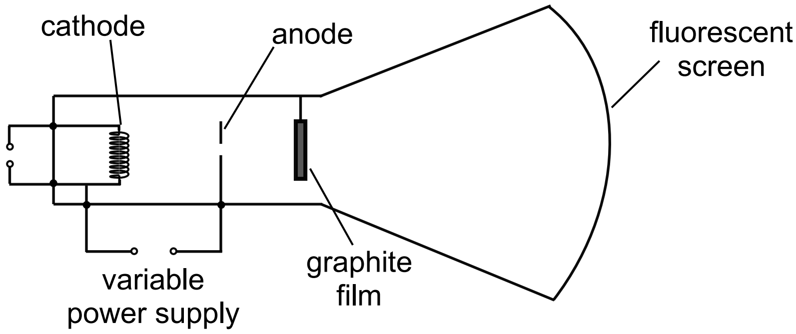

Fig 9.3

Concentric rings of light are observed on the screen.

(i) Explain how the observation of the concentric rings of light provides evidence for the wave nature of electrons.

....

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....

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.... [2]

(ii) The electrons are accelerated from rest through a potential difference of 5.0 kV.

Calculate the de Broglie wavelength of the accelerated electrons.

wavelength = ... m [3]

(iii) Optical and electron microscopy techniques are widely utilised for imaging and analysing microscopic structures.

With reference to **(c)(ii)**, state and explain an advantage of an electron microscope compared to an optical microscope.

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.... [2]

[Total: 20]

End of Paper 3 Section B

Centre Number	Class Index Number	Name	Class
S3016			

RAFFLES INSTITUTION

2024 Preliminary Examination

PHYSICS	**9749/04**
Higher 2	**12 August 2024**
Paper 4 Practical	**2 hours 30 minutes**

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces provided at the top of this page.

Write in dark blue or black pen 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.

Candidates answer on the Question Paper.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and maximum of one hour for Question 3. You are advised to spend approximately 30 minutes for 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 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	/ 12
2	/ 10
3	/ 22
4	/ 11
Total	/ 55

1 In this experiment, you will investigate the force required to lift different masses.

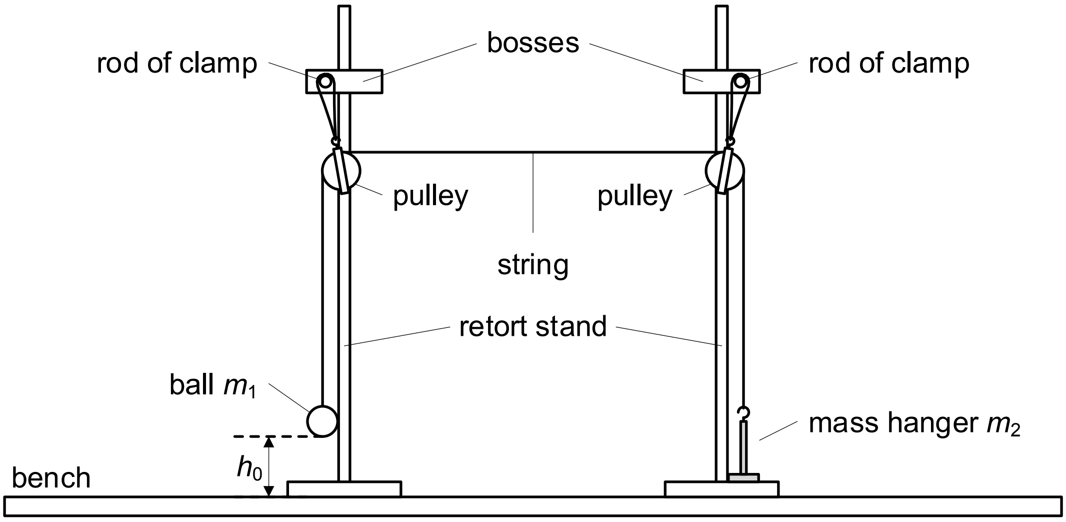

Fig. 1.1

(a) Set up the apparatus as shown in Fig. 1.1. Hang the pulleys to the rods of the clamps. The top of the pulleys should be approximately 42 cm above the bench.

Pass the string through the pulleys. Attach the end of the string with a small loop to the mass hanger and the other end to a ball of modelling clay.

