Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME

CLASS 2T

PHYSICS

Paper 1 Multiple Choice Questions

9749/01
September 2025
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

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

Read the instructions on the Answer Sheet 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.

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} mol^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

FORMULAE

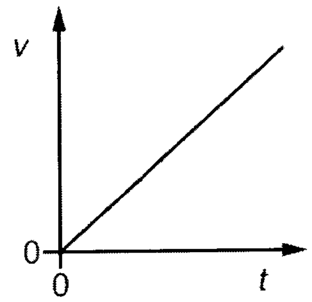
uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/K = T/{}^{\circ}C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
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	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 Which length is equal to 1 dm?

A 1×10^0 mm **B** 1×10^1 mm **C** 1×10^0 cm **D** 1×10^1 cm

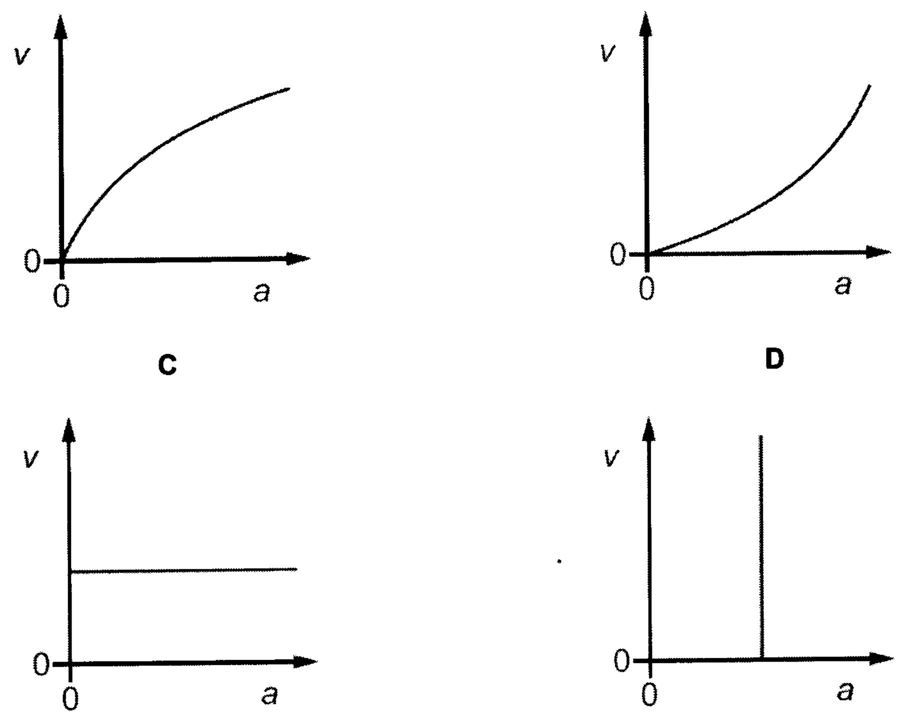
2 A particle accelerates from rest.

The graph shows the variation of the velocity *v* of the particle with time *t*.

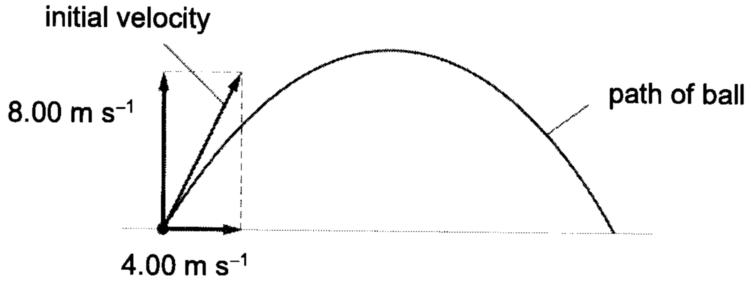


Which graph shows the variation of the velocity *v* with the acceleration *a* of the particle?

A **B** **C** **D**



3 An astronaut on the Moon, where there is no air resistance, throws a ball. The ball's initial velocity has a vertical component of 8.00 m s^{-1} and a horizontal component of 4.00 m s^{-1}, as shown.

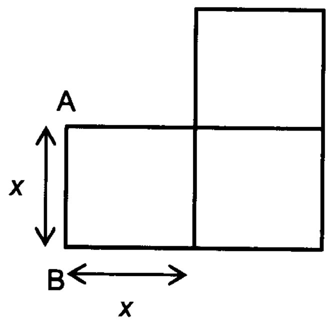


The acceleration of free fall on the Moon is 1.62 m s^{-2}.

What will be the speed of the ball 9.00 s after being thrown?

A 6.60 m s^{-1} **B** 7.70 m s^{-1} **C** 10.6 m s^{-1} **D** 14.6 m s^{-1}

4 A uniform square metal sheet of length x is cut into an 'L' shape.



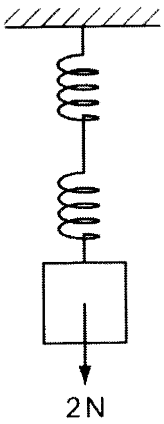
What is the distance of the centre of gravity of the sheet of metal from side AB?

A 1.0 x **B** 1.2 x **C** 1.5 x **D** 1.8 x

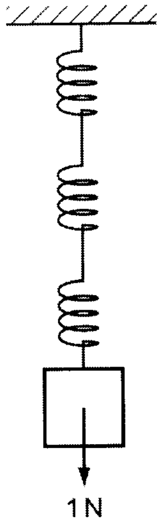
5 Several identical springs, each having the same spring constant, are joined in four arrangements. A different load is applied to each arrangement.

Which arrangement has the largest extension?

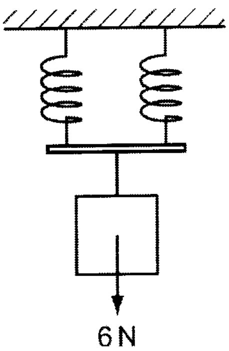
A



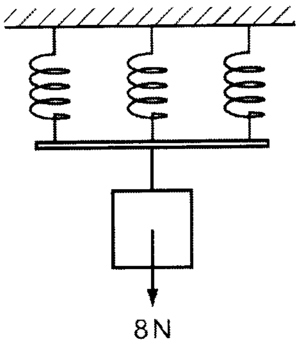
B



C



D



6 The energy conversions inside a power station burning fossil fuel can be simplified as shown.

chemical energy W → thermal energy X → electrical energy Y

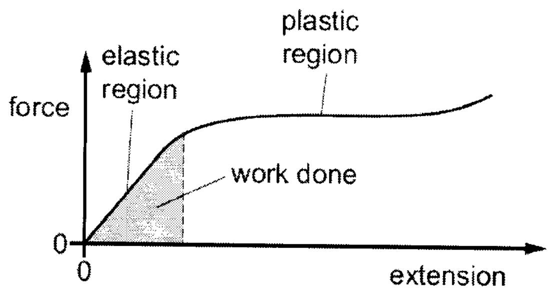
Which expression gives the efficiency of the power station?

A $\dfrac{Y}{W}$ **B** $\dfrac{Y}{(W+X)}$ **C** $\dfrac{Y}{X}$ **D** $\dfrac{Y}{(W+X+Y)}$

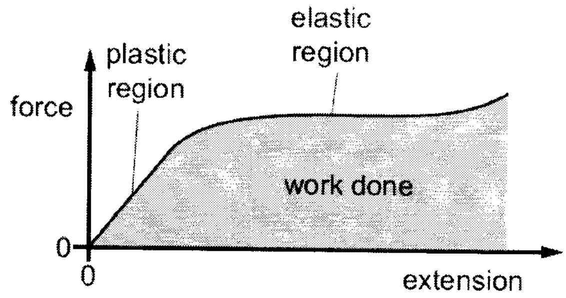
7 A metal wire is stretched to breaking point and the force–extension graph is plotted.

Which graph is correctly labelled with the elastic region, the plastic region and the area representing the work done to stretch the wire until it breaks?

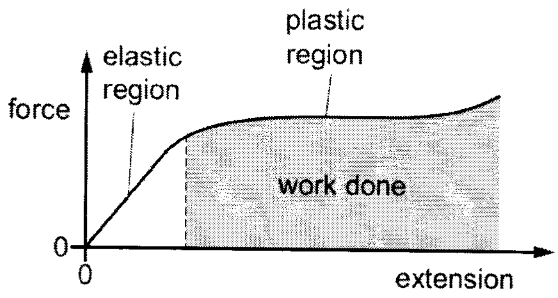
A



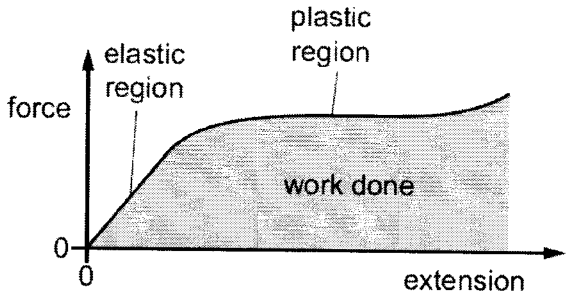
B



C



D



8 The Earth takes 24 hours to complete one rotation on its axis.

What is the angular velocity of the Earth as it rotates on its axis?

A 1.75×10^{-3} rad s^{-1}

B 1.99×10^{-7} rad s^{-1}

C 4.36×10^{-3} rad s^{-1}

D 7.27×10^{-5} rad s^{-1}

[Turn over

9 A stone is attached to a string. The stone is then caused to swing in a vertical circular motion at a constant speed.

Which of the following statements is **incorrect**?

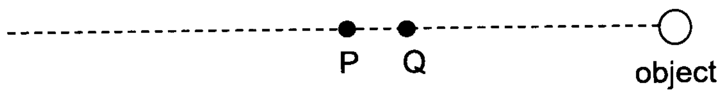
A The magnitude of resultant force acting on the stone is constant throughout the circular motion.

B The acceleration is always directed towards the centre of the circle throughout the circular motion.

C The kinetic energy of the stone is constant throughout the circular motion.

D The tension in the string when the stone is at the highest point of the circular motion is higher than that when the stone is at the lowest point.

10 Two points P and Q are located a fixed distance apart on a straight line joining them to an object considered as a point mass.



The two points P and Q are moved closer to the point mass, while keeping the separation between them constant.

What happens to the magnitudes of their individual gravitational potentials and to the magnitude of the gravitational field strength between the two points?

	magnitudes of gravitational potentials	magnitudes of gravitational field strength difference
A	both decrease	decreases
B	both decrease	increases
C	both increase	stays the same
D	both increase	increases

11 A gas molecule of mass m moves with velocity v and collides elastically with a wall perpendicular to that direction.

If the molecule makes N such collisions per second with the wall, what is the average force F exerted by the molecule on the wall?

