TEMASEK JUNIOR COLLEGE
2025 JC2 PRELIMINARY EXAMINATION
Higher 2

TEMASEK JUNIOR COLLEGE

PHYSICS — 9749/01

Paper 1 Multiple Choice

18 September 2025

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name and Civics group on the Answer Sheet in the spaces provided.

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

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.

Do NOT open the booklets until you are told to do so.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} or $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} Js
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	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin\omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos\omega t$
		=	$\pm\omega\sqrt{(x_o^{\,2} - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin\omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

1 A capacitor is a device used to store electric charges. It consists of a pair of conducting plates. The capacitance C of a capacitor is defined as the ratio of the charge Q on either plate to the magnitude of the potential difference V between the plates, as depicted in the formula:

$$C = \frac{Q}{V}$$

Which of the following shows the SI base units for capacitance C?

A $A^2\ s^4\ m^{-2}\ kg^{-1}$ **B** $s^2\ m^{-2}\ kg^{-1}$ **C** $A^2\ m^{-2}\ kg^{-1}$ **D** $C^2\ kg^{-1}\ m^{-2}\ s^2$

2 Four students conduct their own experiments to determine the value of Planck's constant. The following table contains their experimental data.

Which student's measurement is accurate but imprecise, compared to the others?

student	Planck's constant, h / 10^{-34} J s				
A	6.64	6.61	6.61	6.64	6.65
B	6.62	6.63	6.63	6.64	6.63
C	6.63	6.68	6.61	6.68	6.65
D	6.62	6.61	6.63	6.62	6.62

3 The relation between the velocity v of waves in the sea with its wavelength λ, the surface tension γ and density ρ of sea water is given by:

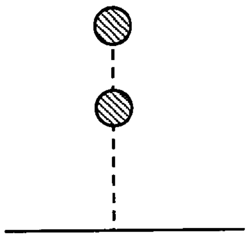
$$v = k\sqrt{\frac{\gamma}{\lambda\rho}}$$

where k = constant of proportionality.

If γ = (4.30 ± 0.05) N m^{-1}, ρ = (1450 ± 20) kg m^{-3} and the percentage uncertainty in λ is 5 %, what is the percentage uncertainty in the velocity of the waves?

A 2% **B** 3% **C** 4% **D** 8%

4 Two identical ball bearings are dropped simultaneously from rest from different heights as shown below. Air resistance is negligible.



As the stones fall, which of the following is true about the distance between them?

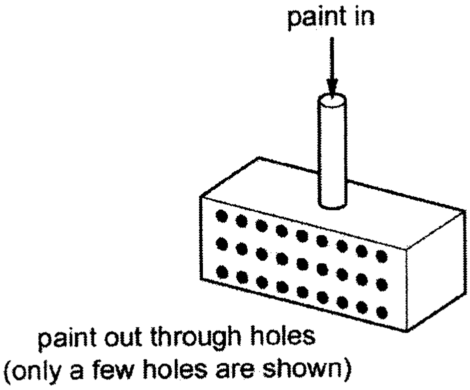
A The distance will remain the same.

B The distance will decrease until they come in contact.

C The distance will increase continuously.

D The distance will increase initially then remain the same.

5 A device for spraying paint consists of a box with its axes horizontal and vertical. One of its vertical faces contains small holes. Paint is fed into the box under pressure via a vertical tube and exits through the holes as fine horizontal streams.

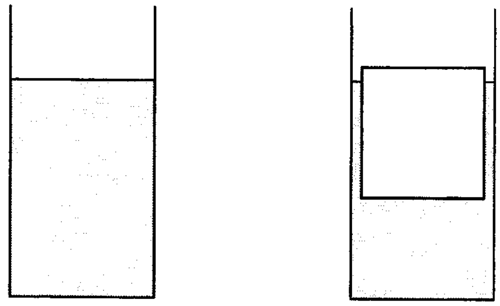


The paint is ejected at a speed of 3.0 m s^{-1} through 27 holes, each of area 0.4 mm^2. The density of the paint is 900 kg m^{-3}.

What is the horizontal force required to hold the device stationary as it ejects the paint?

A 21 mN B 29 mN C 44 mN D 87 mN

6 A cup contains 100 g of water. The pressure at the bottom of the cup is P.

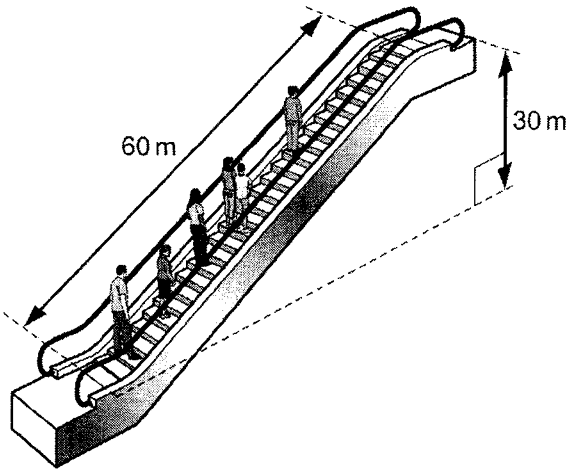


50 g of water is removed from the cup, frozen into ice, and added back to the cup, as shown above. 10% of the volume of the ice is above the surface of the water.

What is the new pressure at the bottom of the cup?

A 0.95P **B** P **C** 1.05P **D** 1.10P

7 An escalator is 60 m long and lifts passengers through a vertical height of 30 m.



To drive the escalator against the forces of friction when there are no passengers requires a power of 2.5 kW.

The escalator is used by passengers of average mass 62 kg and the power to overcome friction remains constant.

How much power is required to drive the escalator when it is carrying 20 passengers and is travelling at 0.75 m s^{-1}?

A 4.6 kW **B** 7.1 kW **C** 9.1 kW **D** 11.6 kW

8 The engine of a boat supplies a constant power of 110 kW to propel the boat forward. The boat attains a maximum speed of 21.0 m s^{-1}.

If the magnitude of the resistive force acting on the boat is proportional to the square of the boat's speed, what is the resultant force acting on the boat when it is moving at the instant when its speed is 15.0 m s^{-1}?

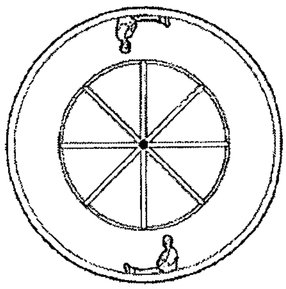
A 2.7 kN **B** 3.6 kN **C** 4.7 kN **D** 7.3 kN

9 An astronomical gas cloud has mass M and radius R. The gravitational potential on its surface S is $-\frac{GM}{R}$ and at its centre 0 it is $-\frac{3GM}{2R}$

A unit mass is moved slowly by means of an external force from the surface S to the centre O. What is the work done on the mass by the external force?

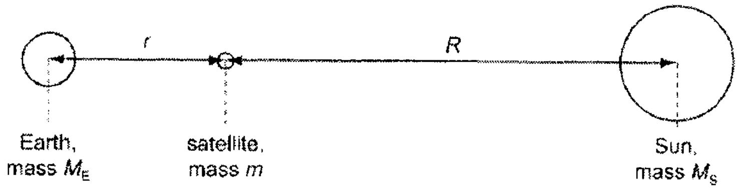
A $-\frac{5GM}{2R}$ **B** $-\frac{GM}{2R}$ **C** $\frac{GM}{2R}$ **D** $\frac{5GM}{2R}$

10 On a fairground ride, passengers are rotated in a vertical wheel of radius 4.00 m. Passengers complete one revolution in 3.70s.
A passenger of mass 77.0 kg is shown in the diagram when at the top of the wheel and when at the bottom of the wheel. What is the force acting by the wheel on the passenger?



	force at top	force at bottom
A	1640 N down	133 N up
B	1640 N up	133 N down
C	133 N down	1640 N up
D	133 N up	1640 N down

11 The diagram shows a solar satellite, mass m, positioned directly between the Earth, mass M_E, and the Sun, mass M_s. The satellite is a distance r from the Earth and a distance R from the Sun.



The satellite rotates in a circle around the Sun once a year and therefore moves around the Sun with the Earth, both having the same angular velocity ω
Which force = mass x acceleration equation applies for the satellite?

A $\frac{GM_Sm}{R^2} = m \times (R\omega^2)$

B $\frac{GM_Em}{r^2} = m \times (R\omega^2)$

C $\frac{GM_Em}{r^2} - \frac{GM_Sm}{R^2} = m \times (R\omega^2)$

D $\frac{GM_Sm}{R^2} - \frac{GM_Em}{r^2} = m \times (R\omega^2)$

12 A satellite orbiting the Earth moves to an orbit further away from the Earth, such that its gravitational potential energy increases **by** E. By how much does its kinetic energy changes?

A It increases by E.

B It decreases by E.

C It increases by $\frac{E}{2}$.

D It decreases by $\frac{E}{2}$.

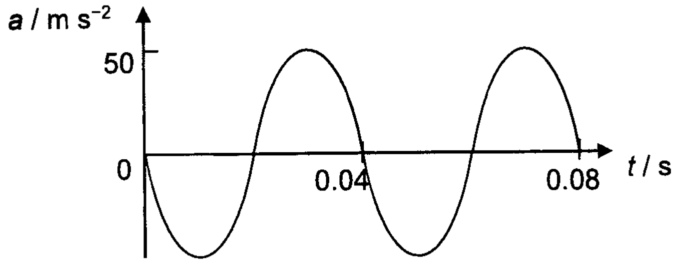
13 Two vessels A and B of volume V and $8V$ respectively are connected by a tube of negligible volume and contain an ideal gas at an initial temperature of 10 °C.

Vessel A initially contains n moles of the ideal gas. Its temperature is then raised to 80 °C while the temperature of B is maintained at 10 °C.

How many moles of gas will be transferred between the vessels when steady state is reached?

A 0.18 n **B** 0.21 n **C** 0.82 n **D** 0.86 n

14 A body performs simple harmonic motion with period T. The graph shows the variation with time t of its acceleration a.



What is the ratio of the body's displacement to its amplitude at time $t = \frac{5T}{8}$?

A -0.71 **B** 0.71 **C** -0.87 **D** 0.87

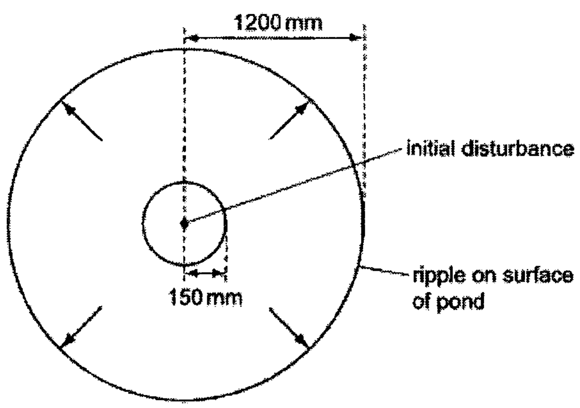
15 In a horizontal spring-mass system, a mass m oscillates with a frequency f and an amplitude x. The total energy of the oscillating system is E.

What is the total energy of a spring-mass system with a mass 0.50 m, frequency 3.0 f and amplitude 0.40 x?