The mass of the ball is m_1 and the mass of the mass hanger is m_2.

Ensure that the ball is suspended above the bench while the mass hanger is resting on the base of the retort stand with the string taut.

Adjust the distance between the retort stands until h_0 is about 5 cm above the bench.

Measure and record h_0.

h_0 = ...

(b) Raise the ball to a height h above the bench as shown in Fig. 1.2.

Release the ball such that it moves in a circular path.

Ensure that the string is taut and the mass hanger is resting on the base of the retort stand at the point of release of the ball.

The **minimum** height of the ball required **to just lift** the mass hanger off the base of the retort stand is h.

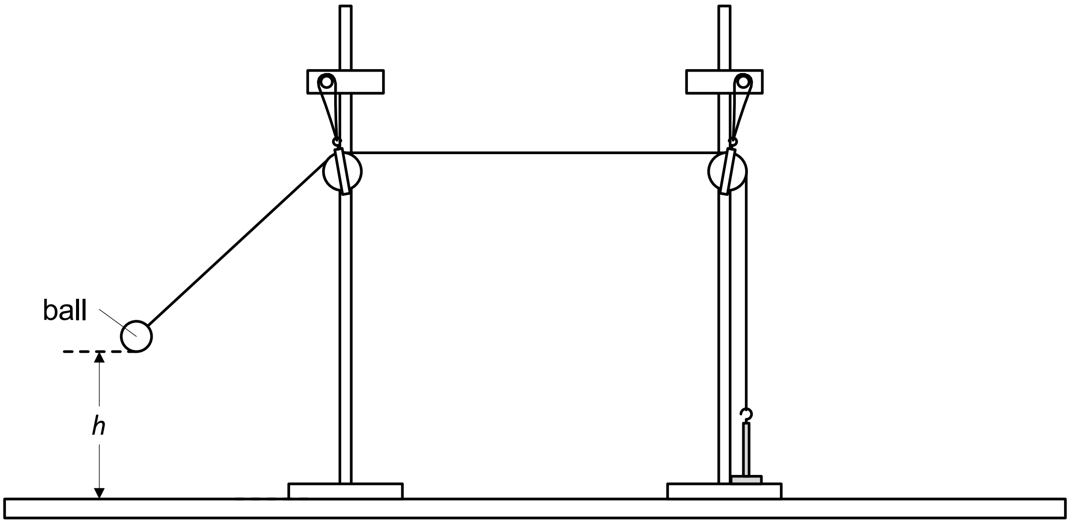

Fig. 1.2

Measure and record h.

Calculate Δh where $\Delta h = h - h_0$.

h = ...

Δh = ...

[1]

(c) Using the same ball of mass m_1, vary m_2 by adding slotted masses to the mass hanger and repeat **(b)**.

Present your results clearly.

[3]

(d) Δh and m_2 are related by the expression:

$$\Delta h = \frac{a\,m_2}{m_1} - a$$

where a and m_1 are constants.

(i) Plot a graph of Δh against m_2 to determine a and m_1.

a = ...

m_1 = ...

[5]

(ii) Explain the significance of the horizontal intercept of the graph.

....

....

.... [1]

(e) **(i)** Suggest one significant source of uncertainty in this experiment.

....

....

.... [1]

(ii) Suggest an improvement that could be made to the experiment to reduce the uncertainty identified in **(e)(i)**.

You may suggest the use of other apparatus or a different procedure.

....

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.... [1]

[Total: 12]

2 In this experiment, you will investigate the properties of a dry cell.

(a) Set up the circuit as shown in Fig. 2.1.

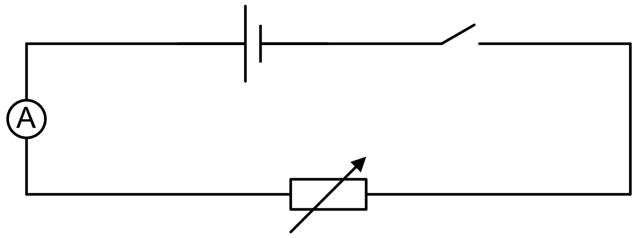


Fig. 2.1

(b) **(i)** Close the switch. Adjust the resistance of the variable resistor until the ammeter reading I is as close to 0.5 A as possible. Measure and record the ammeter reading I.