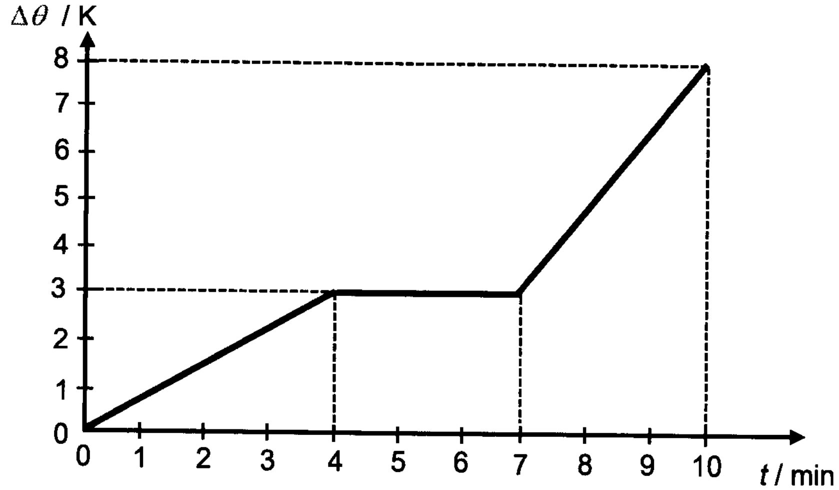
A $F = mvN$ **B** $F = 2mvN$ **C** $F = \frac{mv^2}{2}$ **D** $F = \frac{mv}{N}$

12 A piece of metal of mass *m*, specific heat capacity *c* and temperature 20 °C is placed into a liquid of temperature 100 °C. The liquid, which is in a well-insulated container, has mass 3*m* and specific heat capacity 2.5*c*.

What is the temperature of the liquid when thermal equilibrium is reached?

A 56 °C **B** 60 °C **C** 85 °C **D** 91 °C

13 The graph shows the variation with time *t* of temperature change $\Delta\theta$ for 1 kg of a substance, initially solid at room temperature. The substance receives heat at a uniform rate of 2000 J min^{-1}.



What can be deduced from this graph?

A The specific heat capacity of the substance is greater when liquid than when solid.

B The specific latent heat of fusion of the substance is 6000 J kg^{-1}.

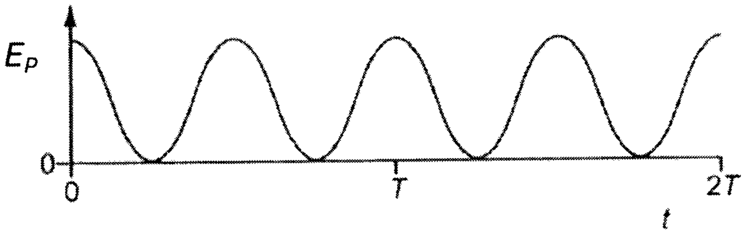
C The substance melts at a temperature of 3 K.

D After 10 min, the substance is all gaseous.

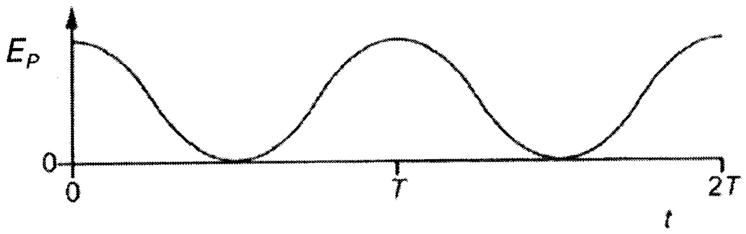
14 A small pendulum bob is displaced to one side and released from rest at time t = 0. The bob then swings with simple harmonic motion with period T.

Which graph represents the variation with time t of the gravitational potential energy E_P?

A



B



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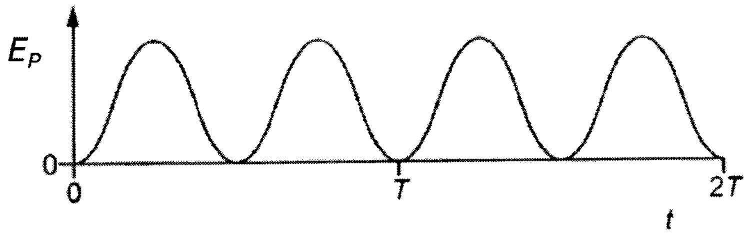
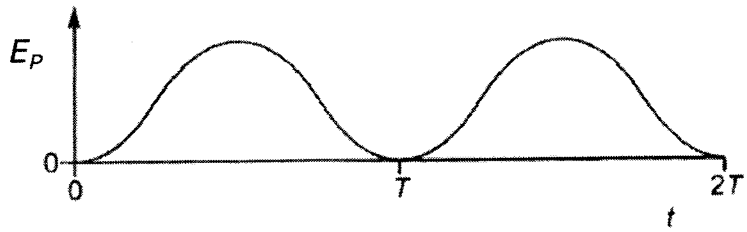
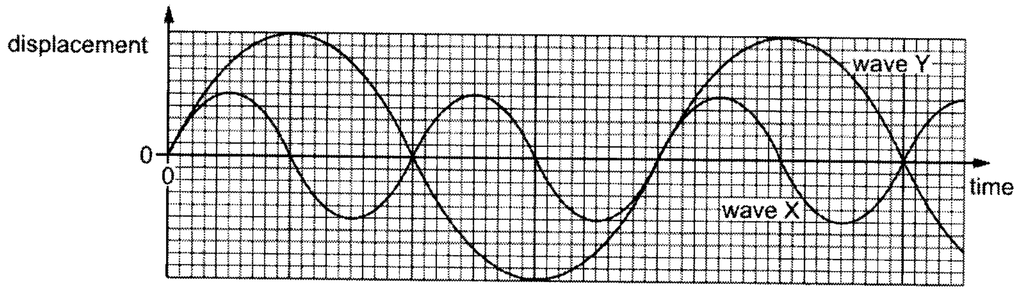


D



15 The graph shows the variation with time of displacement for two transverse waves X and Y travelling through the same medium. For such mechanical waves, intensity is proportional to the square of frequency.



Wave X has frequency f and intensity I.

What is the frequency and intensity of wave Y?

	frequency	intensity
A	$\frac{f}{2}$	$4I$
B	$\frac{f}{2}$	I
C	$2f$	I
D	$2f$	$4I$

16 Two polarising filters are placed next to each other so that their planes are parallel. The first polarising filter has its transmission axis at an angle of 50° to the vertical.

The second polarising filter has its transmission axis at an angle of 20° to the vertical. The angle between the transmission axes of the two polarising filters is 30°.

A beam of vertically polarised light of intensity 8.0 W m^{-2} is incident normally on the first polarising filter.

What is the intensity of the light that is transmitted from the second polarising filter?

A zero **B** 2.5 W m^{-2} **C** 2.9 W m^{-2} **D** 6.0 W m^{-2}

17 Which of the following is **not** an application of the Rayleigh criterion?

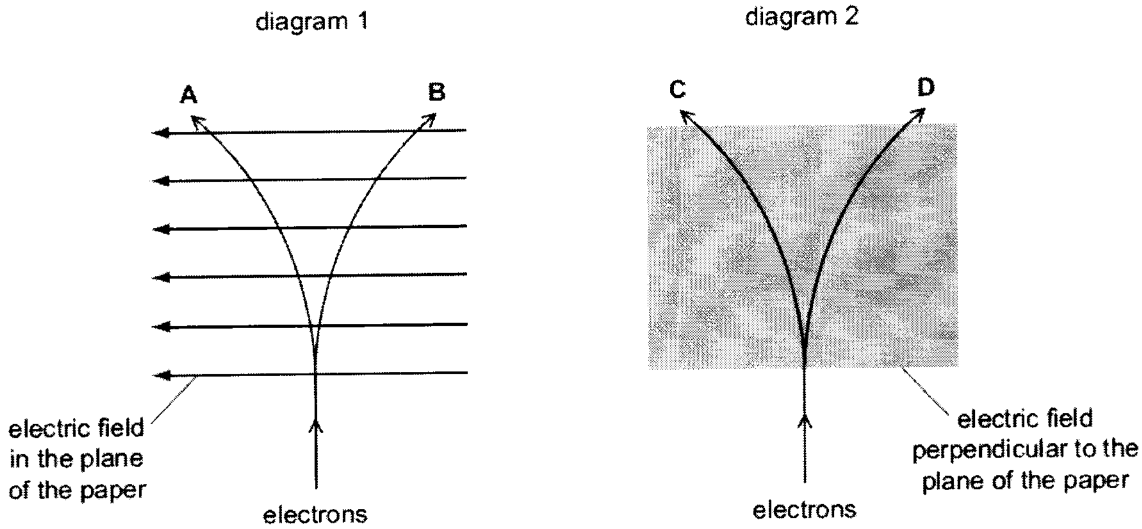
A Assessing the resolving power of a telescope or microscope.
B Calculating the minimum angular separation between two point sources to distinguish them.
C Determining the angular position of the first minima in single slit diffraction.
D Predicting whether two stars appear distinct in astronomical observations.

18 A beam of electrons is directed into an electric field and is deflected by it.

Diagram 1 represents an electric field in the plane of the paper. Diagram 2 represents an electric field directed perpendicular to the plane of the paper.

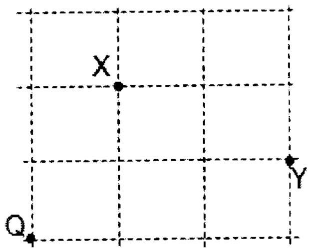
The lines A, B, C and D represent possible paths of the electron beam. All paths are in the plane of the paper.

Which line best represents the path of the electrons inside the field?



19 An isolated point charge is placed at point Q. The electric potential at point X is measured to be 720 V.

The relative positions of the three points Q, X, and Y are shown on the grid of squares below.



If the electric potential at X is 720 V, what is the electric potential at Y?

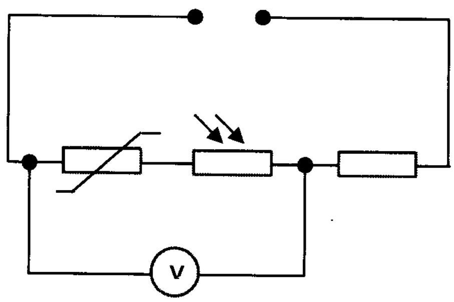
A 509 V **B** 581 V **C** 720 V **D** 936 V

20 A cylindrical piece of wire has resistance R. It is stretched uniformly so that its length becomes three times longer, but its volume remains constant.

What is its new resistance in terms of R?

A $\frac{R}{3}$ **B** R **C** $3R$ **D** $9R$

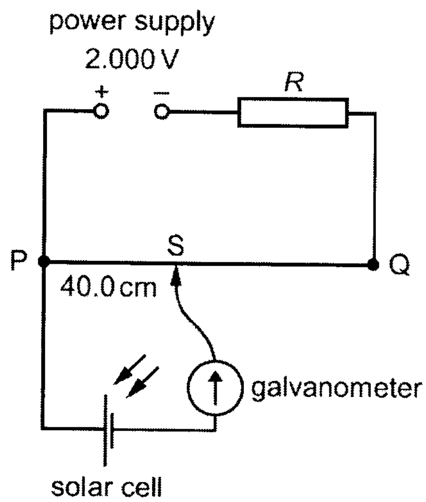
21 A negative temperature coefficient thermistor, an LDR and a fixed resistor are connected in series to a power supply. A voltmeter is placed across the thermistor-LDR combination.