A 0.24E **B** 0.60E **C** 0.72E **D** 1.8E

16 Ripples on the surface of a pond spread out in circles from the point of an initial disturbance. Assume that the energy of the wave is spread over the entire circumference of the ripple.

For one such ripple, the amplitude of the ripple at a distance of 150 mm from the disturbance is 2.0 mm.



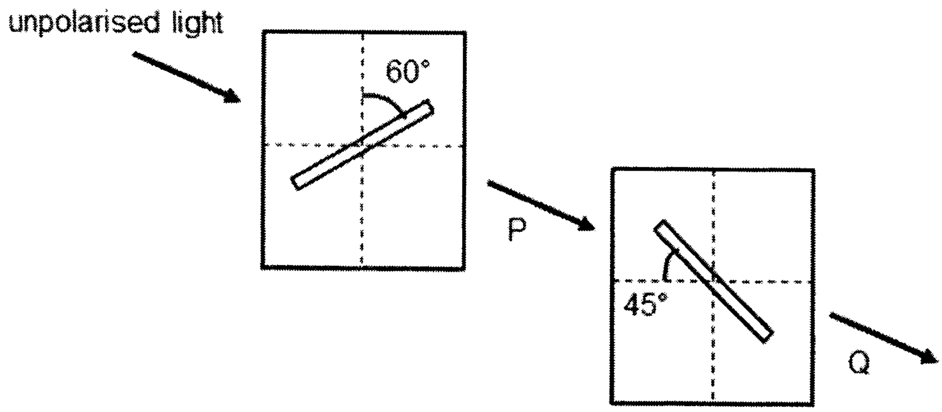
What will be the amplitude of the ripple at a distance of 1200 mm from the disturbance?

(Assume no energy is lost in the propagation of the ripple.)

A 0.031 mm **B** 0.13 mm **C** 0.25 mm **D** 0.71 mm

17 A beam of unpolarised light with amplitude A and intensity I is passed through two optical polarisers.

The first polariser's transmission axis is oriented at 60° to the vertical, while the second polariser's transmission axis is oriented at 45° to the horizontal.

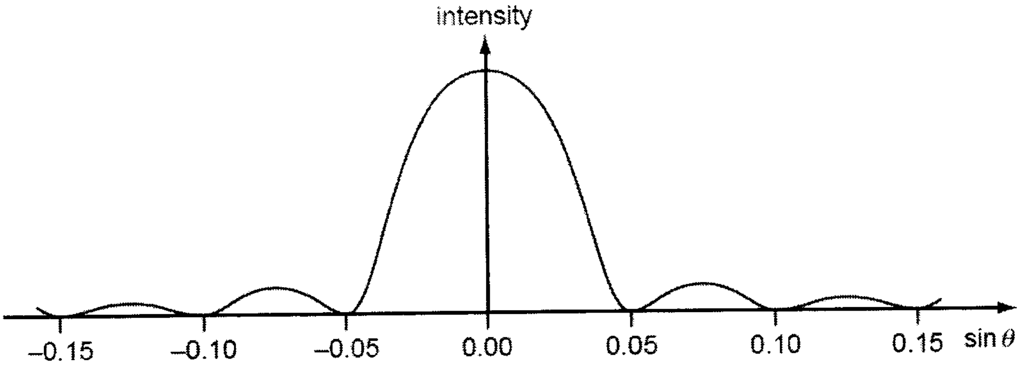


What is the intensity of the light at P and amplitude of the light at Q?

	Intensity of light at P	Amplitude of light at Q
A	$\frac{1}{\sqrt{2}}I$	$A\sin 15^\circ$
B	$\frac{1}{\sqrt{2}}I$	$\frac{1}{2}A\sin 15^\circ$
C	$\frac{1}{2}I$	$A\sin 15^\circ$
D	$\frac{1}{2}I$	$\frac{1}{\sqrt{2}}A\sin 15^\circ$

18 A parallel, monochromatic beam of electromagnetic radiation is incident at right angles onto a single slit of width 0.010 mm.

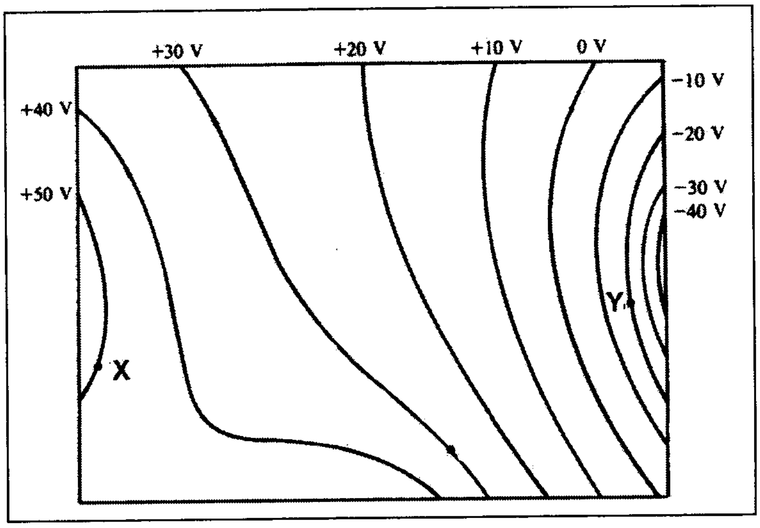
The graph shows how the intensity of the radiation varies with the sine of the angle θ through which the light is diffracted.



What is the wavelength of the radiation?

A 500 nm **B** 750 nm **C** 500 μm **D** 750 μm

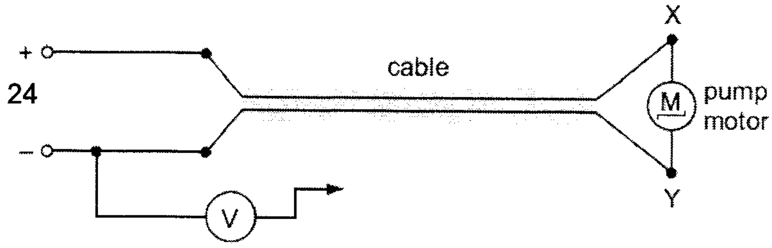
19 The diagram shows the electric equipotential lines in a non-uniform electric field.



An electron moves from point X to Y. Which of the following is correct with regard to the comparison of the electric potential energy *U* as well as the magnitude of the electric force *F* of the electron at point **X** and **Y**?

	Electric Potential energy	Magnitude of electric force
A	$U_Y < U_X$	$F_Y < F_X$
B	$U_Y < U_X$	$F_Y > F_X$
C	$U_Y > U_X$	$F_Y < F_X$
D	$U_Y > U_X$	$F_Y > F_X$

20 The diagram shows the electric motor for a garden pump connected to a 24 V power supply by an insulated two-core cable.

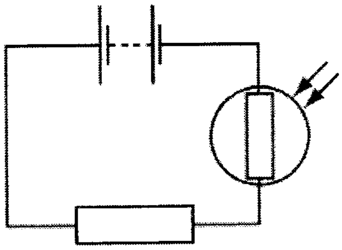


The motor does not work, so to find the fault, the negative terminal of a voltmeter is connected to the negative terminal of the power supply and its other end is connected in turn to terminals X and Y at the motor.

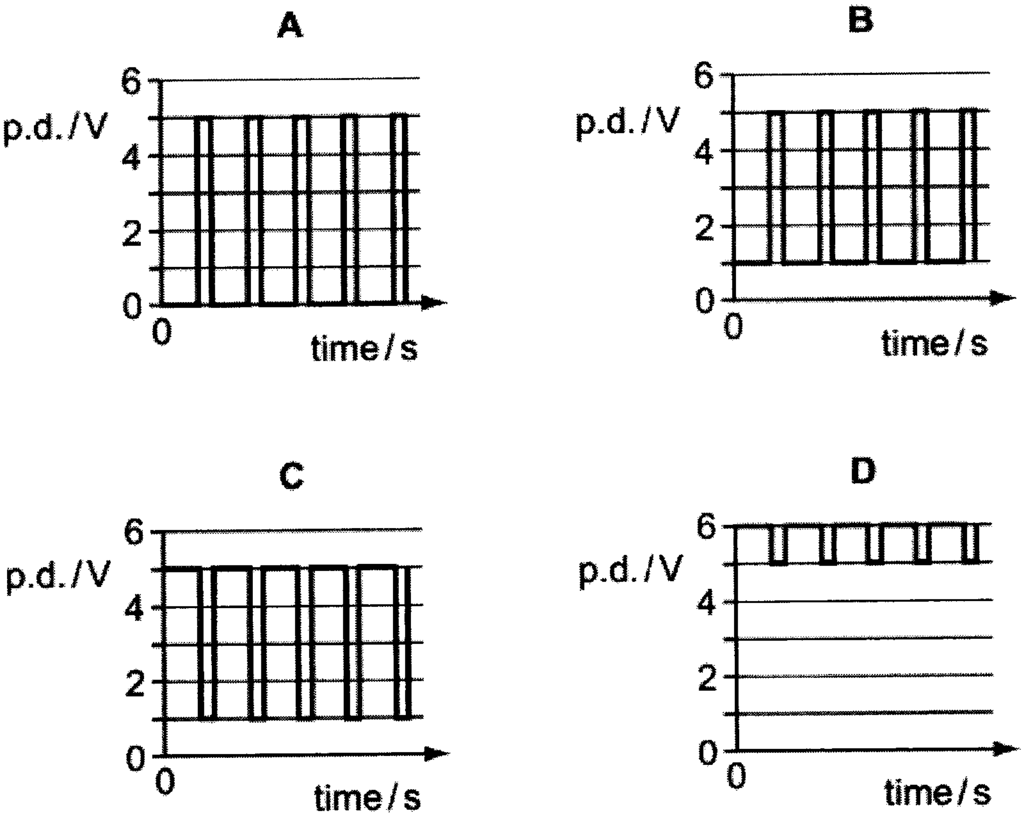
Which row represents the correct conclusion from two voltmeter readings?

	voltmeter reading connected to X / V	*voltmeter reading connected to Y / V*	*conclusion*
A	24	0	break in positive wire of cable
B	24	12	break in negative wire of cable
C	24	24	break in connection within the motor
D	24	24	break in negative wire of cable

21 The resistance of a light-dependent resistor (LDR) is 5 MΩ in the dark and 1 kΩ when light shines on it. The LDR is connected in series with a 6 V battery with negligible internal resistance and a 5 kΩ resistor. The circuit is placed in a dark room and the LDR is then illuminated by a flashing lamp



Which diagram shows how the p.d. across the 5kΩ resistor varies with time?