I = ...

(ii) Open the switch.

(c) A resistor of resistance R is made using three $1.0\ \Omega$ resistors connected as shown in Fig. 2.2.

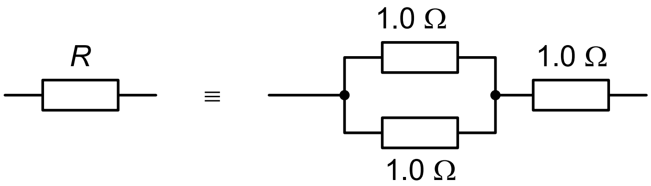


Fig. 2.2

Set up the circuit as shown in Fig. 2.3. The resistance of the variable resistor should be the same as that in **(b)(i)**.

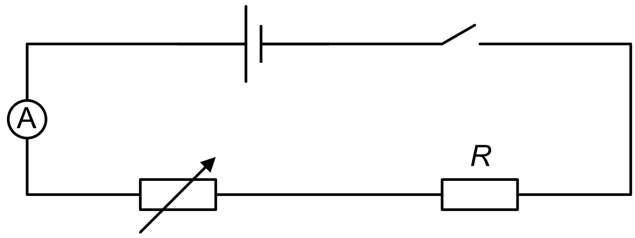


Fig. 2.3

(i) Record the effective resistance R.

R = ...

(ii) Close the switch.

Measure and record the ammeter reading I.

I = ...

(iii) Open the switch.

(d) Vary R by re-arranging the $1.0\ \Omega$ resistors and repeat **(c)**.

You may use any number of the $1.0\ \Omega$ resistors.

Present your results clearly.

[3]

(e) R and I are related by the expression:

$$\frac{1}{I} = \frac{R}{E} + \frac{r}{E}$$

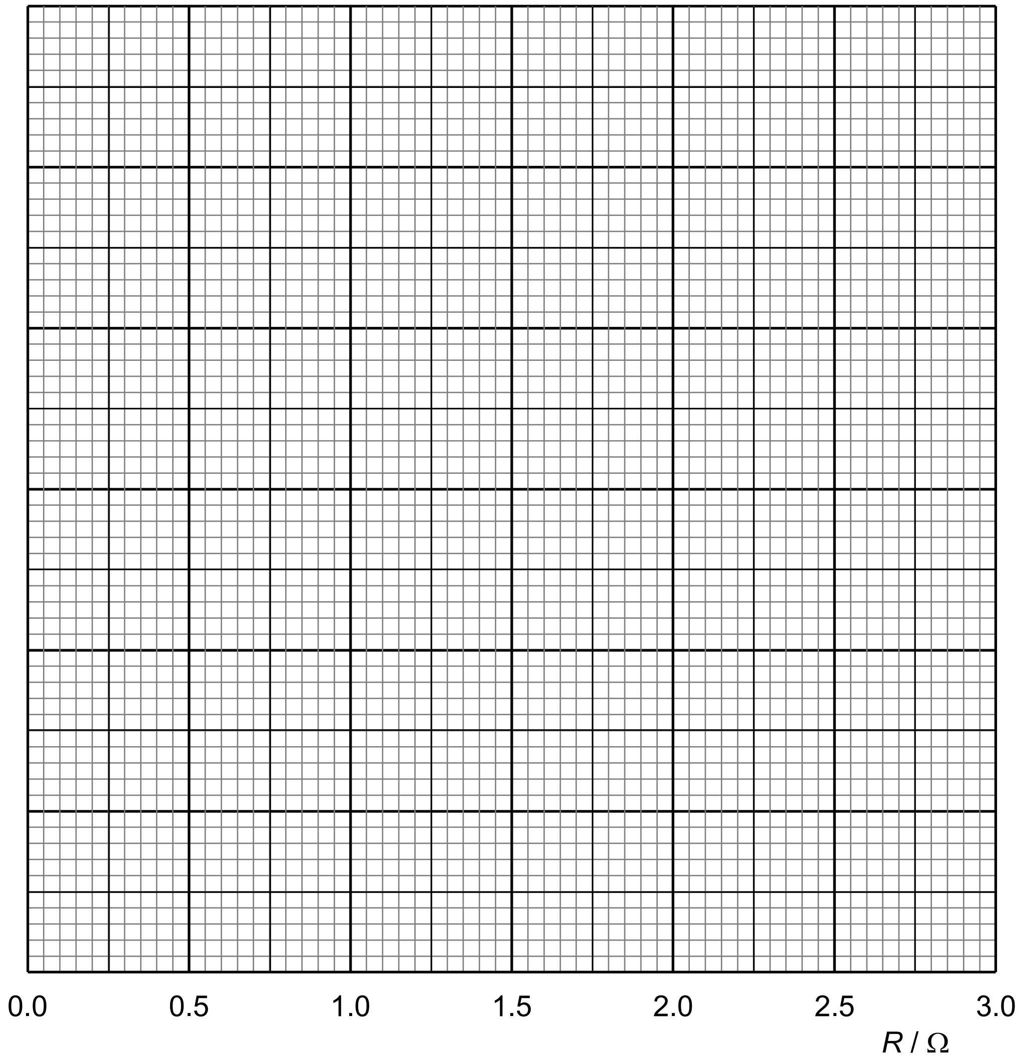
where E is the electromotive force (e.m.f.) of the dry cell and r is the sum of the resistance of the variable resistor and the internal resistance of the dry cell.