Which conditions of brightness and temperature will produce the smallest reading on the voltmeter?

	temperature	brightness
A	high	high
B	high	low
C	low	high
D	low	low

22 A power supply and a solar cell are compared using the potentiometer circuit shown.



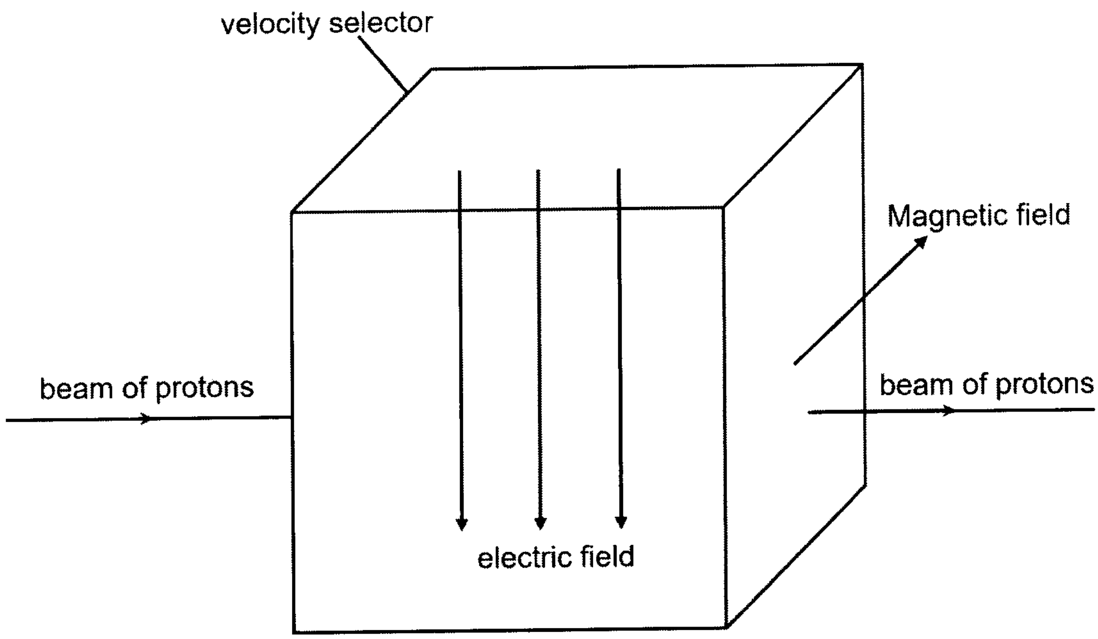
The potentiometer wire PQ is 100.0 cm long and has a resistance of 5.00 Ω. The power supply has an e.m.f. of 2.000 V and the solar cell has an e.m.f. of 5.00 mV.

When the galvanometer shows zero deflection, the balance length PS is found to be 40.0 cm.

What is the resistance of *R* so that the galvanometer reads zero at this balance length?

A 395 Ω **B** 795 Ω **C** 995 Ω **D** 1055 Ω

23 A beam of protons enters a velocity selector as shown. The electric field E acts vertically downwards, and the magnetic field B is directed into the page.



If only protons with a particular speed emerge undeflected, which change would result in the protons being deflected downwards?

A Increasing the electric field strength only

B Increasing the magnetic field strength only

C Increasing both E and B by the same factor

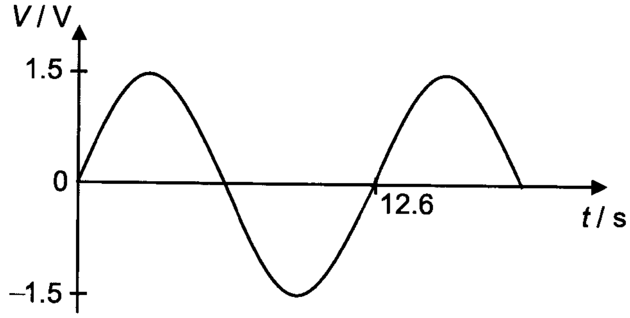
D Increasing the proton's speed

24 A rectangular coil of wire lies in a uniform magnetic field of 0.30 T. The field is perpendicular to the plane of the coil. The coil is stretched from dimensions 0.20 m × 0.50 m to 0.20 m × 0.80 m in 2.0 seconds.

What is the average emf induced in the coil during this time?

A 0.009 V **B** 0.018 V **C** 0.027 V **D** 0.036 V

25 The variation of an alternating voltage V with time t is shown in the graph below.



Which expression best represents V in terms of t?

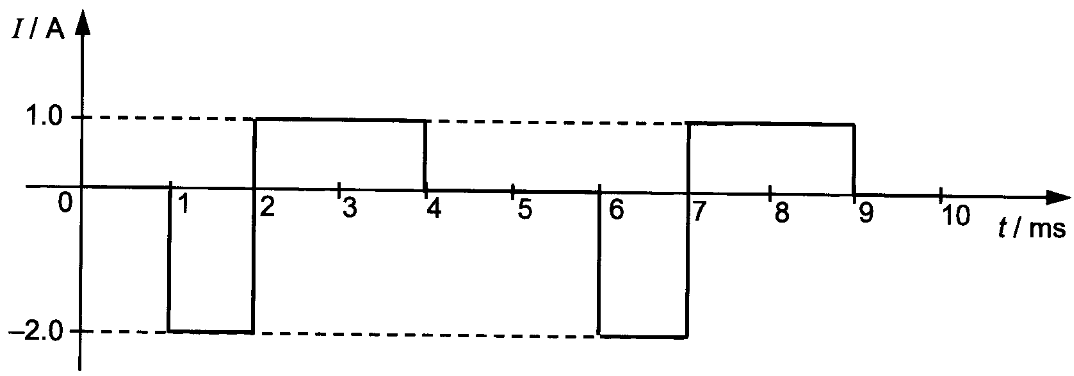
A $V = 1.5\sin(0.499t)$

B $V = 1.5\sin(2.01t)$

C $V = 3.0\sin(0.249t)$

D $V = 1.5\sin(12.6t)$

26 An alternating current with a rectangular waveform as shown in the diagram below flows through a 10 Ω resistor.



What is the average power dissipated by the resistor?

A 0 W **B** 8 W **C** 12 W **D** 28 W

27 A photon of light has frequency *f*, momentum *p*, and speed *c*. The Planck constant is *h*.

Which expressions for the momentum and the energy of the photon are correct?

	momentum	energy
A	hf	pc
B	hf	$\frac{pc}{2}$
C	$\frac{hf}{c}$	pc
D	$\frac{hf}{c}$	$\frac{pc}{2}$

28 An electron in an atom transitions from –25.0 eV to –80.0 eV. A photon is emitted in the process.

What is the wavelength of the emitted photon?

A 15.5 nm **B** 22.6 nm **C** 49.7 nm **D** 300 nm

29 Which of the following best describes the Heisenberg's uncertainty principle?

A The uncertainty principle applies only to microscopic particles like electrons.

B The uncertainty principle only applies to particles moving close to the speed of light.

C The product of the uncertainties in position and momentum of a particle has a minimum value.

D It is possible to reduce the uncertainty in both position and momentum of a particle to zero with advanced measuring techniques.

30 Thorium-232 undergoes the following fission reaction:

$$^{232}_{90}\text{Th} \rightarrow {}^{140}_{54}\text{Xe} + {}^{90}_{36}\text{Kr} + 2{}^{1}_{0}\text{n}$$

The binding energy per nucleon for the nuclei involved are:

Thorium-232: 7.6 MeV
Xenon-140: 8.3 MeV
Krypton-90: 8.5 MeV

What is the energy released by this fission reaction?

A 1.64×10^{8} J **B** 2.63×10^{-11} J **C** 1.47×10^{-12} J **D** 2.63×10^{-17} J

END OF PAPER

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME

CLASS 2T

PHYSICS

9749/02

Paper 2 Structured Questions

August 2025

2 hours

Candidates answer on the Question Paper.

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, 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		
Q1		/ 10
Q2		/ 8
Q3		/ 12
Q4		/ 8
Q5		/ 9
Q6		/ 11
Q7		/ 22
PAPER 2		/ 80

DATA

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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	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 A toy car of mass 0.42 kg is released from rest and accelerates along a straight track towards a wall. It hits the wall and rebounds in the opposite direction. The variation with time t of the momentum p of the toy car when not in contact with the wall is shown in Fig. 1.1

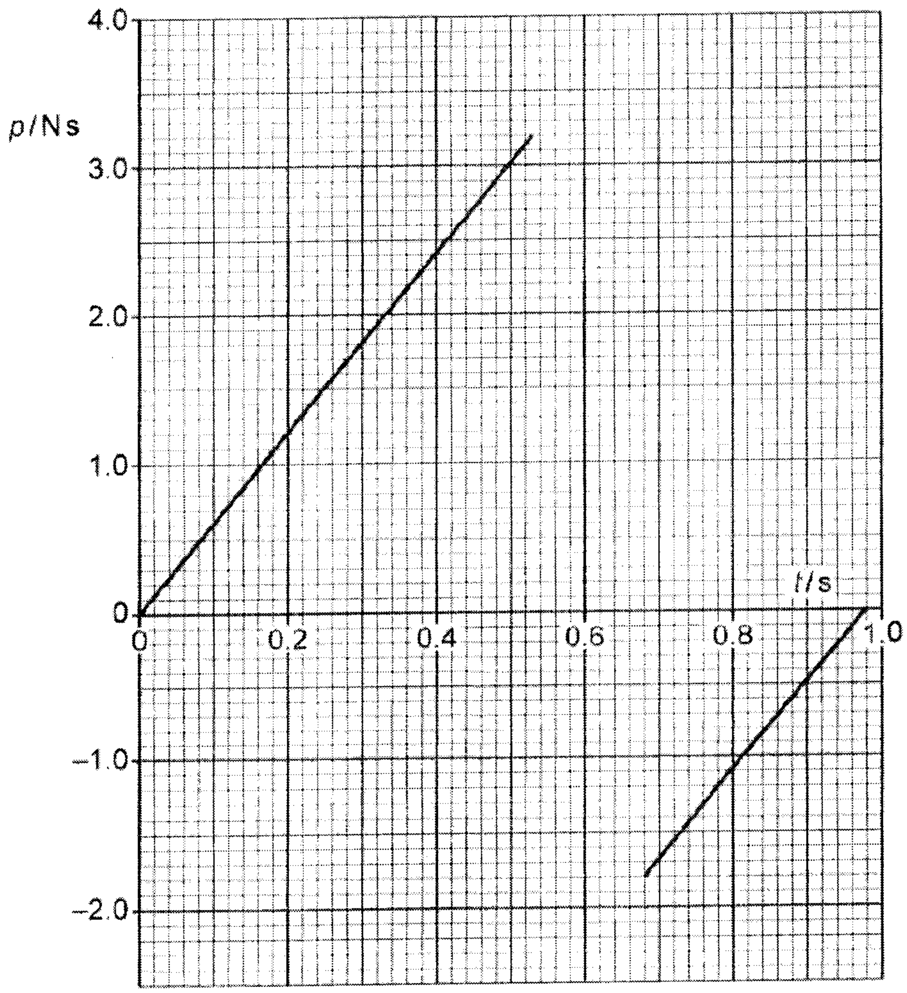

Fig 1.1

(a) Using Fig 1.1, calculate the impulse acting on the toy car during the collision.

impulse = ... N s [2]

(b) Calculate the magnitude of the average acceleration of the car during the collision and state the direction of this acceleration relative to the initial motion of the car.

average acceleration = ...m s^{-2}

direction = ... [3]

(c) Explain why the collision was inelastic.

....

....

....

....

.... [2]

(d) Calculate the percentage change in the kinetic energy of the car as a result of the collision.

percentage change = ... % [3]

[Total: 10]

[Turn over

2 (a) State what is meant by the centre of gravity of an object.

....

.... [1]

(b) A hollow plastic sphere is attached at one end of a bar. The sphere is partially submerged in water and the bar is attached to a fixed vertical support by a pivot P, as shown in Fig. 2.1.