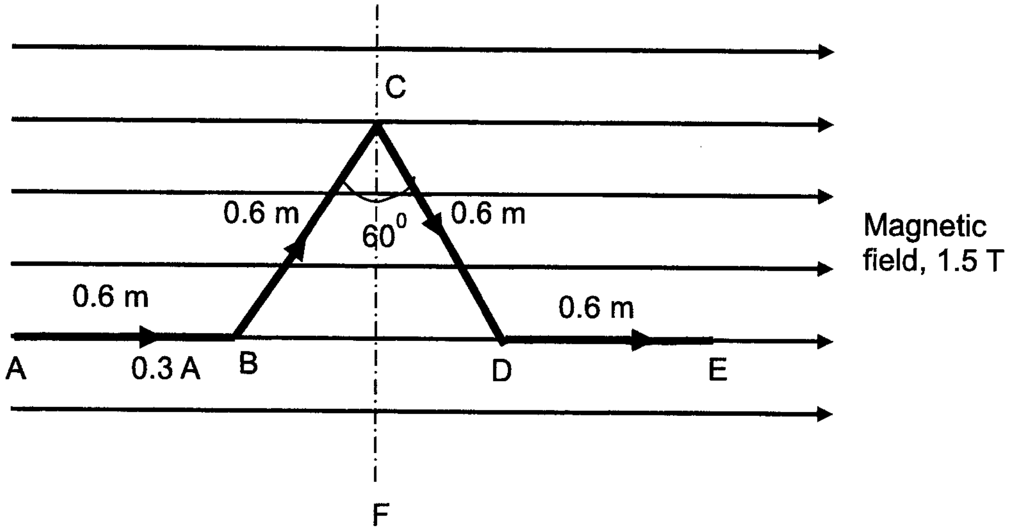
22 A steady current *I* dissipates a certain power in a variable resistor. When a sinusoidal alternating current is used, the variable resistor has to be reduced to one quarter of its initial value to obtain the same power. What is the peak value of the alternating current?

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

23 Two very long, straight, parallel wires carry equal steady current I in opposite directions. The distance between the wires is d. At a certain instant of time, a point charge q is at a point equidistant from the two wires, in the plane of the wires. Its instantaneous velocity v is perpendicular to this plane. The magnitude of the force due to the magnetic field acting on the charge at this instant is

A 0 N B $\frac{\mu_0 I q v}{2\pi d}$ C $\frac{\mu_0 I q v}{\pi d}$ D $\frac{2\mu_0 I q v}{\pi d}$

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

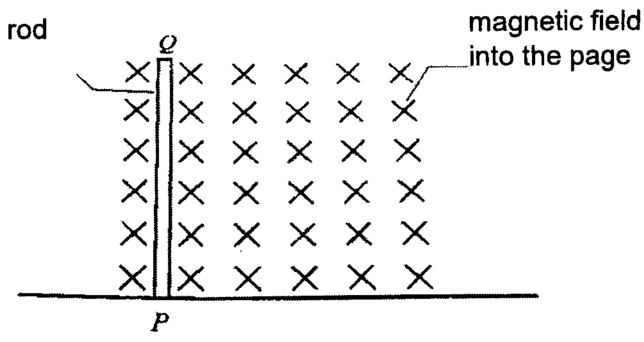


The conductor is inside a region of a uniform magnetic field having a magnetic field strength of 1.5 T. AB and DE are parallel to the magnetic field. Angle BCD is 60°. The lengths of segments AB, BC, CD and DE are 0.6 m each.

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

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

25 A vertical rod PQ is hinged to a flat surface at the end P and placed in a uniform magnetic field that acts into the page, as shown in the diagram. When the rod is lightly pushed to the right at the end Q, it swings downwards while still hinged at P.



Just before the end Q hits the flat surface, which of the following statements is correct?

A Q is at a higher electrical potential than P.

B An upward magnetic force acts on the rod.

C An induced current flows to Q from P

D The rod rotates clockwise with a constant angular speed.

26 The magnetic flux linking a conducting loop changes sinusoidally with time.

Which of the following describes the phase difference between the magnetic flux linkage and the e.m.f. induced?

A They are in phase with each other.

B They are out of phase by $\pi/4$ rad.

C They are out of phase by $\pi/2$ rad.

D They are out of phase by π rad.

27 A metal surface is illuminated with a beam of monochromatic electromagnetic radiation. Based on the photoelectric effect, photoelectrons may be emitted from the metal surface.

Which statement about the photoelectrons is correct?

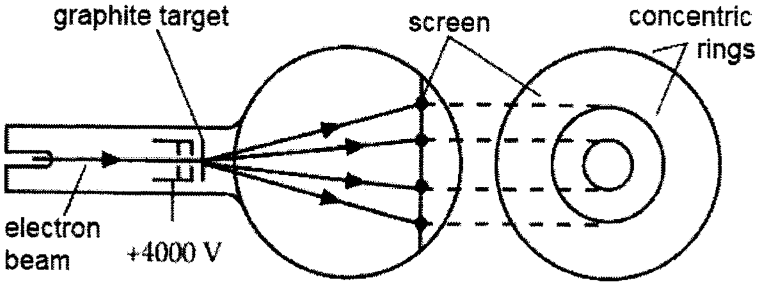
A No emission of photoelectrons occurs if the radiation is below a threshold intensity.

B Photoelectrons are emitted only if the wavelength of the radiation is greater than a minimum value.

C The maximum speed of the photoelectrons emitted increases when the intensity of the radiation increases provided frequency of radiation remains constant.

D The rate of emission of photoelectrons decreases when the frequency of the radiation increases at constant intensity.

28 In an experimental setup, a beam of accelerated electrons strikes an extremely thin layer of polycrystalline graphite target and concentric rings are seen on the tube face as shown.



If the setup is modified such that instead of electron beam, a beam of protons strike the graphite target with the same speed, what can be observed on the screen?

A The radii of the concentric rings decrease.

B The radii of the concentric rings increase.

C The radii of the concentric rings remain the same.

D No rings appear can be seen

29 A radioactive source consists of a mixture of two isotopes P and Q.

P has a half-life of 60 minutes and Q has a half-life of 30 minutes. The initial count rate recorded by a suitable counter is 800 min^{-1}. After 120 minutes the counter registers a count rate of 80 min^{-1}.

What was the initial count rate of P?

A 160 min^{-1} **B** 240 min^{-1}

C 480 min^{-1} **D** 640 min^{-1}

30 Uranium-238 decays by a series of alpha, beta and gamma decays into a final stable nuclide.

Which of the following is the final stable nuclide of the series?

A ^{205}Tl **B** ^{206}Pb

C ^{207}Pb **D** ^{208}Pb

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TEMASEK JUNIOR COLLEGE
2025 JC2 PRELIMINARY EXAMINATION
Higher 2

TEMASEK JUNIOR COLLEGE

CANDIDATE NAME	

CENTRE NUMBER	S					INDEX NUMBER	

PHYSICS **9749/02**

Paper 2 **29 August 2025**

Structured Questions **2 hour**

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your name and civics group 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	
1	
2	
3	
4	
5	
6	
7	
s.f	
Total	

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} or $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} Js
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	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin\omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos\omega t$
		=	$\pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin\omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

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

1 Fig. 1.1 shows a force diagram that represents a boat that is being lifted by two ropes so that the boat remains horizontal and travels vertically upwards at a constant speed after leaving the water.

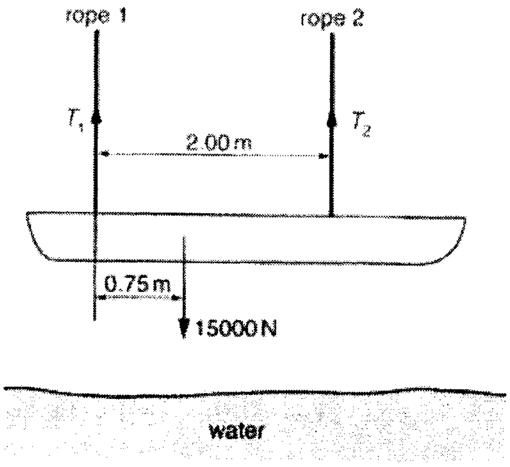

Fig. 1.1

The weight of the boat is 15000 N and the tensions in the ropes 1 and 2 are T_1 and T_2 respectively.

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(a) The position of the centre of gravity of the boat is not at its midpoint. Suggest what this implies about the distribution of mass in the boat.

....

....

.... [1]

(b) Explain two conditions required for the boat to be in a state of equilibrium while it is moving upwards.

....

....

....

.... [2]

(c) Determine the tension in the two ropes

T_1 = ... N

T_2 = ... N [3]

(d) The two ropes are connected to a motor.
Calculate the minimum power generated by the motor to lift the boat off the water onto a 30.0 m cliff within a time of 12s.

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P = ... W [2]
[Total: 8]

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2 An open cube is placed in a liquid of density ρ, with a length l submerged as shown in Fig. 2.1. The cross-sectional area of the cube A is constant.

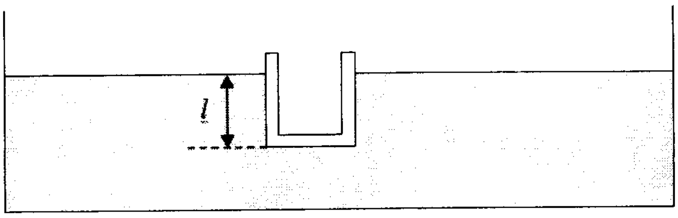

Fig. 2.1

When the cube is displaced downwards by a small distance from the equilibrium position and released, it resulted in simple harmonic motion of the cube. The frequency f of the cube is given by $f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$.

In an experiment, surface water waves of speed 0.90 m s^{-1} and wavelength 0.45 m are generated using a dipper shown in Fig. 2.2. The generated waves are incident on the cube, causing resonance in its up-and-down motion.

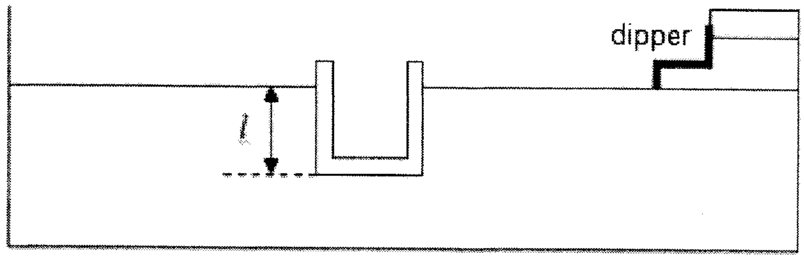

Fig. 2.2

(a) Explain why the cube undergoes *resonance.*

....

....

.... [2]

(b) Calculate the length *l*.

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l = ... m [2]

(c) Describe and explain what happens to the amplitude of the vertical oscillations of the cube after the following changes are made independently:

(i) the distance between the wave crests increases,

....

....

.... [2]

(ii) some water is poured into the cube, without sinking it.

....

....

.... [2]

(d) Explain why the value of l that you found in **(b)** is larger than the actual measurement of l in the experiment

....

....

....

....

.... [2]

[Total: 10]

3 A sound wave that is *propagating towards the left* is represented by the two graphs below.
Fig. 3.1 shows the variation with position along the wave of the displacement of the air particles from their equilibrium position at time $t = 0$.
Fig. 3.2 shows the variation with time t of the displacement of an air particle from its equilibrium position.