Plot a suitable graph to determine a value for E and r.

E = ...

r = ...

[6]



(f) Without taking further readings, sketch a line on your graph to show the results you would expect if the experiment was repeated with a dry cell with a larger e.m.f. and a smaller internal resistance than the one used.

Label this line Z. [1]

[Total: 10]

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3 An interrupted pendulum is a simple pendulum which strikes a rod below its pivot during its oscillation, causing the pendulum to deviate from its original trajectory into a trajectory of a smaller radius.

In this experiment, you will investigate how the behaviour of an interrupted pendulum depends on the position of the rod and the initial angle of release.

You have been provided with a simple pendulum and a wooden rod.

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

Attach the wooden rod to the retort stand with the boss. Ensure that the wooden rod is below the pivot such that the string of the pendulum is just touching the rod, with the string remaining vertical.

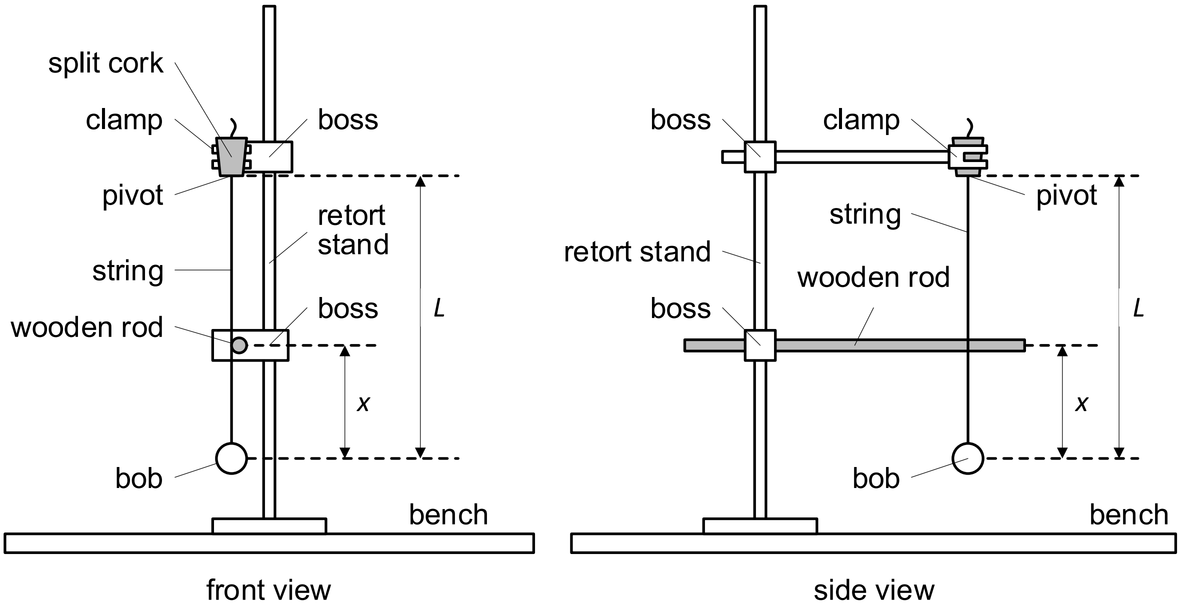

Fig. 3.1

The length of the pendulum is L. The distance between the rod and the pendulum bob is x.

