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2023
PHYSICS

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TEST QUESTIONS AND ANSWER KEYS

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JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		**CT GROUP**	**22S**
TUTOR NAME			

PHYSICS **9749/01**

Paper 1 Multiple Choice **20 Sep 2023**

60 minutes

Additional Materials: Optical Mark Sheet

INSTRUCTIONS TO CANDIDATES

Write in soft pencil.

Write your name, CT, NRIC or FIN number on the optical mark sheet (OMS). Shade your NRIC or FIN in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the OMS.

Each correct answer will score one mark. A mark will **not** be deducted for a wrong answer.

Any rough working should be done in this booklet.

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This paper consists of **19** printed pages.

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Data

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

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

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
$\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}

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

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

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

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

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

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

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

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

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

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

Formulae

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

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1 Which of the following are the correct units of magnetic flux?

	SI unit	SI base units
A	T	kg s^{-2} A^{-1}
B	T	kg m^2 s^{-2} A^{-1}
C	Wb	kg s^{-2} A^{-1}
D	Wb	kg m^2 s^{-2} A^{-1}

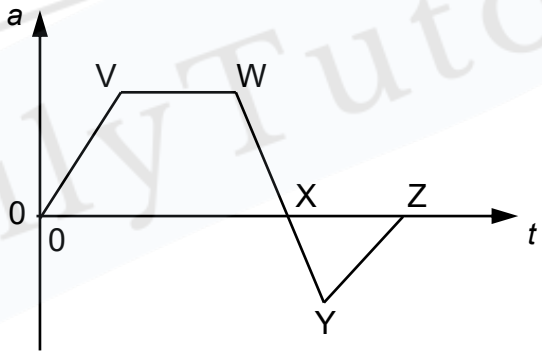
2 A point source is emitting a steady sound wave uniformly in all directions.

A sound intensity meter placed at a distance (2.0 ± 0.1) m away from the source detects an intensity of (0.25 ± 0.05) W m^{-2}.

What is the uncertainty in calculating the power of the source?

A 0.3 W **B** 1 W **C** 3 W **D** 4 W

3 A car starts from rest and moves along a straight road. The graph shows the variation with time *t* of its acceleration *a* during part of its journey.



At which points on the graph does the car have its greatest velocity and greatest displacement?

	greatest velocity	greatest displacement
A	V	W
B	W	Z
C	X	Y
D	X	Z

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4 A block is placed on the floor of a lift that moves upwards.
When the lift is slowing down, the magnitude of the force exerted on the block by the floor is always

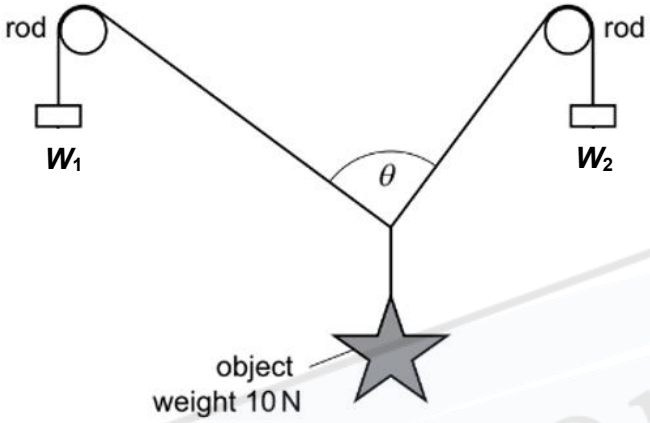
A equal to the magnitude of the weight of the block.

B less than the magnitude of the weight of the block.

C greater than the magnitude of the weight of the block.

D different from the magnitude of the force exerted on the lift floor by the block.

5 An object hangs by means of two cords around two rods, as shown in the diagram below.



The object is held in equilibrium by the weights W_1 and W_2, such that it is nearer to W_2.
The object weighs 10 N. There is negligible friction between the rods and cords.

Which pair of weights gives an angle θ of 90°?