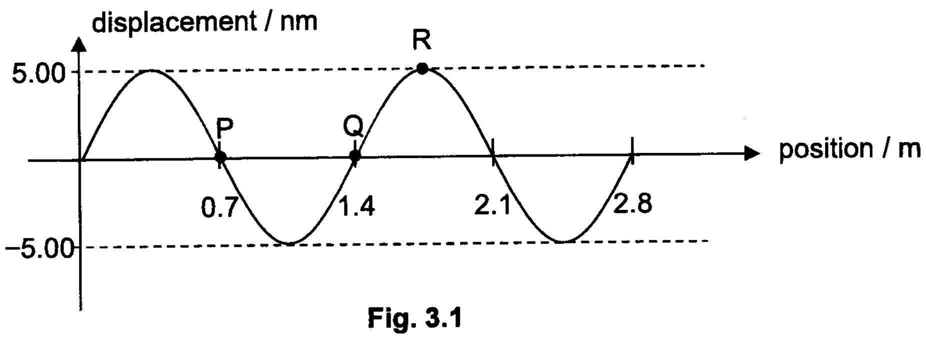

Fig. 3.1

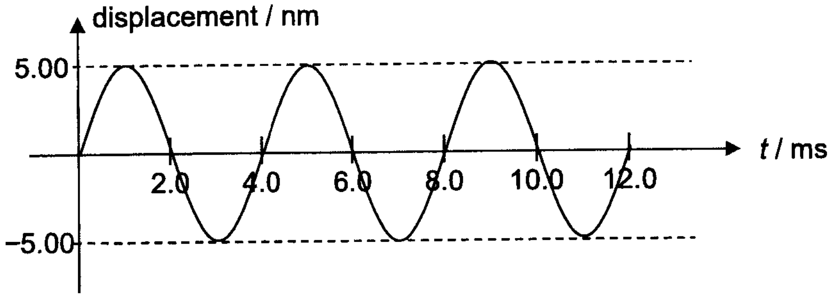

Fig. 3.2

(a) Calculate the speed of the sound wave.

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

(b) Fig. 3.1 shows three particles P, Q and R along the sound wave.
Taking rightwards to be positive, identify the particle that is

(i) instantaneously at rest at $t = 0$,

particle = ... [1]

(ii) at the centre of a rarefaction at $t = 0$.

particle = ... [1]

(iii) Explain why displacement-time graph for particle Q is represented by Fig. 3.2.

.... [1]

(c) (i) Sketch in Fig. 3.1 the graph of the wave 1.0 ms later. Label the graph Y. [2]

(ii) Particle S is 0.70 m to the right of particle R. [2]

Sketch in Fig. 3.2, the graph that corresponds to particle S. Label the graph Z.

[Total: 9]

4 (a) Two coherent light wavetrains having the same plane of polarization meet at a point. State two conditions that must be fulfilled before **totally destructive interference** can occur.

1. ....

....

2. ....

.... [2]

(b) Fig. 4.1 shows an experiment to demonstrate interference effects with microwaves. A transmitter, producing microwaves of wavelength λ is placed in front of two slits separated by a distance a. A receiver is used to detect the strength of the resultant wave at different points along the line YZ which is at a distance D in front of the slits.

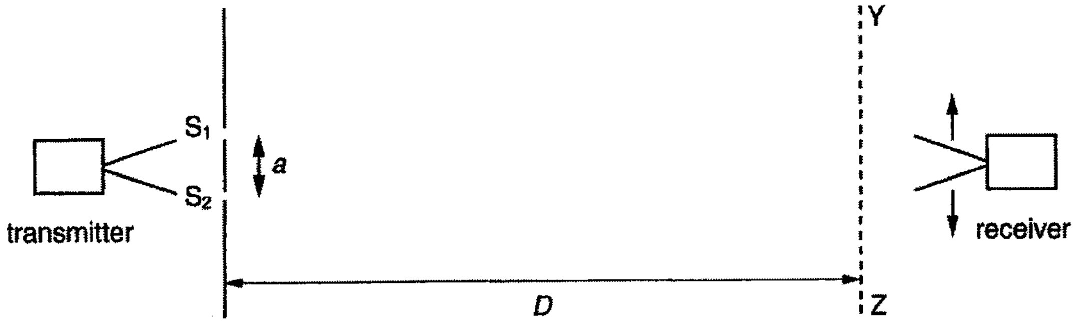

Fig. 4.1

(i) Explain, in terms of the path difference between the wavetrains emerging from the slits S_1 and S_2, why a series of interference maxima are produced along the line YZ.

....

....

....

.... [2]

(ii) State how the distance *x* between neighbouring maxima on the line YZ would change if the distance *a* was doubled while the distance *D* was halved.

....

.... [1]

(iii) In another experiment using the apparatus in Fig. 4.1, a student notices that the distances between the maxima are not equal. Suggest a reason for this difference.

....

.... [1]

(iv) Describe how you could test whether the microwaves leaving the transmitter were plane polarised.

....

....

....

.... [2]

(c) The microwave transmitter is now placed in front of a plane reflector as shown in Fig. 4.2 and stationary waves are set up in the space between them.

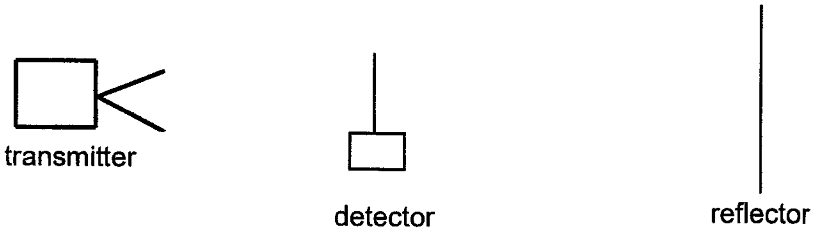

Fig. 4.2

A detector is moved between the transmitter and the reflector at a constant speed of 10 mm s^{-1}. The frequency of detection of minima is 1.5 Hz.

Determine the frequency of the microwave oscillator.

frequency = ... Hz [3]

(d) In a separate experiment, white light is incident on a diffraction grating, as shown in Fig. 4.3.

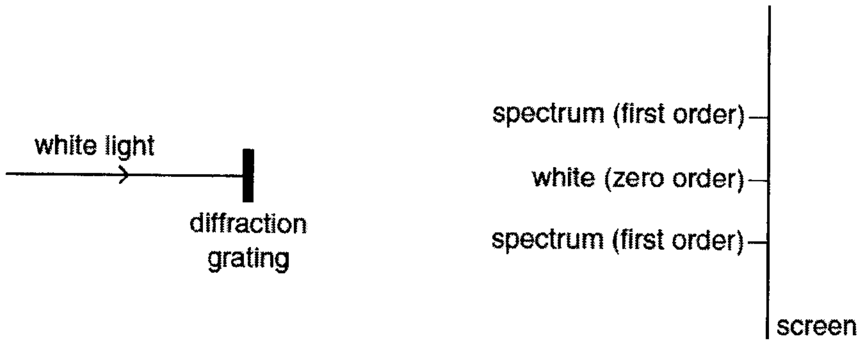

Fig. 4.3

The diffraction pattern formed on the screen consists of a white light band in the zeroth order and coloured spectra in other orders.

Describe how the principle of superposition is used to explain

(i) the presence of white light in the zeroth order.

....

....

....

.... [2]

(ii) the difference in the angular positions of red and blue light in the first-order spectra.

....

....

....

.... [2]

[Total: 15]

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5 **(a)** The variation of an alternating voltage V_P in volts with time t in seconds is given by

$$V_P = 170 \sin (314t)$$

Determine

(i) the r.m.s. potential difference $V_{r.m.s.}$

$V_{r.m.s}$ = ... V [1]

(i) the period, T of the voltage supply.

T = ... s [1]

(b) The alternating voltage V_P is connected to the primary coil of a transformer as shown in Fig. 5.1.

An electric heater with resistance 130 Ω is connected to the secondary coil of the transformer.

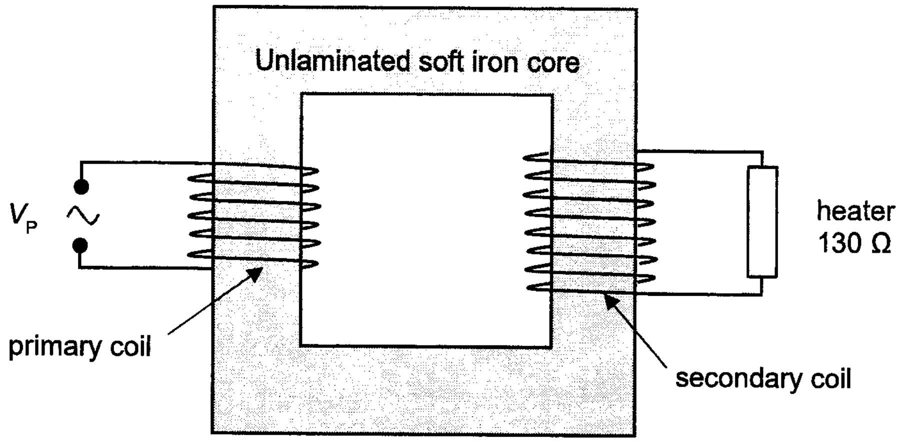

Fig. 5.1

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The primary coil consists of 2000 turns and the secondary coil consists of 3500 turns.

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(i) Determine peak potential difference, V_S of the secondary coil.

V_s = ... V [2]

(ii) Determine the peak current, I_P in the primary coil.

I_P = ... A [2]

(iii) It was subsequently verified that the actual peak current, I_P in the primary coil is 8.00 A. Using this data, determine the efficiency of the transformer.

efficiency = ... % [1]

(iv) Suggest what could have led to the efficiency calculated in **(b) (iii)**.

....

....

....

.... [1]

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(c) A diode and another identical heater are connected to the secondary coil as shown in Fig. 5.2.

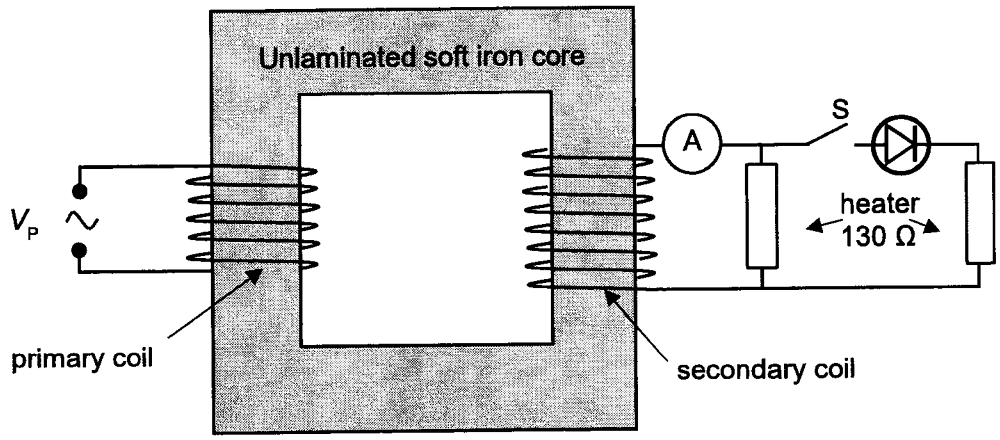

Fig. 5.2

Sketch on the axes of Fig. 5.3, the variation with time of the current *I* in the secondary coil when switch S is closed. Label the axes with appropriate values, Include on your graph a time equal to two periods of the alternating potential difference.