Adjust the positions of the pendulum and the rod so that L is approximately 50 cm and x is approximately 10 cm.

(i) Measure and record L and x.

L = ...

x = ...

[1]

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

percentage uncertainty in *L* = ...

[1]

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

percentage uncertainty in *x* = ...

[1]

(b) (i) Displace the pendulum by a small angle θ away from the rod, as shown in Fig. 3.2. Ensure that θ does not exceed $5°$.

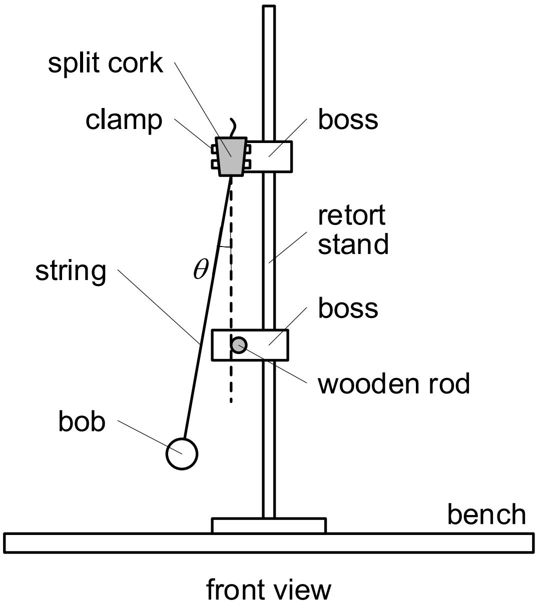

Fig. 3.2

Release the pendulum from this angle. It will swing and oscillate, with the string striking the rod halfway through its oscillation.

Record your value of θ.

Determine the period T of these oscillations.

θ = ...

T = ...

[2]

(ii) Adjust the wooden rod so that x is approximately 30 cm.

Measure and record your value of x. Repeat **(b)(i)**, using the same value of θ.

x = ...

T = ...

[1]

(c) It is suggested that

$$T = p\sqrt{x} + q$$

where p and q are constants.

Use your values in **(a)(i)**, **(b)(i)** and **(b)(ii)** to determine a value for p.

p = ...

[2]

(d) At larger angles of oscillation, the period T of an interrupted pendulum is thought to be dependent on the angle of release θ. You will now investigate this dependency.

In the following experiment, you will use the **same value** of x throughout.

(i) Choose **one** value of x from your values in either **(a)(i)** or **(b)(ii)** to use in the following experiment.

Record your choice of x and the period T_x of the oscillation of the pendulum at this value of x from your values in either **(b)(i)** or **(b)(ii)**.

x = ...

T_x = ...

Explain your choice of x.

....

....

....

[1]

(ii) Displace the pendulum away from the rod by an angle θ, as shown in Fig. 3.2, where θ is approximately $30°$.

Measure and record θ.

θ = ...

(iii) Estimate the percentage uncertainty in your value of θ.

percentage uncertainty in θ = ...

[1]

(iv) Release the pendulum from this angle, allowing it to oscillate.

Determine the period T of these oscillations.

T = ...

(e) Repeat steps **(d)(ii)** and **(d)(iv)** with a larger value of θ where $\theta \leq 60°$.

θ = ...

T = ...

[1]

(f) It is suggested that

$$t = k\sqrt{\frac{L}{x}}\,\theta^2$$

where k is a constant, θ is in radians, and t is given by

$$t = \frac{T}{T_x} - 1$$

(i) Use your value of L in **(a)(i)** and your values of x, T_x, θ and T in **(d)** and **(e)** to determine two values of k.

first value of k = ...

second value of k = ...

[2]

(ii) State whether or not the results of your experiment support the suggested relationship. Justify your conclusion by referring to your values in **(a)(ii)**, **(a)(iii)** and **(d)(iii)**.

....

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[1]

(g) Remove the wooden rod so that the pendulum is now able to swing freely as a simple pendulum.

Vary L and determine the period of oscillation T, using the same value of θ in **(b)(i)**.

Present your results clearly.