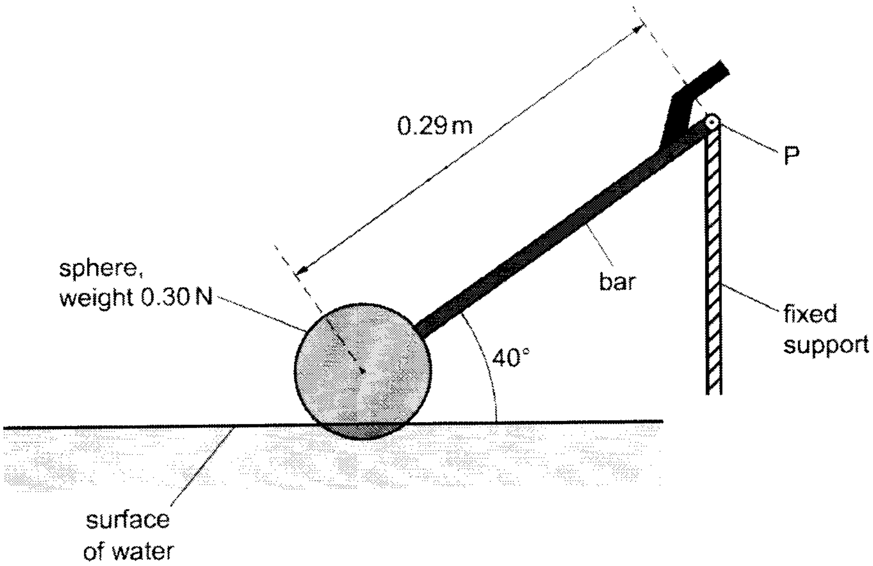

Fig. 2.1 (not to scale)

The sphere has weight 0.30 N. The distance from P to the centre of gravity of the sphere is 0.29 m. The weight of the bar is negligible.

The system shown in Fig. 2.1 is part of a mechanism that controls the amount of water in a tank. Water enters the tank and causes the sphere to rise. This results in the bar becoming horizontal as shown in Fig. 2.2.

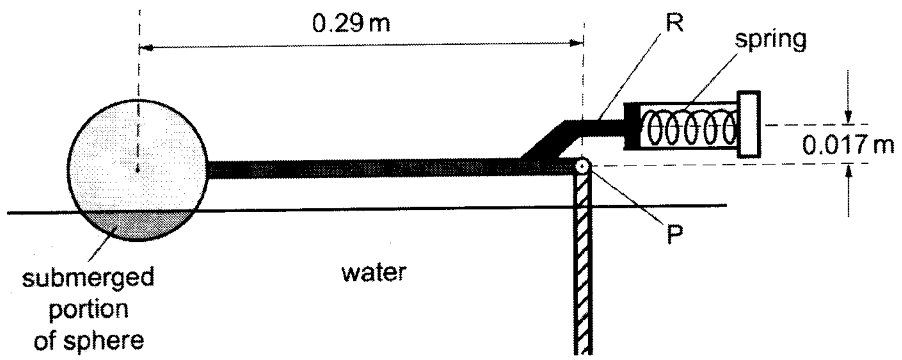

Fig. 2.2 (not to scale)

At the position shown in Fig. 2.2, the system is stationary and in equilibrium. The rod R exerts a force to compress a horizontal spring that controls the water supply to the tank. The spring has a spring constant of 2100 N m^{-1}. R is positioned at a perpendicular distance of 0.017 m above P.

(i) The radius of the sphere is 0.0480 m and 26.0% of the volume of the sphere is submerged.

The density of water is 1.00×10^3 kg m^{-3}.

Show that the upthrust on the sphere is 1.18 N.

[2]

(ii) For the position shown in Fig. 2.2, by taking moments about P, determine the force exerted on the spring by the rod R.

force = ... N [2]

(iii) Calculate the elastic potential energy E_P of the compressed spring.

E_P = ... J [2]

(c) When the sphere moves from the position shown in Fig. 2.1 to the position shown in Fig. 2.2, the upthrust on the sphere does work. Assume that resistive forces are negligible.

Explain why the work done by the upthrust is not equal to the gain in elastic potential energy of the spring.

....

....

.... [1]

[Total: 8]

3 **(a)** Fig. 3.1 shows a string stretched between two fixed points P and Q.

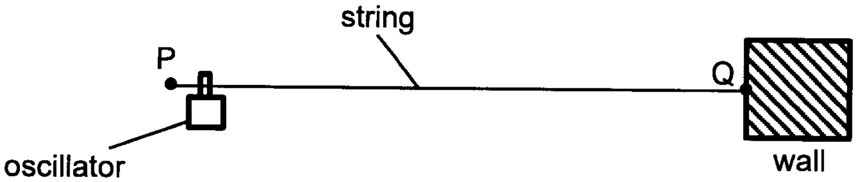

Fig. 3.1

An oscillator is attached near end P of the string. End Q is fixed to a wall. The oscillator has a frequency of 480.0 Hz.

The stationary wave produced on PQ at an instant time *t* is shown in Fig. 3.2. Each point on the string is at its maximum displacement.

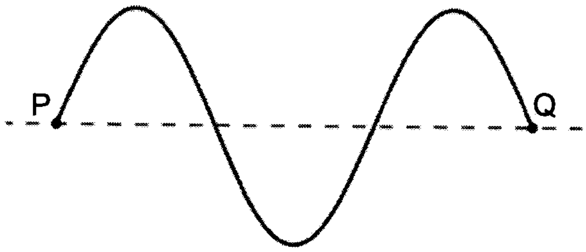

Fig. 3.2

(i) On Fig. 3.2, label all the nodes with the letter **N** and the antinodes with the letter **A** along the dotted line PQ.

[2]

(ii) Calculate the lowest possible frequency of the wave that can be formed between end P and Q of the string.

frequency = ... Hz [3]

[Turn over

(b) A loudspeaker is connected to a signal generator. It is then oriented to face a wall as shown in Fig. 3.3. Sound waves are produced between the speaker and the wall to form a stationary wave.

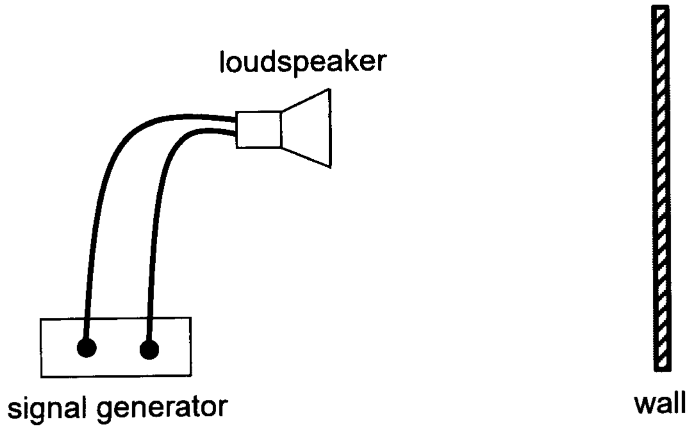

Fig. 3.3

(i) Explain why there are alternate regions of high and low intensity detected between the loudspeaker and the wall.

....

....

....

....

....

.... [3]

(ii) Outline how you would use this setup to obtain the speed of sound waves in air.

....

....

....

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....

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....

....

.... [4]

[Total: 12]

4 A battery B, a variable resistor R and a uniform resistance wire PQ are connected in series, as shown in Fig. 4.1

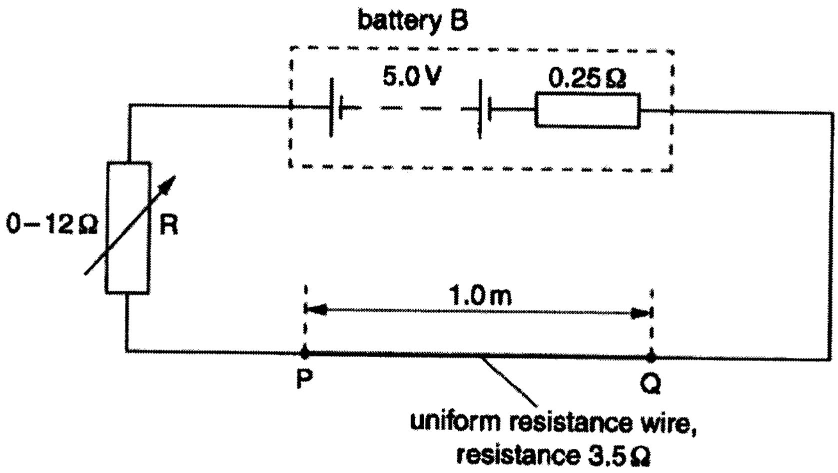


Fig. 4.1

Battery B has electromotive force (e.m.f.) 5.0 V and internal resistance 0.25 Ω.

Wire PQ has length 1.0 m and resistance 3.5 Ω at room temperature.

(a) The resistance of R is set to 4.0 Ω.

Calculate, when the circuit is just turned on,

(i) the potential difference across wire PQ,

p.d. = ... V [2]

(ii) the percentage of total power transferred to wire PQ.

percentage = ... % [2]

(b) The temperature of the wire is gradually increased from room temperature to a maximum steady temperature.

(i) Describe and explain the variation in the terminal potential difference (p.d.) across B. Numerical values are not required.

....

....

....

.... [2]

(ii) Suggest why the temperature of the wire will reach a steady maximum value.

....

....

.... [2]

[Total: 8]

5 (a) An ideal gas is said to consist of molecules that are hard elastic identical spheres.

State two further assumptions of the kinetic theory of gases.

....

....

....

.... [2]

(b) The number of molecules per unit volume in an ideal gas is n.

If it is assumed that all the molecules are moving with speed v_x in the x-direction, the pressure p exerted by the gas on the walls of the vessel is given by

$$p = nmv_x^2$$

where m is the mass of one molecule.

Explain the reasoning by which this expression is modified to give the formula

$$p = \frac{1}{3}nm\langle c^2 \rangle$$

where $\langle c^2 \rangle$ is the mean square speed of the molecules.

....

....

....

.... [2]

(c) The density of an ideal gas is 1.2 kg m^{-3} at a pressure of 1.0×10^5 Pa and a temperature of 27 °C.

(i) Calculate the root-mean-square (r.m.s.) speed of the molecules of the gas at 27 °C.

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

(ii) Calculate the mean-square speed of the molecules at 207 °C.

mean-square speed = ... $m^2\ s^{-2}$ [2]

[Total: 9]

6 **(a)** When ultraviolet radiation of a specific frequency is incident on a metal surface, electrons are emitted with a range of kinetic energies up to a maximum value.

Explain why the emitted electrons have a range of kinetic energies up to a maximum value.

....

....

....

....

....

.... [3]

(b) The maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is measured for different wavelengths λ of the electromagnetic radiation. The variation of E_{MAX} with $\frac{1}{\lambda}$ is shown in the Fig. 6.1.