[2]

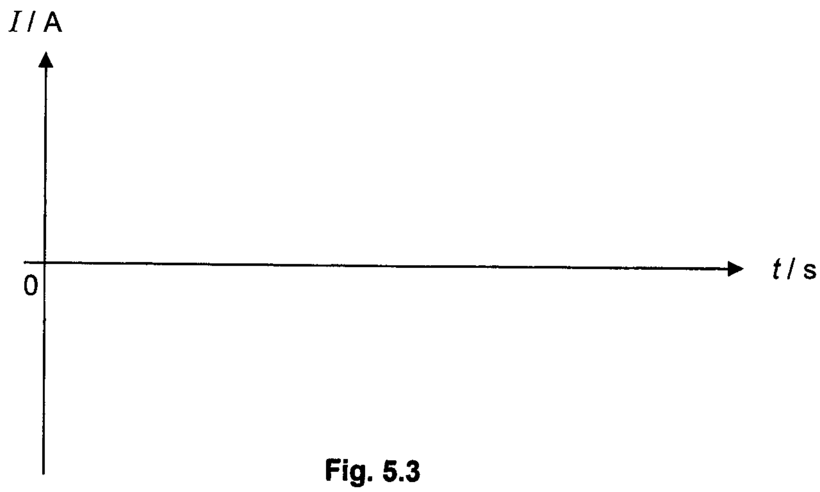

Fig. 5.3

[Total :10]

6 A solenoid of length 15 cm, cross-sectional area 2.5×10^{-4} m^2, and 3000 turns is placed in the middle of a coil of 1500 turns as shown in Fig. 6.1. The solenoid is connected to a battery, a rheostat and an ammeter. The coil is connected to a galvanometer.

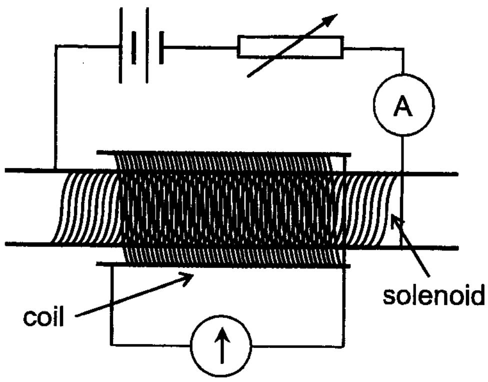

Fig. 6.1

Fig. 6.2 shows the variation with time t of the current I through the solenoid as the resistance of the rheostat is varied.

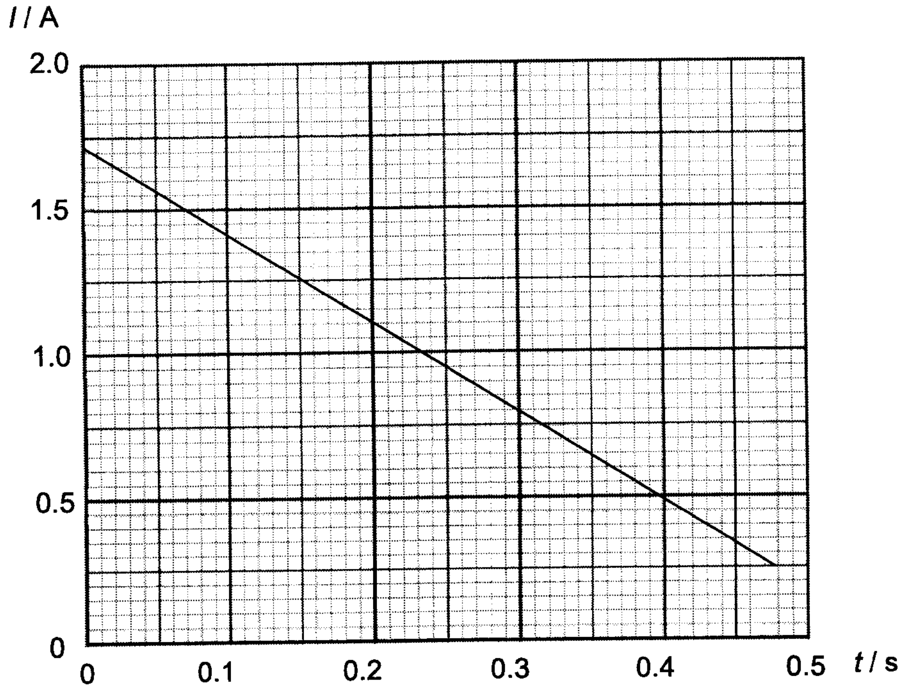

Fig. 6.2

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(i) Show that the magnetic flux density produced in the solenoid at $t = 0.070$ s is 3.77×10^{-2} T

[2]

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

emf = ... V [3]

(iii) State and explain the direction of the current through the galvanometer.

....

....

....

....

....

....

.... [3]

[Total :8]

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7 In 1977, two robotic interstellar probes, Voyager 1 and Voyager 2, were launched. The spacecrafts as shown in fig. 7.1, now still travelling at around 17 km s^{-1}, are the most distant human-made objects from Earth and the first two to leave the Solar System. Having operated for 48 years as of 2025, they still receive routine commands and transmit data back to Earth.

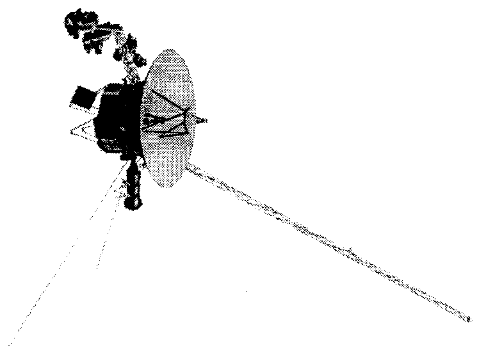

Fig. 7.1

Their trajectories were calculated to bring them very close to the planets Jupiter, Saturn, Uranus and Neptune, which were in a rare alignment at that time. Besides being able to collect data of these planets, their close fly-bys also allowed them to use the gravitational attraction of the planets to increase their momentum and bend their trajectories from one planet to the next as shown in fig. 7.2. Without such *gravity assists*, the chemical energy available from the propellant fuel carried by the spacecraft would not allow them to even reach Saturn before the Sun's gravity pulled them back. Saturn is roughly 9.6 AU from the Sun. (1 AU, or astronomical unit, is roughly the distance from the Sun to the Earth.)

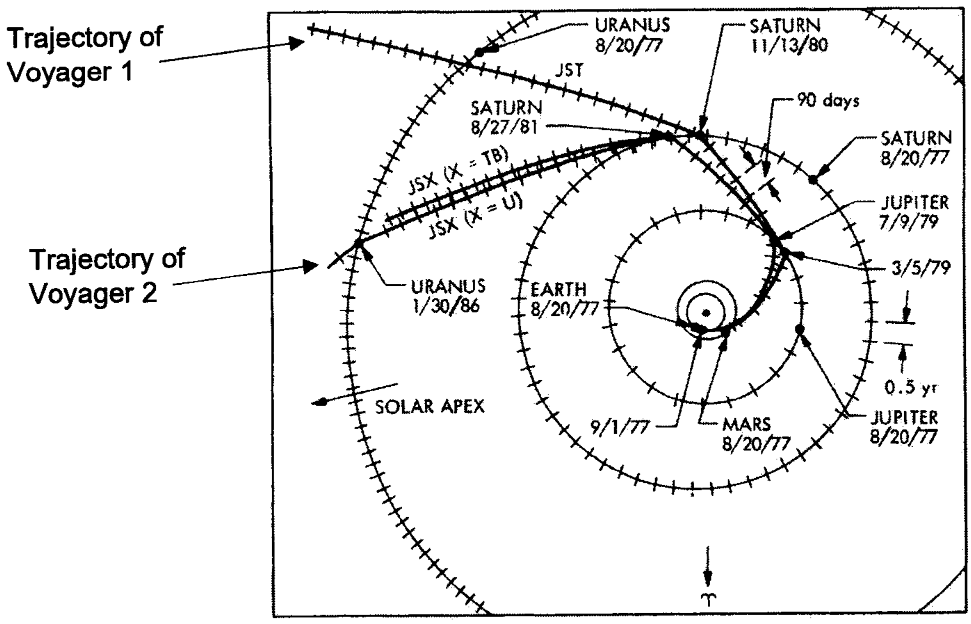

Fig. 7.2

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Data

	Mass / kg	Average distance from the Sun / AU
Sun	2.0×10^{30}	0.0
Earth	6.0×10^{24}	1.0
Jupiter	1.9×10^{27}	5.2
Saturn	5.7×10^{26}	9.6

The Voyager spacecraft each has a mass of 773 kg. On board are scientific cameras and sensors, a power source, a radio communication system, and small rocket thrusters that expel propellant.

The variation with distance (from the Sun) of the speed of Voyager 2 is shown in Fig. 7.3.

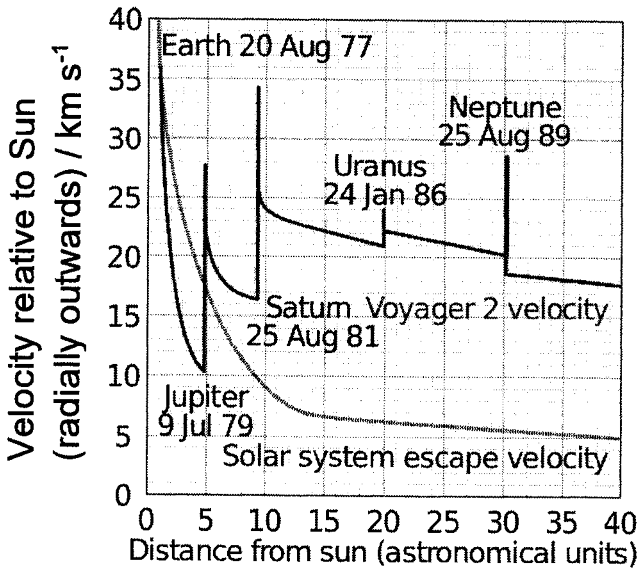

Fig. 7.3

The spacecraft reached Jupiter in 1979. Both spacecraft used the gravity of Jupiter to bend their trajectories toward Saturn. The two spacecraft next visited Saturn, reaching the planet in 1980 and 1981.

Electrical power is supplied by three radioisotope thermoelectric generators (RTGs), which use the heat produced from the nuclear fission of its radioactive plutonium-238 fuel to generate electricity using thermocouples. They provided approximately 470 W when the spacecraft was launched. Plutonium-238 decays with a half-life of 87.74 years.

The two spacecraft transmit radio signals to Earth. As they move farther away from the Earth, their radio signals reaching us become weaker, making communication increasingly difficult. In the 1980's, to address this problem, the total receiving area of the antennae on Earth was increased. It is estimated that, by 2030, the intensity of the radio signals from Voyager 1 arriving at Earth will be too low to be detected.

In 1990, as it was about to leave the Solar system, Voyager 1 took a photograph of Earth from a distance of 40.47 AU. Due to the great distance, Earth appeared as only a tiny dot in the photograph.

(a) The Earth takes 365 days to orbit the Sun. The orbital path can be assumed to be circular in shape with a radius of 1 AU (astronomical unit).

Show that the distance represented by 1 AU is 1.50×10^{11} m.

1 AU = ... m [3]

(b) **(i)** Suggest why it is reasonable to assume that the gravitational influence of all the planets is small compared with that of the Sun when determining the motion of the spacecraft in the solar system.