	W_1 / N	W_2 / N
A	4.0	6.0
B	5.0	5.0
C	6.0	8.0
D	8.0	6.0

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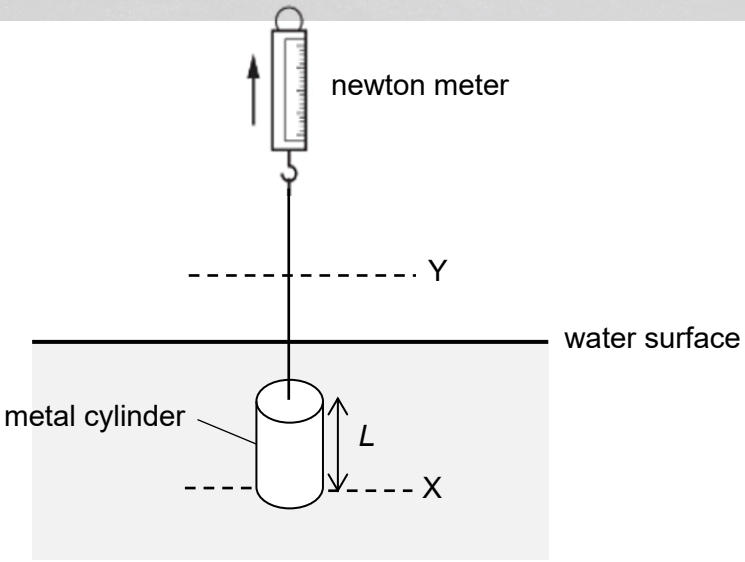
6 A metal cylinder, totally immersed in water, is hung from a newton meter.

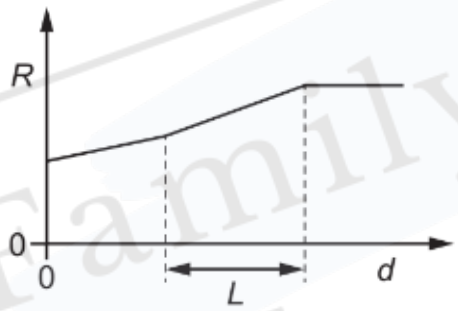


The cylinder, of height *L*, is slowly raised vertically by lifting the newton meter. Drag forces are assumed to be negligible.

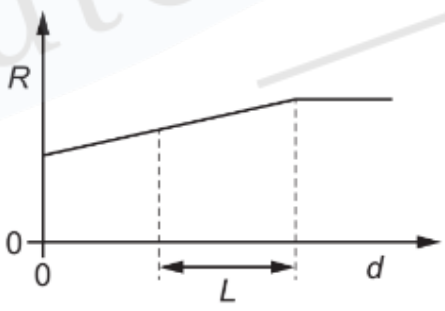
As the base of the cylinder moves from line X in the water to line Y above the surface of the water, the reading *R* on the newton meter is recorded. Assume that the velocity of the cylinder is constant.

Which graph best shows the variation of *R* with the distance *d* of the base of the cylinder from line X?

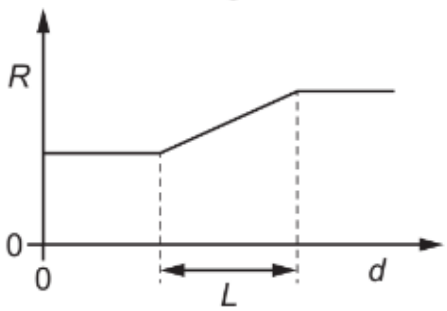
A



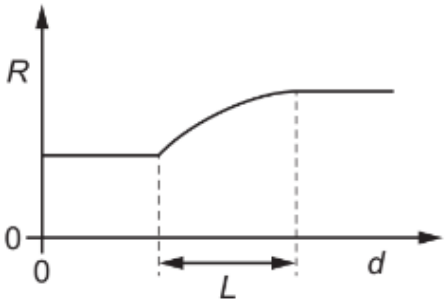
B



C



D



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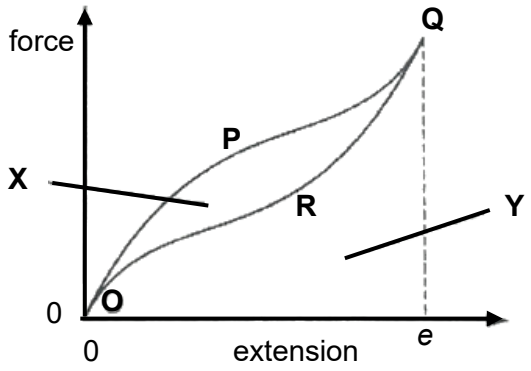
7 A rubber band is stretched and then relaxed to its original length.
The diagram shows the force-extension graph for this process.



As the force is increased, the curve follows the path OPQ to extension *e*. As the force is reduced, the curve follows the path QRO to return to zero extension.
The area labelled X is between the curves OPQ and QRO.
The area labelled Y is bounded by the curve QRO and the horizontal axis.
Which statement about the process is correct?