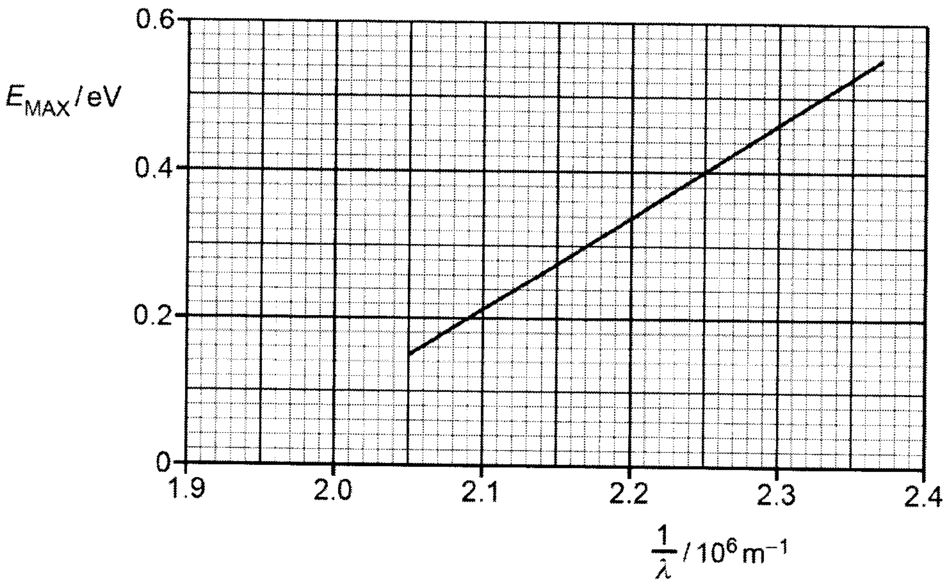


Fig. 6.1

Use the graph to:

(i) determine the threshold frequency f_o of the metal.

f_o = ... Hz [2]

(ii) determine a value for the Planck constant *h*. Explain your working clearly.

h = ... J s [3]

(c) The electromagnetic radiation is now incident on a metal with a larger work function energy than the metal in **(b)**.

On Fig 6.1, sketch the variation with $\frac{1}{\lambda}$ of E_{MAX}. [1]

(d) Infrared radiation of the same intensity is now incident on the same metal surface used in **(b)**.

Explain why no electrons are emitted from the metal surface.

....

....

....

.... [2]

[Total: 11]

7 Read the passage and answer the questions that follow.

Zircon ($ZrSiO_4$) crystals found in rocks serve as reliable timekeepers for determining the age of geological formations. These crystals readily incorporate uranium atoms into their crystal lattice during formation but strongly exclude lead. As a result, any lead found in a zircon crystal can be assumed to be the product of radioactive decay, making the crystal an effective record of the time that has passed since it solidified.

Two uranium decay chains are used in zircon dating: uranium-238 (U-238) decaying to lead-206 (Pb- 206), and uranium-235 (U-235) decaying to lead-207 (Pb-207). These decay processes follow predictable rates, governed by their half-lives: 4.47 billion years for U-238 and 704 million years for U-235. By measuring the ratio of lead to uranium isotopes in a zircon, geologists can determine its age, and thus the age of the rock in which it was found.

The age of a sample of zircon can be derived from the radioactive decay equation and the measured ratio of the lead to uranium isotopes $\frac{D}{N}$. For each parent isotope, the number of daughter atoms D accumulated over time is given by:

$$D = N_0 - N$$

where N_0 is the initial number of the parent atom and N is the number of remaining parent atoms.

When both decay systems (U-238 to Pb-206 and U-235 to Pb-207) are measured in a single zircon sample, the results can be plotted on a Concordia diagram—a graph of the isotopic ratios $\frac{\text{Pb-206}}{\text{U-238}}$ against $\frac{\text{Pb-207}}{\text{U-235}}$. The curve on this graph, known as the Concordia curve, represents points where both decay systems yield the same age, as shown in Fig. 7.1.

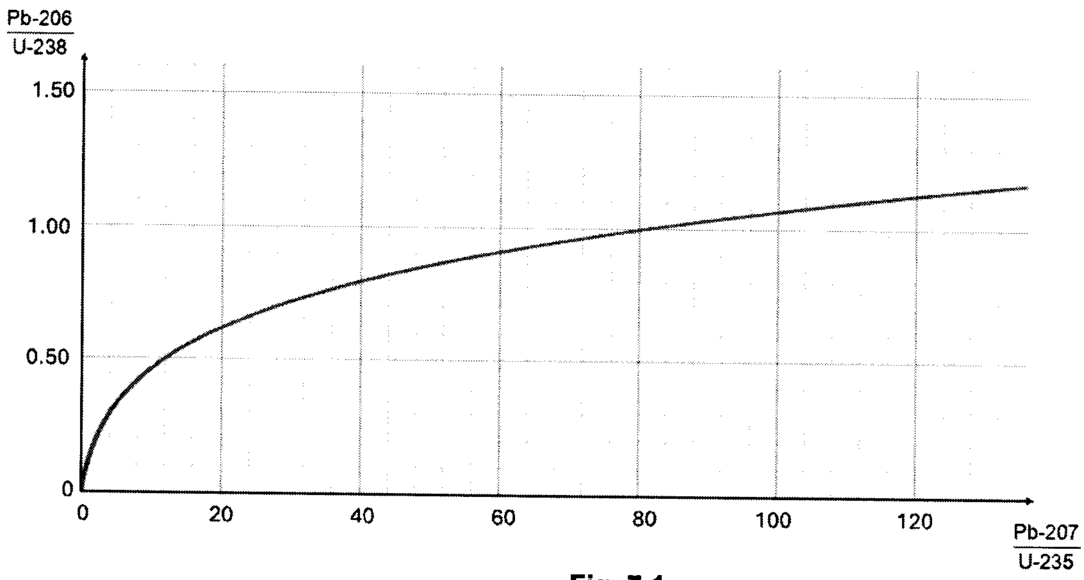


Fig. 7.1

A zircon that has remained isolated from chemical changes since its formation will have ratios of isotopes that lie on this curve, and its age can be confidently determined. If the sample has been altered by natural processes, the resulting isotopic ratios will not be on the curve, indicating that further analysis is required.

To determine these isotopic ratios, geologists use a technique called Secondary Ion Mass Spectrometry (SIMS). In SIMS, a focused primary ion beam (typically O^- or Cs^+) bombards the zircon crystal, releasing atoms from its surface. Some of these atoms are ionised, forming secondary ions that include the uranium and lead isotopes of interest. These ions are then accelerated through a potential difference of 10 kV, gaining kinetic energy as they do so.

After acceleration, the ions enter a uniform magnetic field of 0.75 T that is perpendicular to their velocity. The magnetic force causes the ions to move in circular arcs, with their radius determined by their mass-to-charge ratio. The mass spectrometer thus separates the ions by isotope, as ions like $^{206}Pb^+$ and $^{238}U^+$ follow different trajectories and strike the detector at different positions. The relative intensities of the ion signals are used to calculate the isotopic ratios. Fig. 7.2 below shows the path of the ions in a mass spectrometer.

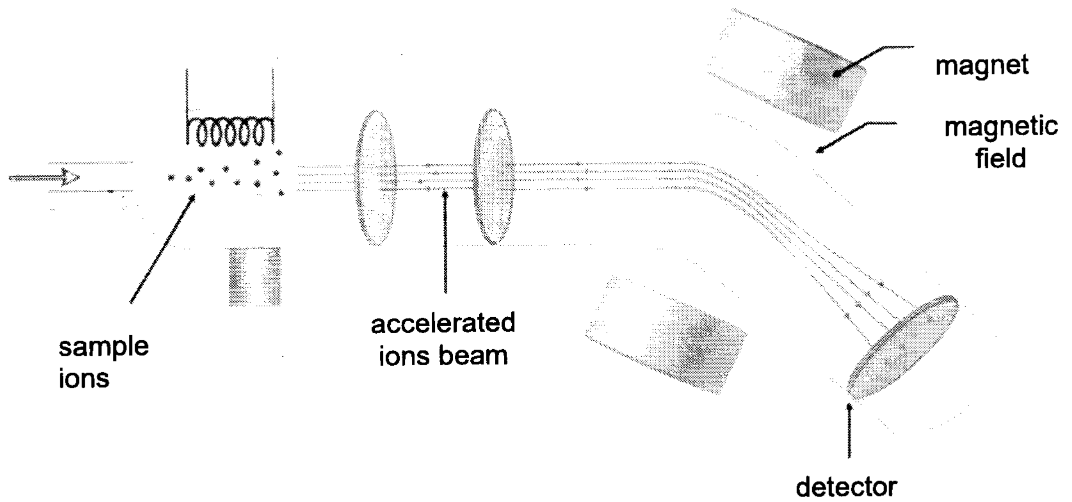


Fig. 7.2

SIMS allows highly precise measurement of isotope ratios in microscopic regions within a single zircon grain. By comparing these measured ratios with those expected from known decay rates and plotting the results on the Concordia diagram, geologists can derive robust and accurate age estimates—often within a few million years—even for samples that are over 4 billion years old.

(a) Explain, using the ratio of daughter to parent nuclei, why isotopes with long half-lives are more suitable than those with short half-lives for dating very old geological samples.

....

....

.... [1]

(b) Uranium-238 decays into stable lead-206 via a series of alpha and beta decays.

(i) In the first step of the uranium-238 decay chain, a uranium-238 nucleus undergoes alpha decay to form a thorium-234 nucleus and an alpha particle.

The atomic masses of the nuclei involved are:

Mass of uranium-238 nucleus = 238.0508 u
Mass of thorium-234 nucleus = 234.0436 u
Mass of helium-4 nucleus = 4.0026 u

Calculate the energy released in this decay in MeV.

energy released = ... MeV [4]

(ii) Calculate the total number of alpha and beta decays in the decay chain of uranium-238 ($^{238}_{92}U$) to lead-206 ($^{206}_{82}Pb$).

number of alpha decays = ...

number of beta decays = ... [3]

(c) **(i)** Using the radioactive decay equation and the information in the passage, show that the age of a sample of zircon t with a ratio of daughter to parent isotopes $\frac{D}{N}$ is given by

$$t = \frac{1}{\lambda}\ln\left(\frac{D}{N} + 1\right)$$

where λ is the decay constant of the parent isotope.

[2]

(ii) In a particular sample of zircon found in Western Australia, the ratio of lead-206 to uranium-238 isotope was found to be 0.978.

Determine the age of the zircon sample t in years.

t = ... years [2]

(iii) The ratio of lead-207 to uranium-235 ratio for the same sample was measured to be 76.0. Using the Concordia diagram (Fig 7.1), determine whether the two ratios agree on the age of this zircon sample.

....

....

.... [2]

(iv) Natural processes may change the number of lead or uranium nuclei in a sample. Suggest what changes may have occurred to the number of nuclei in a certain sample for it to have a data point that lies below the Concordia curve.

....

.... [1]

(d) **(i)** The ions from a zircon crystal in a SIMS device are accelerated through a potential difference of V before entering a uniform magnetic field of magnetic flux density B where they move in a circular arc of radius r.

Show that the mass to charge ratio of the ions $\frac{m}{q}$ is given by

$$\frac{m}{q} = \frac{B^2 r^2}{2V}$$

[3]

(ii) For the SIMS described in the passage, determine the expected arc radius *r* for a singly charged $^{206}Pb^{+}$ ion.

The mass of a $^{206}Pb^{+}$ ion is 205.974 u.

r = ... m [2]

(iii) State and explain whether the arc radius of the singly charged $^{238}U^{+}$ ion will be larger or smaller than that of the lead ion from **(d)(ii).**

....

.... [2]

[Total: 22]

END OF PAPER

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
CLASS	2T

PHYSICS
Paper 3 Longer Structured Questions

9749/03
September 2025
2 hours

Candidates answer on the Question Paper.

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, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

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.

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

FOR EXAMINER'S USE	
SECTION A	
Q1	/ 8
Q2	/ 8
Q3	/ 11
Q4	/ 6
Q5	/ 10
Q6	/ 7
Q7	/ 10
SECTION B	
Q8	/ 20
Q9	/ 20
PAPER 3	/ 80
PAPER 2	/ 80
PAPER 1	/ 30
PAPER 4	/ 55
TOTAL (WEIGHTED)	%

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} mol^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

FORMULAE

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
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	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 A solid iron sphere of density 8000 kg m^{-3} and volume 4.50×10^{-4} m^3 is completely submerged in a liquid of density 800 kg m^{-3}. The iron sphere is resting on a spring, as shown in Fig. 1.1. The spring is compressed by 10.2 cm.