....

....

.... [1]

(ii) Determine the minimum speed that an object near Jupiter must have for it to be able to overcome the Sun's gravitational field and escape to infinity. Explain your working.

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

(iii) Explain how Fig. 7.3 shows that the Voyager 2 was not travelling fast enough from Jupiter on 9 July 1979 to escape from the solar system.

....

....

.... [1]

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(iv) Using Fig. 7.3, calculate the gain in momentum by Voyager 2 as it interacted with Jupiter's gravitational field during its flyby.

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

(v) Using the principle of conservation of momentum or otherwise, explain how Voyager 2 gains momentum as it flew by Jupiter.

....

....

.... [1]

(c) **(i)** Calculate the percentage decrease in the activity of the plutonium-238 radioactive fuel in the RTG over a duration of one year.

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Percentage decrease = ... % [3]

(ii) By 2036, the activity of the plutonium-238 will be 62.3 % of its initial activity when the spacecraft was launched.
Estimate the power available to the spacecraft in 2036.

Power available = ... W [2]

(iii) Explain why the receiving area of the antennae on Earth was increased in the 1980s.

....

....

....

.... [2]

(d) The angular diameter of a planet is the angle subtended by its diametrically opposite edges at the position of the observer.

The radius of the Earth is 6.4×10^6 m.

Calculate the angular diameter of the Earth from the point of view of Voyager 1 when it took the photograph of Earth in 1990. Express your answer in radians.

Angular diameter of Earth = ... rad [2]

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[Total: 20]

BP~527

TEMASEK JUNIOR COLLEGE
2025 JC2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CENTRE NUMBER S

INDEX NUMBER

PHYSICS **9749/03**

Paper 3 **17 September 2025**

Longer Structured Questions **2 hour**

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your name and civics group 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.

Section A
Answer **all** questions.

Section B
Answer **one** question only
You are advised to spend one and a half hour 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	
1	
2	
3	
4	
5	
6	
7	
8	
s.f	
Total	

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} or $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} Js
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	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin\omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos\omega t$
		=	$\pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin\omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{ln2}{t_{1/2}}$

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Section A

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

1 Using a handheld catapult, a student projected a stone of mass 130 g, horizontally from a building rooftop of height 32 m, as illustrated in Fig. 1.1, aiming for it to land in an adjacent river.

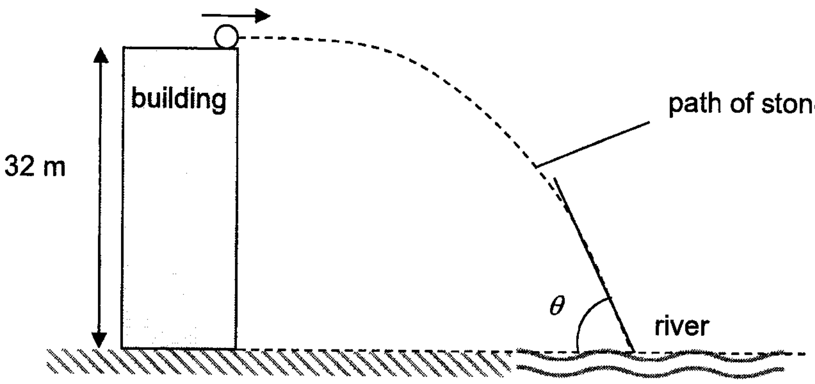

Fig. 1.1

Air resistance is negligible and the stone enters the water at a speed of 34 m s^{-1} after time t s.

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(a) Determine for the stone as it hits the water,

(i) the vertical component of the velocity of the stone

vertical component of velocity = ... m s^{-1} [2]

(ii) the angle θ to the horizontal of the stone's plunge

θ = ... ° [2]

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(b) Use *energy* considerations to suggest why, if the stone causes a large splash on hitting the water surface, it decelerates in a shorter distance than when no splash is produced.

....

....

....

.... [1]

(c) (i) On Fig. 1.2, sketch the variation with time *t* of the potential energy E_p of the stone with respect to the water level.

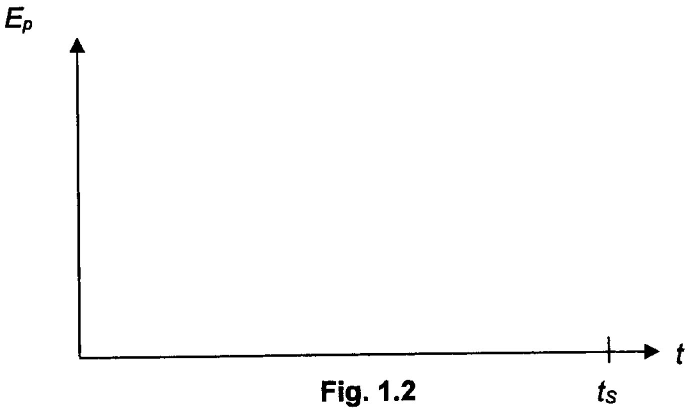

Fig. 1.2

[2]

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(ii) On Fig. 1.3, sketch the variation with time *t* of the kinetic energy E_k of the stone for the same period.

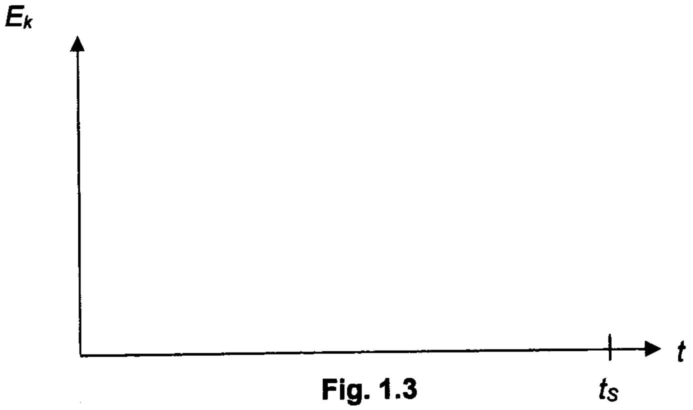

Fig. 1.3

[1]

[Total: 8]

2 (a) State the relation between force and momentum.

....

....

.... [1]

(b) A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 2.1.

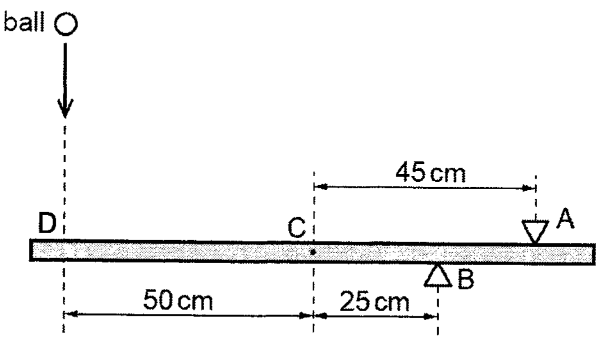

Fig. 2.1

Support A is 45 cm from the centre of mass C of the bar while support B is 25 cm from C.

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

The variation with time t of the velocity v of the ball before, during and after hitting the bar is shown in Fig. 2.2.

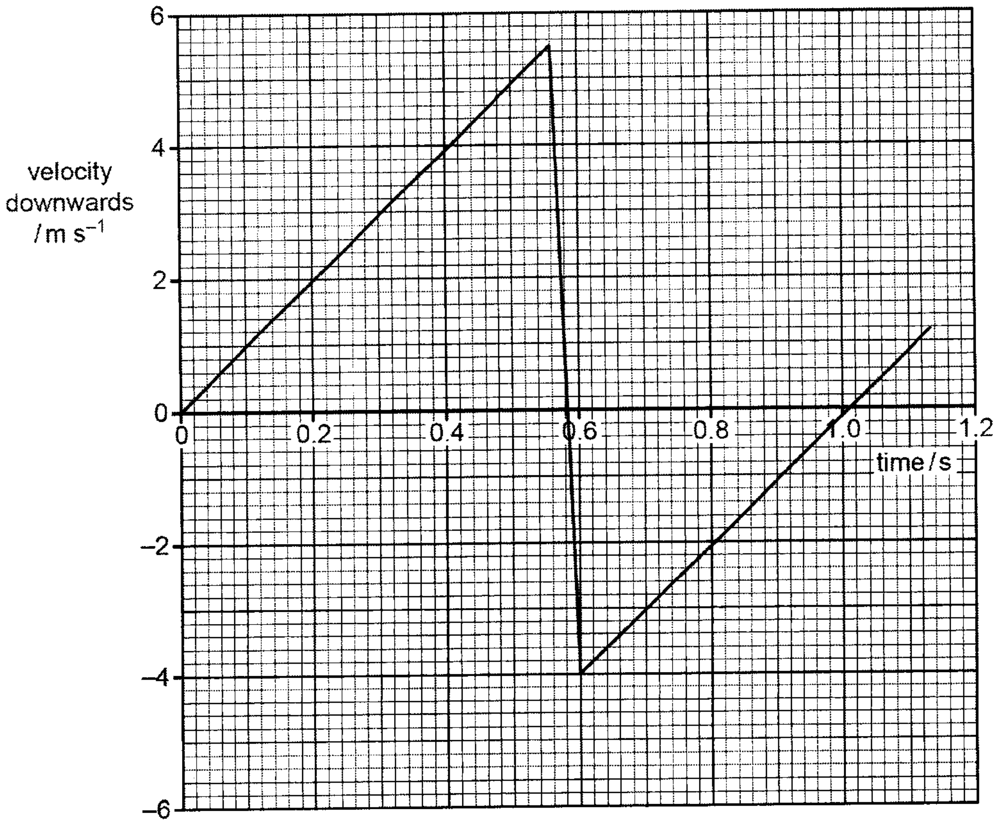

Fig. 2.2

For the time that the ball is in contact with the bar, use the data provided to

(i) determine the change in momentum of the ball,

change in momemtum = ... kg m s^{-1} [2]

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DO NOT WRITE IN THIS MARGIN

(ii) show that the magnitude of the average force exerted by the ball on the bar is 35 N,

[2]

(iii) calculate the average force exerted on the bar by the support A.

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DO NOT WRITE IN THIS MARGIN

force = ... N [2]

(iv) determine the net energy lost by the ball due to the inelastic collision with the bar at D.

energy = ... J [1]

(c) The ball is now dropped under the same conditions, this time with a light cushion fitted at point D.

Explain the effect on your answer to **(b)(iii)** when the ball makes contact at point D.

....

....

.... [2]

[Total: 10]

3 A cycle of changes in pressure, volume and temperature of gas inside a cylinder of a petrol engine with a movable piston is illustrated in Fig. 3.1. The gas is assumed to be ideal.