Use your results to estimate a value of L for the simple pendulum where the value of T is the same as your answer in **(b)(i)**.

L = ...

[3]

(h) An engineer wishes to design an amusement park ride based on an interrupted pendulum, with the bob representing the ride carriage.

However, instead of getting the carriage to oscillate, the engineer wants the carriage to swing and make a full circle around the rod, with the string looping around the rod.

It is suggested that the ratio $\frac{x}{L}$ is directly proportional to $1-\cos\theta_0$, where θ_0 is the minimum angle of release from the vertical for the carriage to complete a full circle around the rod.

Explain how you would investigate this relationship.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show direct proportionality
- how you would use your results to find the minimum angle of release for an amusement park ride where $L = 100$ cm and $x = 70$ cm.

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4 A thermoelectric cooler is made up of pairs of n- and p-type semiconductors sandwiched between two metal contact plates. This arrangement enables the semiconductor pairs to be electrically connected in series. The metal contact plates are in turn glued to flat ceramic substrates.

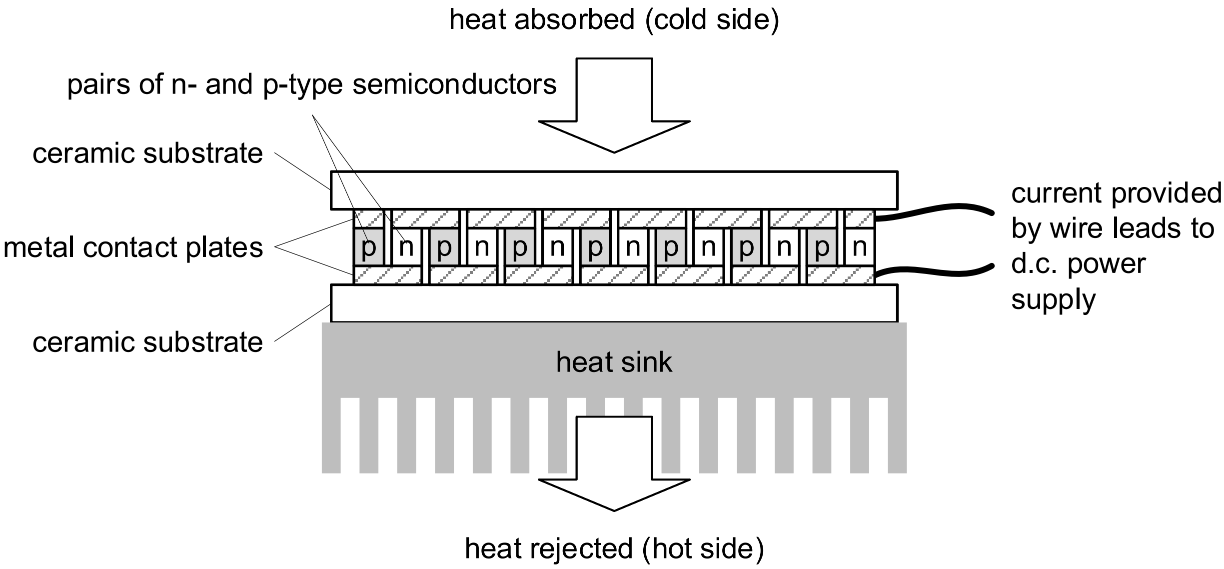

Fig. 4.1 Cross section of a thermoelectric cooler.

When current flows through the semiconductors, heat is absorbed by the thermoelectric cooler at the cold side and rejected by the heat sink at the hot side as shown in Fig. 4.1.

The thermoelectric cooler unit can be used to cool a beaker of water. The rate of heat transfer *P* across the thermoelectric cooler depends on the current I through the thermoelectric cooler and the *N* number of pairs of n- and p-type semiconductors.

The rate of heat transfer *P* is given by

$$P = k\, I^{\alpha}\, N^{\beta}$$

where *k*, α and β are constants.

Design an experiment to determine the values of α and β.

You are provided with thermoelectric coolers of different number of pairs of n- and p-type semiconductors with heat sinks attached.

Draw a diagram to show the arrangement of your apparatus. You should pay particular attention to:

- the equipment you would use
- the procedure to be followed
- the control variables
- any precautions that would be taken to improve the accuracy of the experiment.

Diagram

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