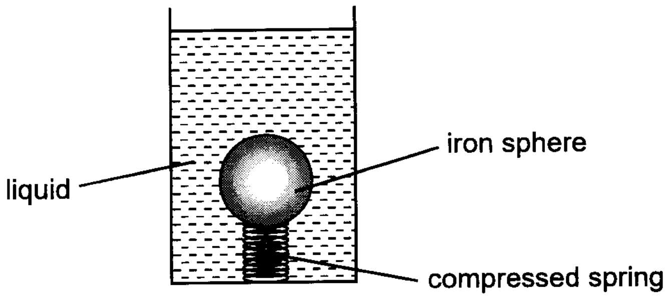


Fig. 1.1

(a) Show that the upthrust on the iron sphere is 3.53 N.

[1]

(b) Hence, calculate the force constant of the spring.

force constant = ... N m^{-1} [2]

(c) A string of breaking strength 32.0 N is used to lift the iron sphere vertically upwards, as shown in Fig. 1.2. The iron sphere is then lifted partially out of the liquid as shown in Fig. 1.3.

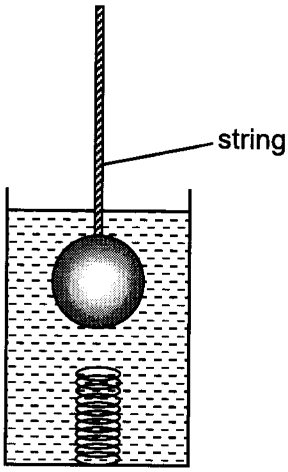


Fig. 1.2

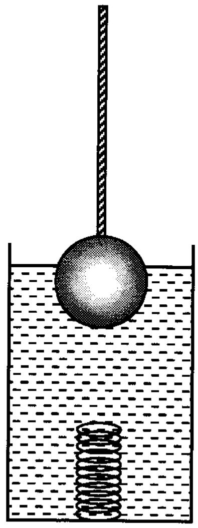


Fig. 1.3

(i) Explain why the string breaks as the sphere emerges from the liquid.

....

....

....

.... [2]

(ii) Calculate the volume of the fluid displaced at the instant when the string breaks.

volume = ... m^3 [3]

[Total: 8]

[Turn over

2 A satellite S of mass m is in a stable circular orbit at an altitude of $2R$ above the surface of a planet of mass M and radius R, as shown in Fig. 2.1.

Assume the planet has no atmosphere and that all its mass is concentrated at its centre.

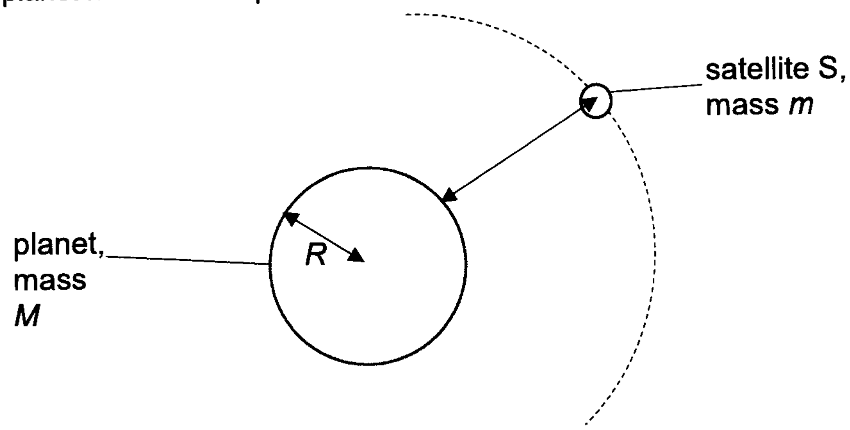


Fig. 2.1

(a) Show that the kinetic energy E_k of the satellite S in orbit is given by the expression:

$$E_k = \frac{GMm}{6R}$$

where G is the gravitational constant.

[2]

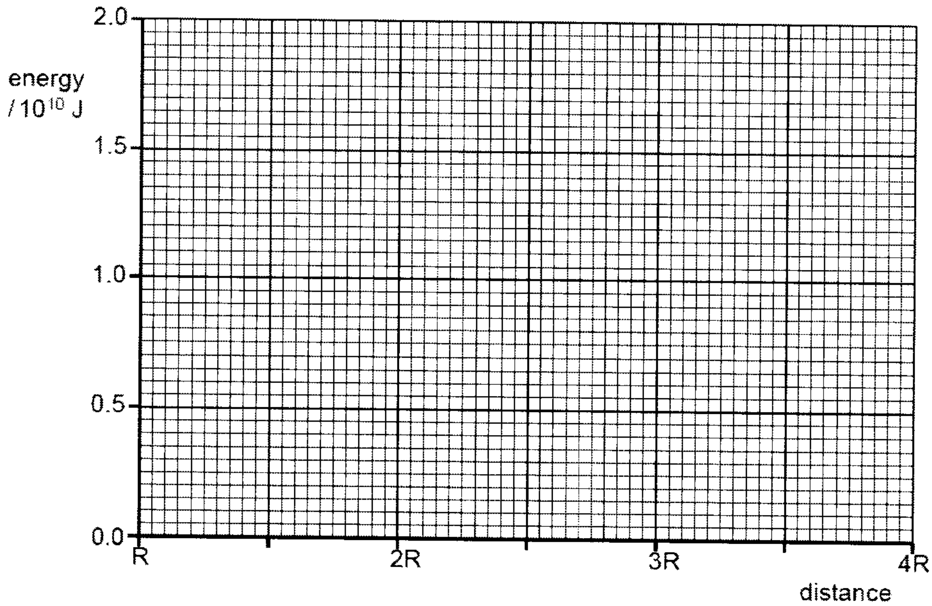
(b) The planet has mass 4.5×10^{24} kg and radius of 5.5×10^3 km. The satellite has a mass of 1500 kg.

Determine the total energy of satellite S in orbit.

total energy = ... J [2]

(c) A second satellite P is launched into orbits from the surface of the same planet with an initial kinetic energy of 2.0×10^{10} J. It rises to a distance of 4R from the centre of the planet.

On the axes provided in Fig 2.2, sketch a graph to show how the satellite's orbital kinetic energy varies with distance from the centre of the planet as it moves from R to 4R.



[2]

Fig 2.2

(d) A third satellite Q is to be launched vertically from the surface of the same planet. Determine the minimum speed that satellite Q must be given at the surface to escape the planet's gravitational field.

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

[Total: 8]

3 A student sets up the apparatus illustrated in Fig. 3.1 in order to observe two-source interference fringes. The double slit with slit separation 0.800 mm, situated 2.50 m from the screen, is illuminated with coherent red light of wavelength 690 nm. Fringes are observed on the screen.

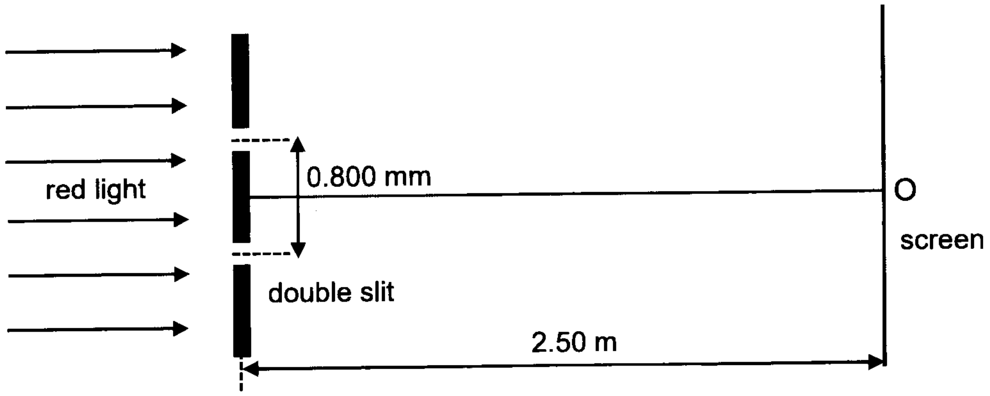


Fig. 3.1

(a) State two conditions necessary for two source interference fringes to be observed.

....

....

....

.... [2]

(b) Explain why a maxima is always observed at Point O.

....

....

....

.... [2]

(c) Calculate the distance from O to the second minima observed on the screen.

separation = ... m [3]

(d) Describe the changes, if any, that occur in the separation of the fringes and the difference in the brightness between bright and dark fringes observed on the screen, when each of the following changes is made separately.

(i) increasing the intensity of the red light incident on the double slit,

....

....

....

.... [2]

(ii) increasing the distance between the double slit and the screen.

....

....

....

.... [2]

[Total: 11]

4 A 3.00 g copper coin at 20.0 °C drops 50.0 m to the ground.

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

Explain what is meant by internal energy.

....

....

....

.... [2]

(b) The coin does not undergo a change in volume after it lands on the ground.

Determine the gain in temperature of the coin given that the specific heat capacity of copper is 385 J kg^{-1} K^{-1}. Assume that 10.0 % of the change in gravitational potential energy of the coin goes to increasing the internal energy of the coin.

gain in temperature = ... K [2]

(c) The first law of thermodynamics for a system can be expressed as

$$\Delta U = q + w$$

where ΔU is the increase in internal energy of the system, q is the heat supplied to the system and w is the work done on the system.

Use the words **positive**, **negative** and **zero** to complete Table 4.1 for the three terms in the equation for each of the processes shown. You may use each word once, more than once, or not at all.

Process	ΔU	q	w
Copper coin drops and lands on the ground			

Table 4.1

[2]

[Total: 6]

5 **(a)** State Faraday's law of electromagnetic induction.

....

....

.... [2]

(b) Two coils of insulated wire are wound on an iron bar, as shown in Fig. 5.1.

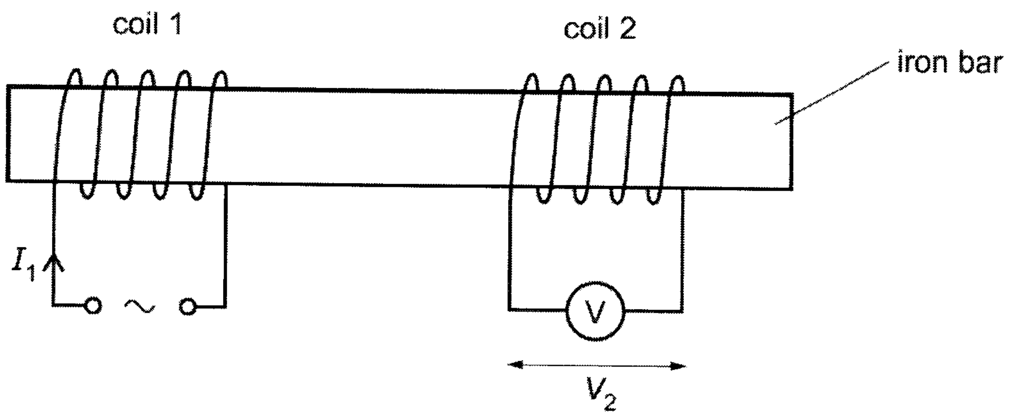


Fig. 5.1

There is a current I_1 in coil 1 that varies with time t as shown in Fig. 5.2.