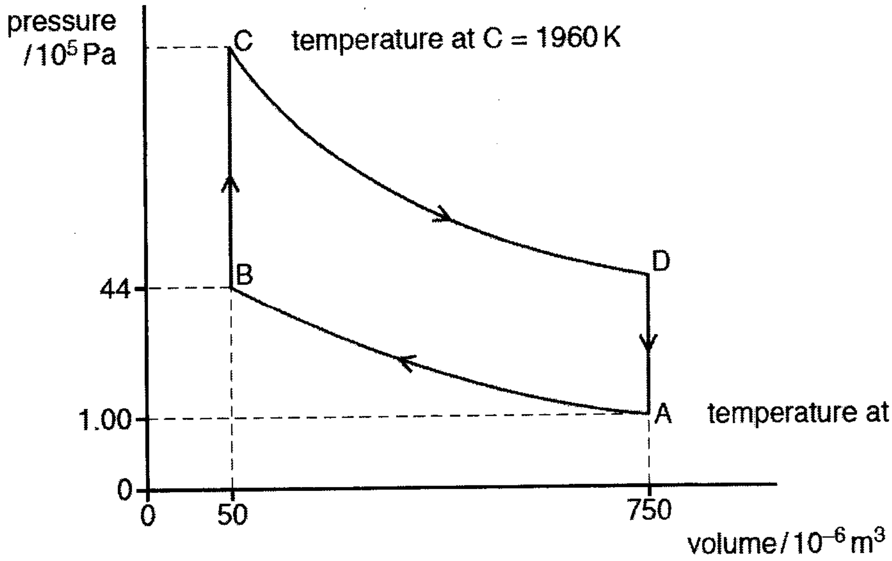

Fig. 3.1 (not to scale)

There are four stages in the cycle.

stage	description
A to B	Rapid compression of the gaseous petrol/air mixture with the temperature rising from 300 K at A and the pressure rising to 44 × 10^5 Pa at B.
B to C	The petrol/air mixture is exploded, resulting in an almost instant rise in pressure. At C the temperature has risen to 1960 K.
C to D	Rapid expansion and cooling of the hot gases.
D to A	Return to the starting point of the cycle.

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

....

....

.... [1]

(ii) Use the values in Fig. 3.1 to determine the number of moles present in the gases in the cycle.

number of moles = ... moles [2]

(b) Complete the table in Fig. 3.2 showing the work done on the gas, the heat supplied to the gas and the increase in the internal energy of the gas, during the four stages of one cycle.

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stage	work done **on** gas /J	heat supplied **to** gas /J	**increase** in internal energy of gas / J
A to B	+ 360	0	
B to C		+ 670	
C to D		0	− 810
D to A			

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Fig. 3.2

[4]

(c) Explain qualitatively how molecular movement causes the fall in temperature of the gas during the stage from C to D.

....

....

.... [2]

(d) Explain using Fig. 3.2 why the engine can be used in cars.

....

.... [1]

[Total: 10]

4 A cell P, a fixed resistor R and a uniform resistance wire AB are connected in a circuit as shown in Fig. 4.1.

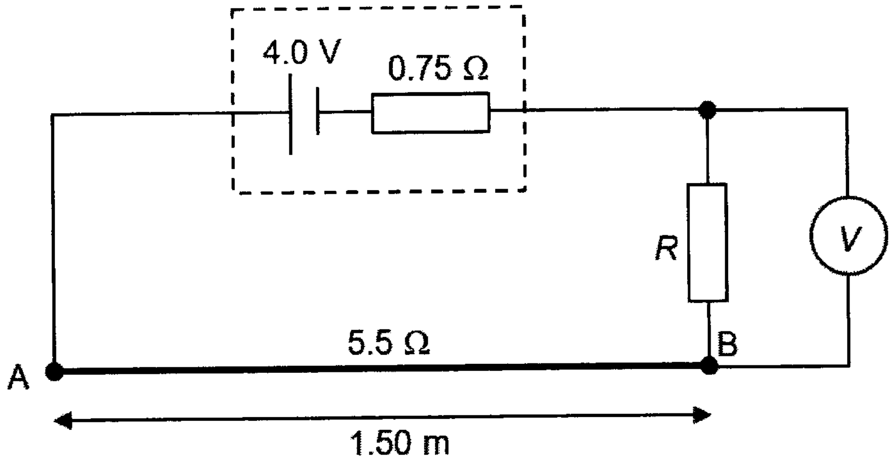

Fig. 4.1

Cell P has e.m.f. 4.0 V and internal resistance 0.75 Ω. Wire AB has length 1.50 m and resistance 5.5 Ω. The voltmeter reads 1.3 V.

(a) Show that the potential difference across AB is 2.4 V.

[2]

(b) A cell Q and a sensitive ammeter are connected to the circuit in Fig. 4.1, as shown in Fig. 4.2.

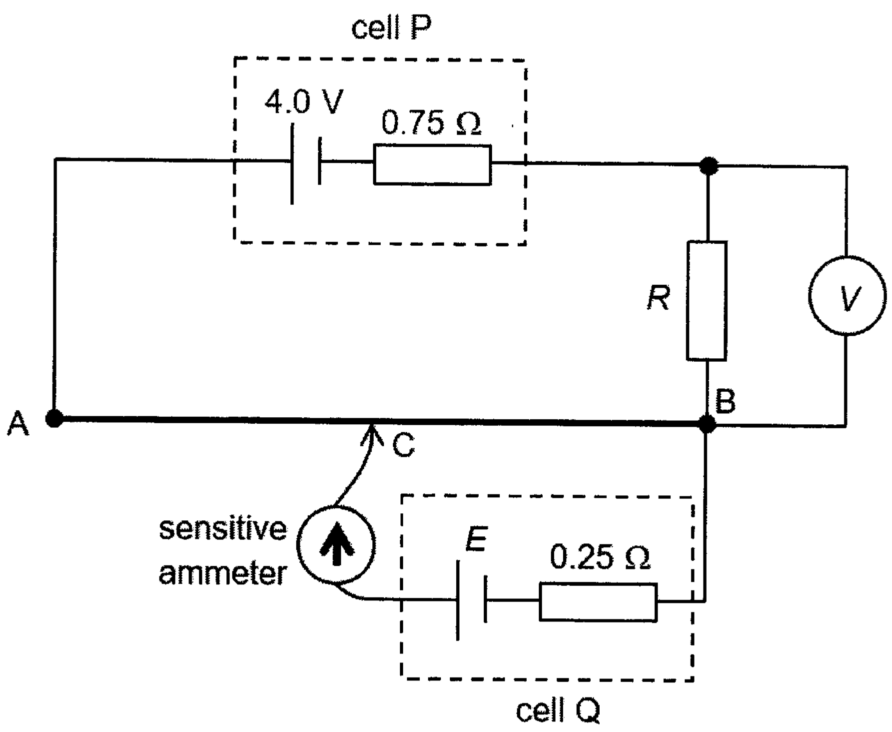

Fig. 4.2

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Cell Q has e.m.f. *E* and internal resistance 0.25 Ω. The ammeter reads zero when the length of AC is 0.56 m.

(i) Determine *E*.

E = ... V [2]

(ii) There is a reading on the ammeter when the connection C is shifted closer to A. State and explain the direction of the current across cell Q.

....

....

....

.... [2]

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(c) The resistance wire AB is detached from the circuit and wound in a circular manner such that there are 2 semi-circular turns above and 3 semi-circular below XY as shown in Fig. 4.3.

X and Y are two metallic fasteners with negligible resistance. They are used to secure the wire so that the distance between X and Y is the diameter of the coil.

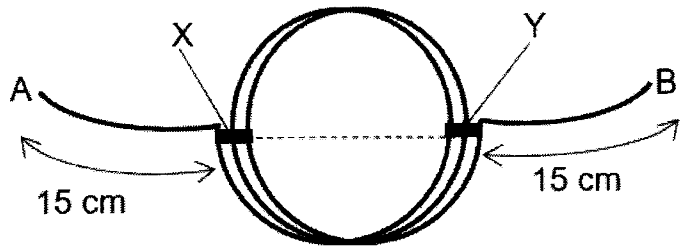

Fig. 4.3

(i) Show that the resistance of wire AB when coiled in this manner is 1.3 Ω.

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[2]

(ii) An e.m.f. source is again connected across AB. State and explain whether the drift velocity of electrons is greater in section AX or section XY.

....

....

....

.... [2]

[Total: 10]

5 Charged particles, of speed 4500 m s^{-1} and mass 2.66×10^{-26} kg, are travelling in a narrow beam in a vacuum as shown in Fig. 5.1.

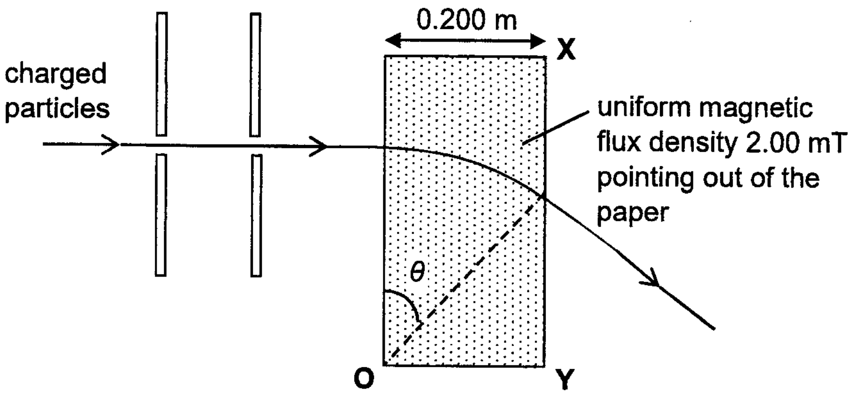

Fig.5.1

The charged particles enter a region of uniform magnetic flux density which is 0.200 m wide. The direction of the magnetic flux is pointing out of the paper.

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(a) (i) Using Newton's Law of motion, explain any changes in the speed of the particles as they move within and exit from the uniform magnetic field.

....

....

.... [2]

(ii) Given that the magnitude of the charge on the particles is e, calculate the radius of the circular motion of the charged particles in the uniform magnetic field.

radius = ... m [3]

(b) In another experiment, similar charged particles are now fired into the magnetic field in Fig. 5.1 with different momentum.
Determine the maximum momentum of particles such that the particles will not exit the magnetic field through XY.

momentum = ... $kg\ m\ s^{-1}$ [3]

[Total: 8]

6 **(a)** Some electron energy levels of the hydrogen atom are illustrated in Fig. 6.1.

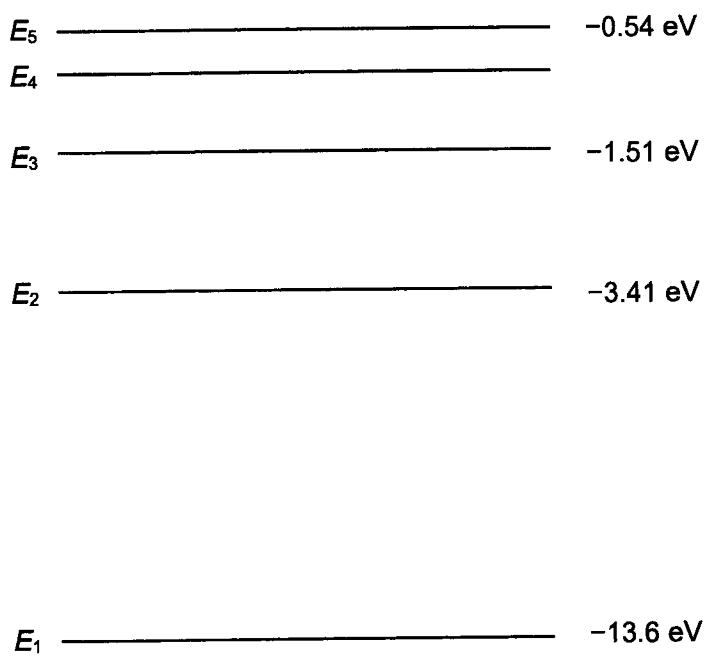

Fig. 6.1 (not to scale)

(i) By considering the transitions between these energy levels, state how many spectral emission lines might be produced by transitions among these levels.

number of lines = ... [1]

(ii) The wavelength of a photon produced by the transition from energy level E_4 to E_1 is 97.5 nm. Calculate the energy level E_4.

energy = ... eV [2]

(b) The radiation emitted from hydrogen atoms is incident on the surface of a sheet of gold. The stopping potential for photoelectrons emitted from the gold surface is 8.13 V.