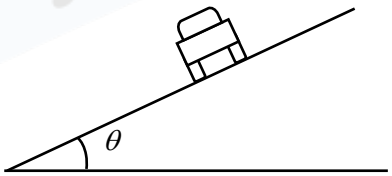
A X is the elastic potential energy stored in the rubber band when it is stretched to *e*.

B (X + Y) is the minimum energy required to stretch the rubber band to *e*.

C (Y – X) is the net work done on the rubber band during the process.

D Y is the energy which heats the rubber band as it is stretched to *e*.

8 A section of highway which has a circular curve, is inclined at an angle θ to the horizontal.
When a car is moving at a particular speed *v*, no frictional force along the road is needed to navigate this bend.



Which of the following correctly describes the directions of the frictional forces on the car along the incline?

	when speed is below *v*	when speed is above *v*
A	upwards along the incline	upwards along the incline
B	upwards along the incline	downwards along the incline
C	downwards along the incline	downwards along the incline
D	downwards along the incline	upwards along the incline

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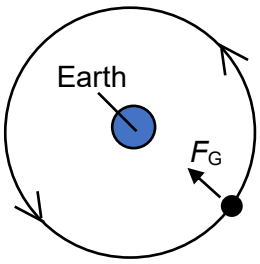
9 A satellite is orbiting the Earth at a constant angular velocity.

The gravitational force on the satellite is F_G.

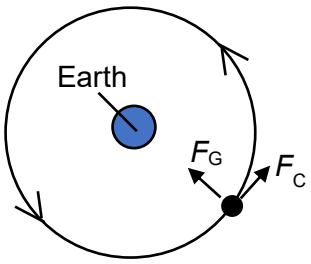
The centripetal force required to maintain the satellite in orbit is F_C.

Which diagram shows the force, or forces, acting on the orbiting satellite?

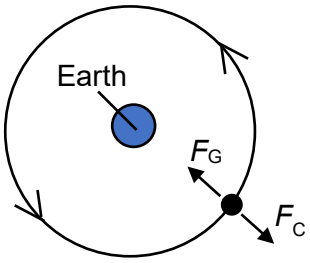
A



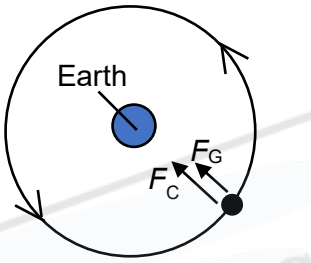
B



C



D



10 Mars has a diameter approximately 0.5 times the diameter of the Earth, and the mass of Mars is about 0.1 times the mass of the Earth.

The gravitational potential at the Earth's surface is -63 MJ kg^{-1}.

What is an approximate value for the gravitational potential at the surface of Mars?

A -13 MJ kg^{-1} **B** -25 MJ kg^{-1} **C** -95 MJ kg^{-1} **D** -320 MJ kg^{-1}

11 Cooling water enters the heat exchanger in the turbine hall of a nuclear power station at 6.0 °C and leaves at 14.0 °C. The rate of heat removal by the water is 6.7 x 10^9 J per minute.

The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

What is the rate of water flow?

A $\frac{6.7\times10^9\times60}{4200\times8.0}$ kg s^{-1}

B $\frac{6.7\times10^9}{4200\times8.0\times60}$ kg s^{-1}

C $\frac{4200\times8.0}{6.7\times10^9\times60}$ kg s^{-1}

D $\frac{4200\times8.0\times60}{6.7\times10^9}$ kg s^{-1}

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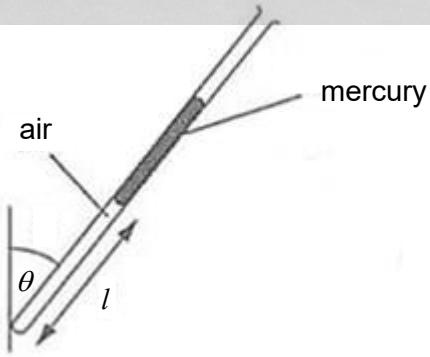
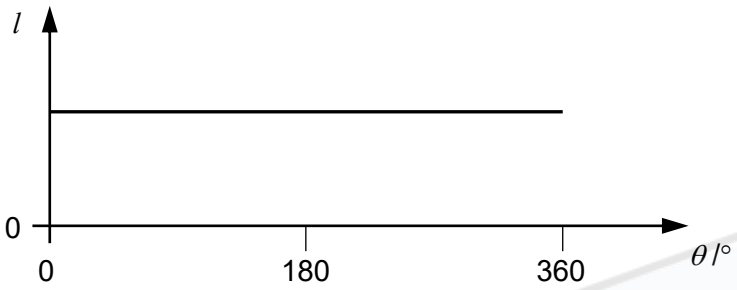
12 A narrow tube, closed at one end, contains a column of dry air that is trapped by mercury.