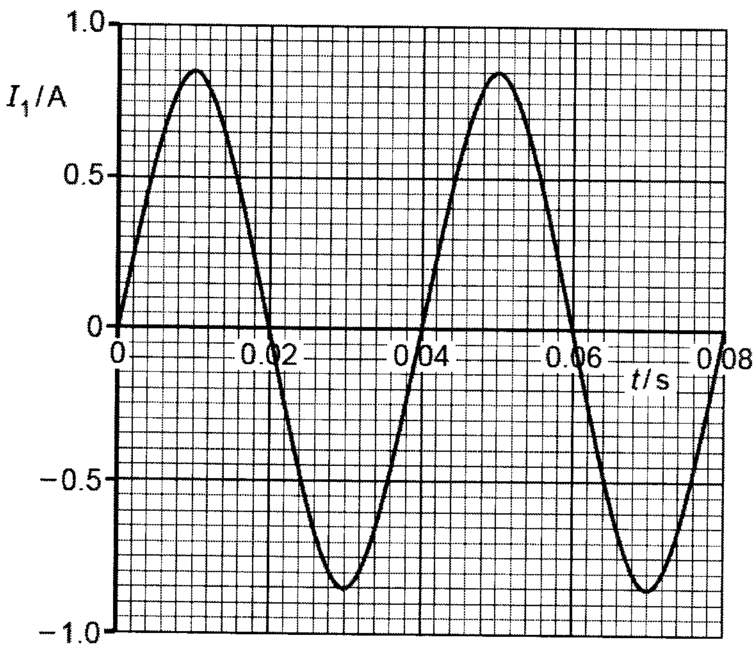


Fig. 5.2

(i) The variation with t of I_1 can be represented by the equation

$$I_1 = A \sin B(t)$$

where A and B are constants.

Use Fig. 5.2 to determine the values of A and B. Give units to your answers.

A = ... unit ....

B = ... unit .... [2]

(ii) The current in coil 1 gives rise to a magnetic field with a flux density that is proportional to I_1.

An electromotive force (e.m.f.) is induced across coil 2. The potential difference (p.d.) across coil 2 is measured using a voltmeter that gives a root-mean-square (r.m.s.) value of 4.6 V.

On Fig. 5.3, sketch a graph to show the variation with t of V_2 between t = 0 and t = 0.08 s.

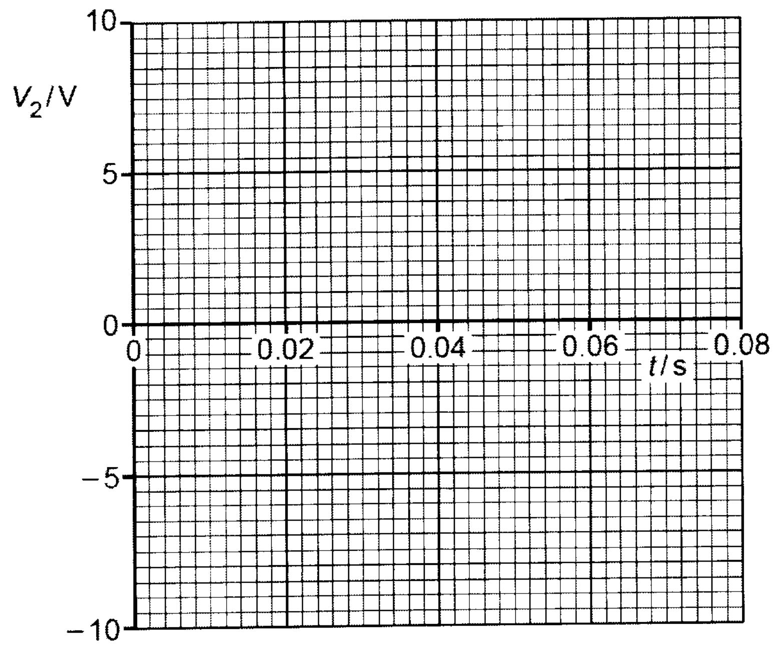


Fig. 5.3

[3]

(iii) Use the laws of electromagnetic induction to explain the shape of your graph in **(b)(ii)**.

....

....

....

....

.... [3]

[Total: 10]

6 A sinusoidal voltage supply of peak voltage 8 V and period of 1.2 s is connected to a circuit as shown in Fig. 6.1. The circuit consists of four resistors P, Q, R and S, which has a resistance of 10 Ω each.

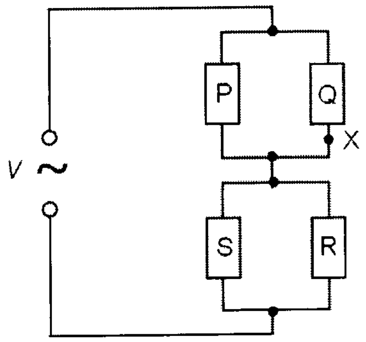


Fig. 6.1

(a) Calculate the maximum potential difference across resistor P.

potential difference = ... V [3]

(b) Determine the peak power dissipated across resistor P.

peak power = ... W [2]

(c) An ideal diode is connected in series with resistor Q at point X.

On Fig. 6.2, sketch the variation with t of the p.d. across resistor Q for a time of 1.2 s. Add a scale to the y-axis.

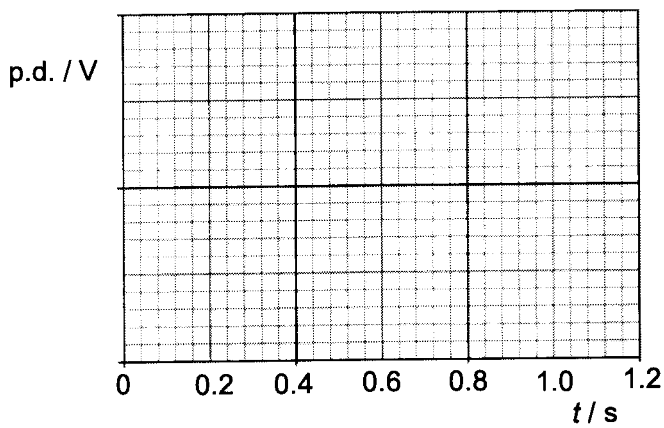


Fig. 6.2

[2]

[Total: 7]

7 (a) In the Rutherford α-particle scattering experiment, α-particles are emitted from a source and travel towards a thin gold foil.

(i) An α-particle is deflected through an angle of approximately 45° as it passes near a stationary gold nucleus. On Fig. 7.1, sketch the path of the α-particle as it passes the gold nucleus.

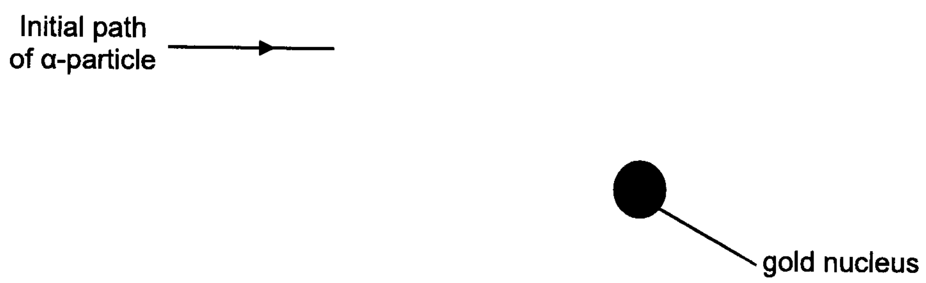


Fig. 7.1

[1]

(ii) Only a small proportion of the α-particles incident on the metal foil are deflected through large angle deflections greater than 90°. Explain the following phenomenon.

....

....

....

....

.... [2]

(ii) In the α-particle scattering experiment, a large number of alpha particles are directed at the metal foil.

Explain why a large number of alpha particles is necessary.

....

....

....

.... [2]

(b) An α-particle with kinetic energy 7.7×10^{-13} J is directed at a stationary gold nucleus ($^{197}_{79}Au$). Determine the minimum separation possible between this α-particle and the gold nucleus.

separation = ... m [3]

(c) The metal foil is changed from gold ($^{197}_{79}Au$) to carbon ($^{12}_{6}C$), while the α-particle energy is kept the same.

State and explain how the number of large-angle deflections would change.

....

....

....

.... [2]

[Total: 10]

Section B

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

8 **(a)** Define *simple harmonic motion.*

....

....

.... [2]

(b) Fig. 8.1 shows the force–extension graph for a light spring.

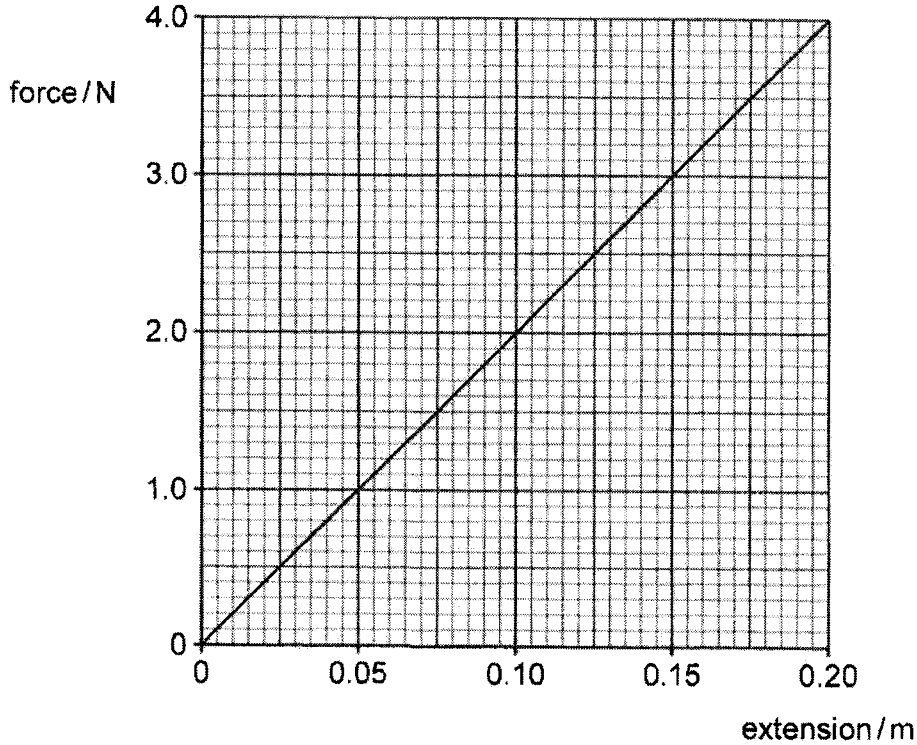


Fig 8.1

The spring described by Fig. 8.1 is attached to a fixed point on the ceiling and a mass of 2.0 N is hung on the spring.

Once the mass reaches its equilibrium position, it is displaced a further 0.15 m downward and released, such that it oscillates with simple harmonic motion.

(i) Determine the force constant *k* of the spring.

k = ... N m^{-1} [2]

(ii) Show that the maximum acceleration of the mass when it is oscillating in simple harmonic motion is 14.7 m s^{-2}.

[3]

(iii) Hence, determine the period of the oscillation.

period = ... s [3]

(c) On Fig. 8.2, sketch the variations with time of the displacement *x*, the velocity *v* and the acceleration *a* of the object for two complete oscillations, starting at $t = 0$ when the mass is at its lowest position. Take upwards as positive.

Include an appropriate scale on the axes.