(i) Calculate the work function of the metal surface.

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work function = ... eV [2]

(ii) Calculate the momentum of the most energetic electrons emitted from the gold surface.

momentum = ... N s [2]

(iii) Hence, determine the de Broglie's wavelength of the electrons in **(b)(ii)**.

wavelength = ... m [2]

(iv) The speed of one of the photoelectrons emitted is measured to be 1.2×10^6 m s^{-1} to an precision of 0.0025 %.
Calculate the minimum uncertainty in the position of this photoelectron.

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minimum uncertainty in position = ... m [2]

(v) In theory, these emitted photoelectrons could be accelerated into a tungsten target via a very strong electric field to emit x-rays. Explain how a continuous spectrum of x-rays could be produced from this process.

....

....

....

....

.... [3]

[Total: 14]

Section B

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

7 **(a)** **(i)** State what is meant by a field of force.

....

....

.... [1]

(ii) Define electric field strength.

....

....

.... [2]

(iii) Suggest why, when defining electric field strength, the test particle must be stationary.

....

....

.... [1]

b **(i)** State the relation between electric field strength *E* and potential *V*.

....

....

.... [1]

(ii) Two charged metal spheres A and B, of diameters 18 cm and 12 cm respectively, are isolated in space, as shown in Fig. 7.1.

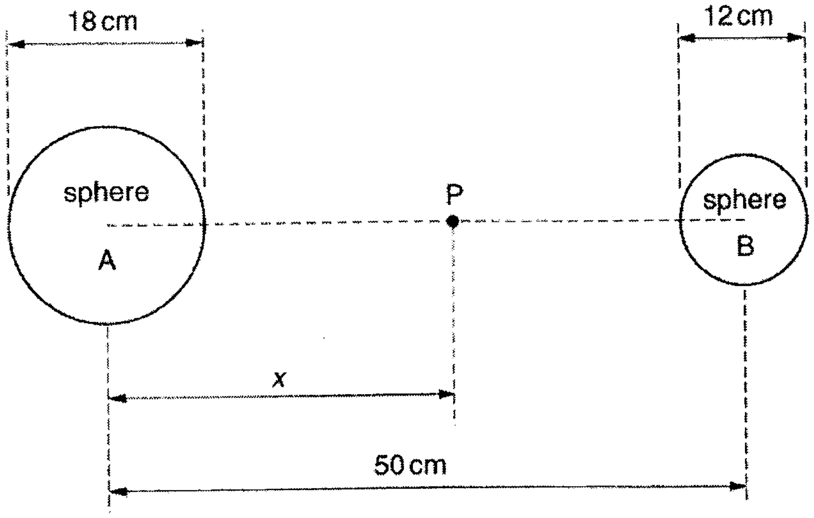

Fig. 7.1

The centres of the spheres are separated by a distance of 50 cm. Point P is at a distance *x* from the centre of sphere A along the line joining the centres of the two spheres. The variation with *x* of the electric potential *V* at P is shown in Fig. 7.2.

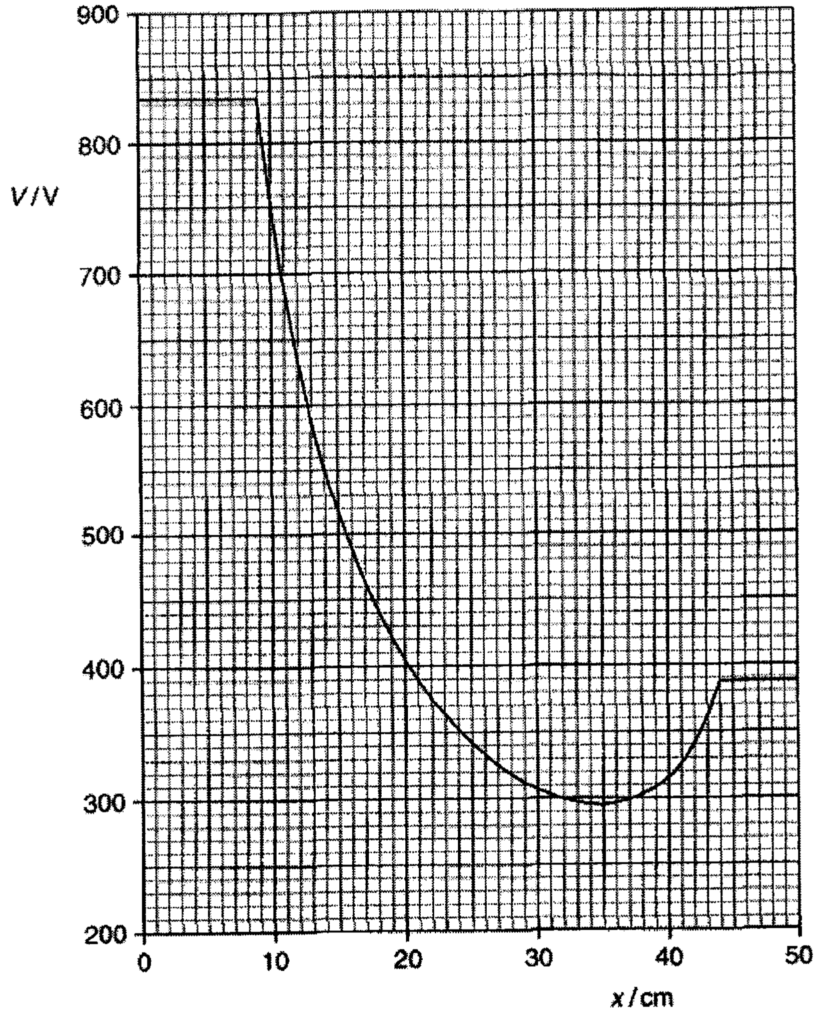

Fig. 7.2

1. State and explain the direction of the electric field at the point P, where x = 25.0 cm .

....

....

.... [2]

2. Use Fig. 7.2 to determine the force on an electron placed at point P, where x= 35.0 cm.

force = ... N [3]

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3. By making reference to electric fields, explain why the potential is constant for distances between x = 0 and x = 9.0 cm.

....

....

.... [2]

(c) A student states that the potential V decreases with distance x for distances between x = 10 cm and x = 25 cm according to the expression

$$Vx = \text{constant}.$$

(i) Without drawing a graph, use data from Fig. 7.2 to show whether the student is correct.

[3]

(ii) Suggest an explanation for your conclusion in **(i)**

....

....

.... [1]

(d) An electron, initially at rest a long distance from the spheres in (b), approaches the spheres and passes between the two spheres.

(i) Calculate the minimum speed of the electron as it crosses the line joining the centres of the two spheres.

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

(ii) Describe the path of the electron for the minimum speed in **(i)**.

....

....

....

.... [2]

[Total: 20]

8 (a) An unstable nucleus of nucleon number (mass number) A undergoes α-decay, as illustrated in Fig. 8.1.

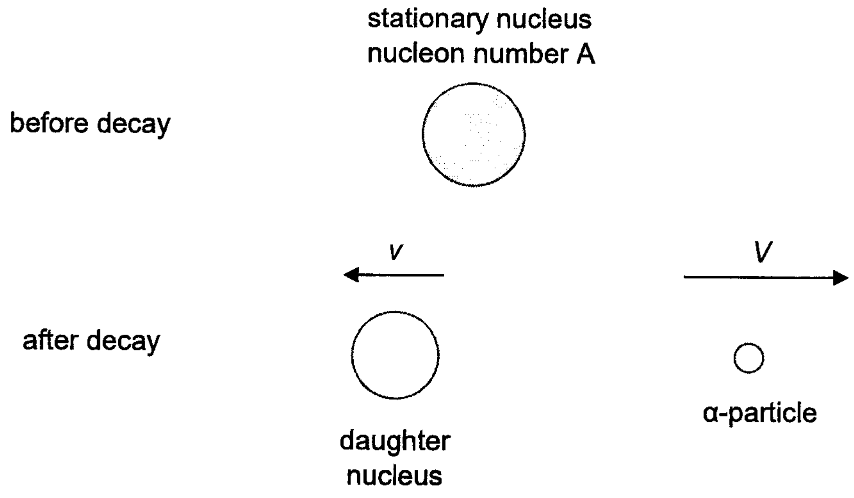

Fig. 8.1

The nucleus is stationary before the decay.

After the decay, the initial speed of the α-particle is V and that of the daughter nucleus is v.

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(i) State an equation, in terms of A, v and V, to represent conservation of linear momentum for this decay.

....

....[2]

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(ii) Show that the ratio

$$\frac{\text{initial kinetic energy of } \alpha\text{-particle}}{\text{initial kinetic energy of daughter nucleus}}$$

is equal to ($\frac{1}{4}A$ -1).

[3]

(b) Data for the α-decay of bismuth-212 ($^{212}_{83}Bi$) to form thallium-208 ($^{208}_{81}Tl$) are given in Fig. 8.2.

nucleus	mass of nucleus/ u
bismuth-212	211.9459
thallium-208	207.9374
helium-4	4.0015

Fig. 8.2

(i) Use the data of Fig. 8.2 to calculate, to two places of decimals, the energy released during the decay.

energy = ... MeV [4]

(ii) Use your answer in **(i)** to show that, based on the expression in **(a)(ii),** the energy of the α-particle is 6.42 MeV.

[2]

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(c) In practice, the α-particle is found to have an energy of 6.10 MeV, rather than 6.42 MeV, as calculated in **(b)(ii)**.

Suggest

(i) an explanation for the difference in energy,

....

....

....[1]

(ii) why it is likely that the thallium nucleus and the α-particle do not move off in opposite directions.

....

....

....

....

....

....[3]

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(d) Some data for the half-lives and decay constants of bismuth-212 and thallium-208 are given in Fig. 8.3.

nucleus	half-life/ s	decay constant/ s^{-1}
bismuth-212	....	1.9×10^{-4}
thallium-208	190	3.7×10^{-3}

Fig. 8.3

(i) Complete Fig. 8.3 by calculating the half-life of bismuth-212.

[1]

(ii) Initially, a radioactive source contains N nuclei of bismuth-212.

After two hours, it is found that the number of bismuth-212 nuclei has reduced to approximately $\frac{1}{4}N$. However, although bismuth-212 decays to form thallium-208, the number of thallium nuclei is much less than $\frac{3}{4}N$.

Suggest an explanation for these observations.

....

....

....

....

....

....

....[4]

[Total: 20]