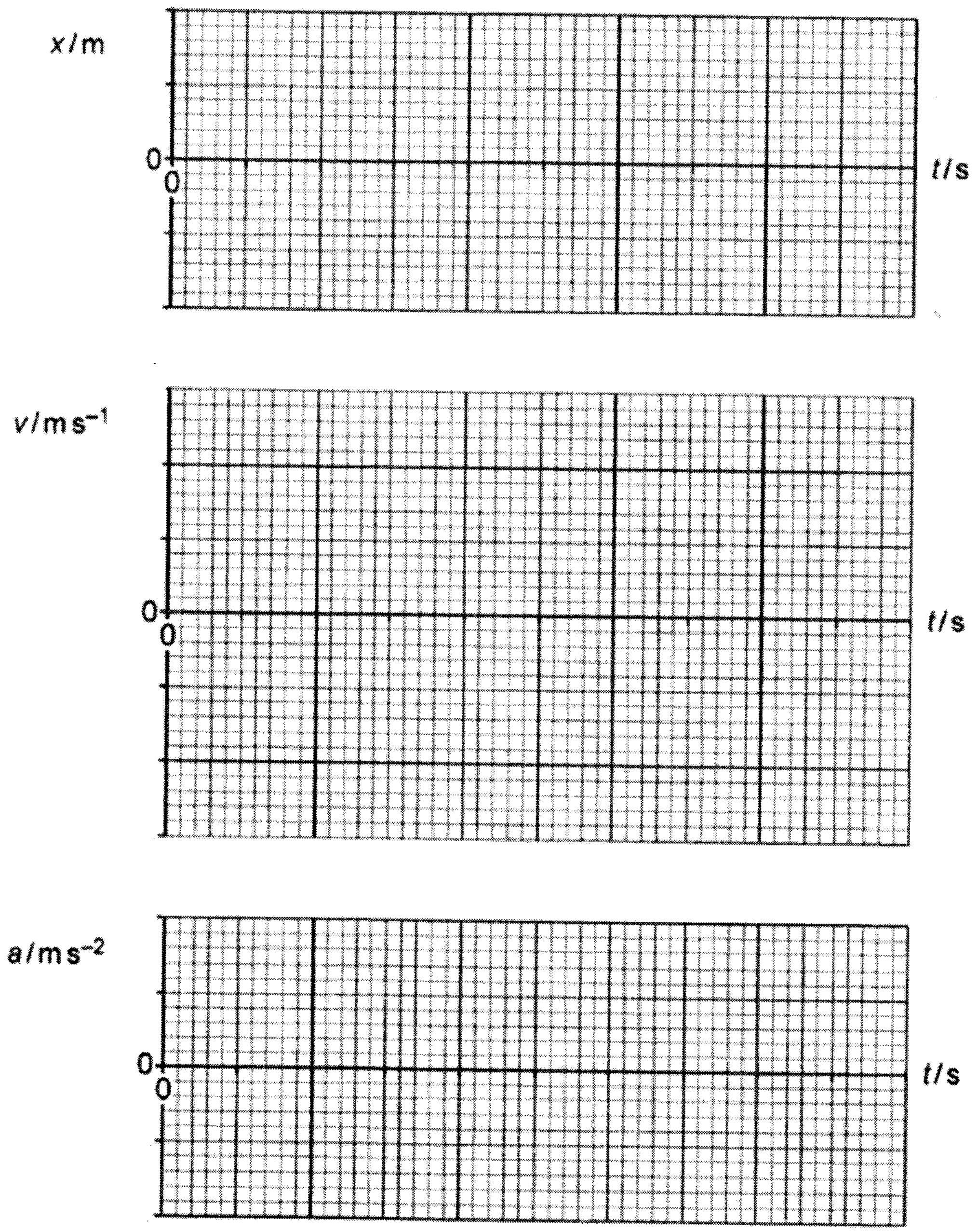


Fig. 8.2

[6]

(d) A second, identical spring is attached in parallel to the first spring as shown in Fig. 8.3.

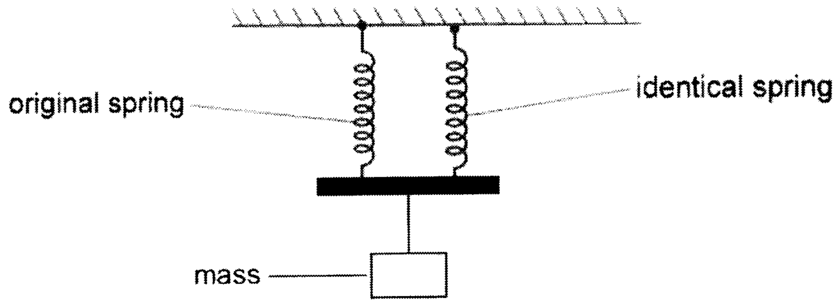


Fig. 8.3

(i) State and explain how the extension of the spring system compares with that of the original single spring when the same 2.0 N mass is suspended from it.

....

....

.... [2]

(ii) The mass is again displaced by 0.15 m and released to oscillate.

State and explain how the period of oscillation of the new system compares with the period found in **(b)(iii)**.

....

....

....

....

.... [2]

[Total: 20]

9 (a) Two point charges A and B are placed in a vacuum 10.0 cm apart, as illustrated in Fig. 9.1. A point P lies on the line joining the charges, at a distance x from charge A. The variation of electric field strength E with distance x is shown in Fig. 9.2.

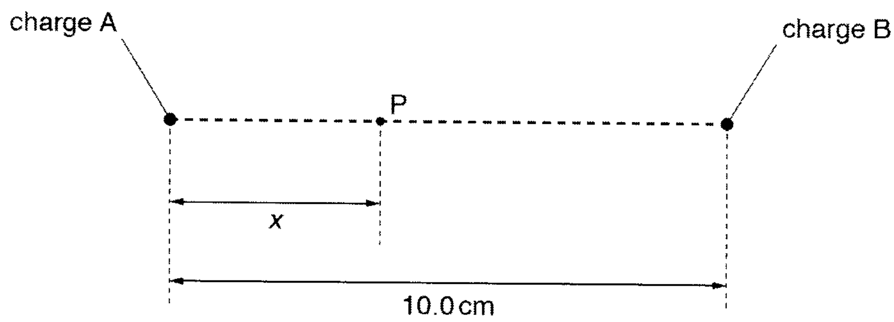


Fig. 9.1

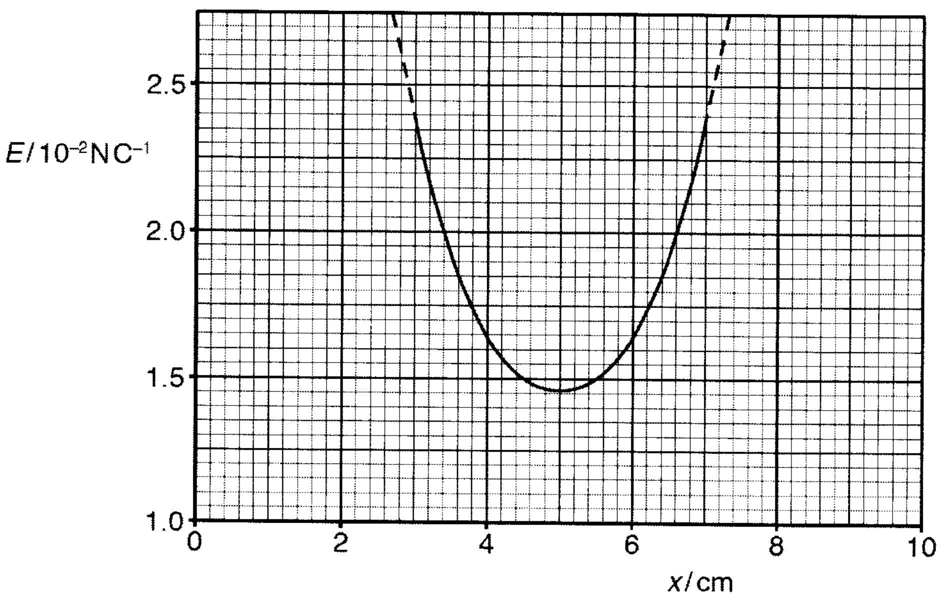


Fig. 9.2

State and explain whether the charges A and B:

(i) have the same, or opposite, signs.

....

....

.... [2]

(ii) State and explain whether the charges A and B have the same, or different, magnitudes.

....

....

.... [2]

[Turn over

(b) An electron is situated at point P.

Without calculation, state and explain the variation in the magnitude of the acceleration of the electron as it moves from the position where x = 3.0 cm to the position where x = 7.0 cm.

....

....

....

....

....

.... [4]

(c) Determine the acceleration of the electron at x = 7.0 cm.

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

(d) A particle of charge $+q$ and mass m is travelling with a constant speed of 1.6×10^5 m s^{-1} in a vacuum. The particle enters a uniform magnetic field of flux density 9.7×10^{-2} T, as shown in Fig. 9.3.

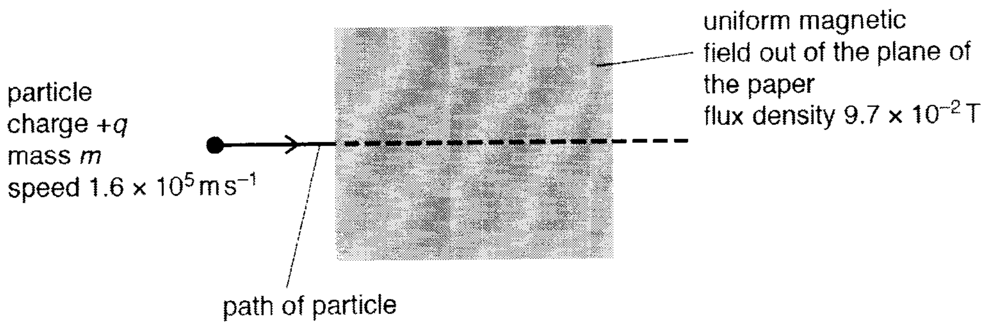


Fig. 9.3

The magnetic field direction is perpendicular to the initial velocity of the particle and perpendicular to, and out of, the plane of the paper.

A uniform electric field is applied in the same region as the magnetic field so that the particle passes undeviated through the fields.

(i) State and explain the direction of the electric field.

....

....

.... [2]

(ii) The electric field is now removed so that the positively charged particle follows a curved path in the magnetic field. This path is an arc of a circle of radius 4.0 cm.

Calculate, for the particle, the ratio $\frac{q}{m}$.

ratio = ...C kg^{-1} [2]

(iii) Determine the time taken for the particle to complete one full circle.

time taken = ... s [2]

(e) With the electric field still switched off, a proton enters the same uniform magnetic field, but at an angle of 30° to the magnetic field lines as shown in Fig. 9.4.

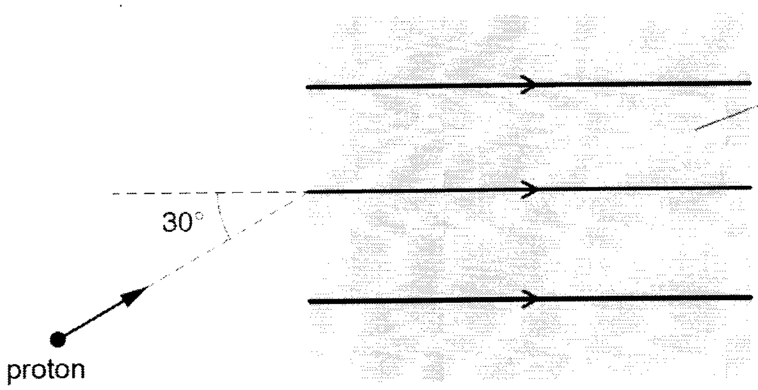


Fig. 9.4.

(i) Describe the resultant path of the proton in the magnetic field.

....

.... [1]

(ii) Calculate the speed of the proton if it experiences a magnetic force of 4.7×10^{-15} N.

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

[Total: 20]

END OF PAPER