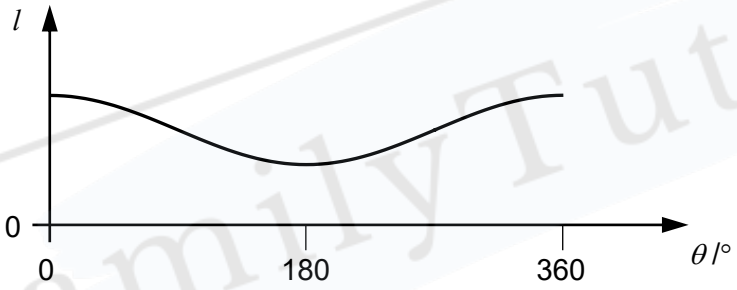


Which diagram best shows the variation of the length l of the air column with the angle θ of the tube to the vertical?

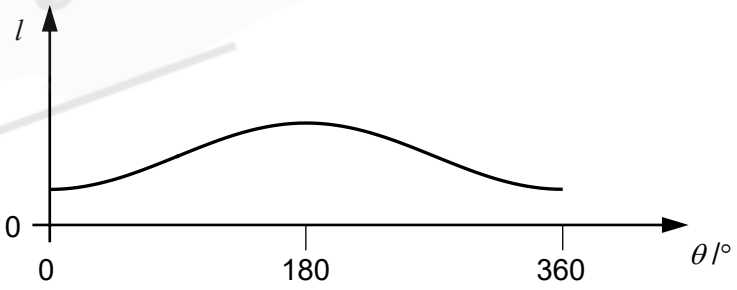
A



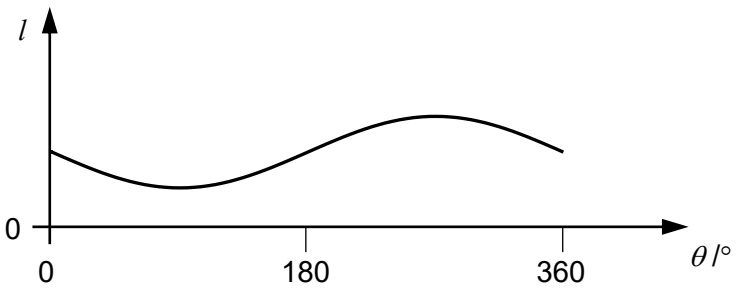
B



C



D



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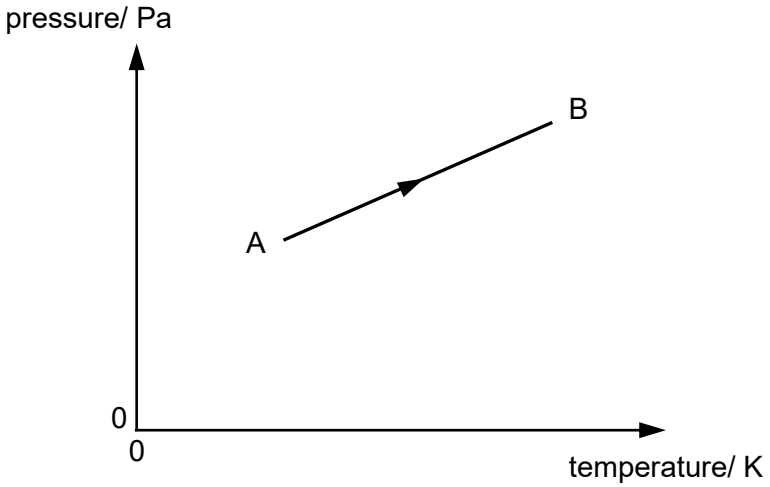
13 A fixed mass of an ideal gas changes from state A to state B via the process as shown in the pressure – temperature diagram below.



Which of the following statements gives the correct description of the process?

A Positive work is done on the gas and heat is supplied to the gas.

B Positive work is done on the gas and heat is released by the gas.

C Positive work is done by the gas and heat is supplied to the gas.

D Positive work is done by the gas and heat is released by the gas.

14 A simple pendulum is 1.0 m long and oscillates with simple harmonic motion of angular amplitude 0.050 rad and period 2.0 s.

What is the angular speed of the pendulum bob when the angular displacement is 0.030 rad?

A 0.0010 rad s^{-1}

B 0.020 rad s^{-1}

C 0.050 rad s^{-1}

D 0.13 rad s^{-1}

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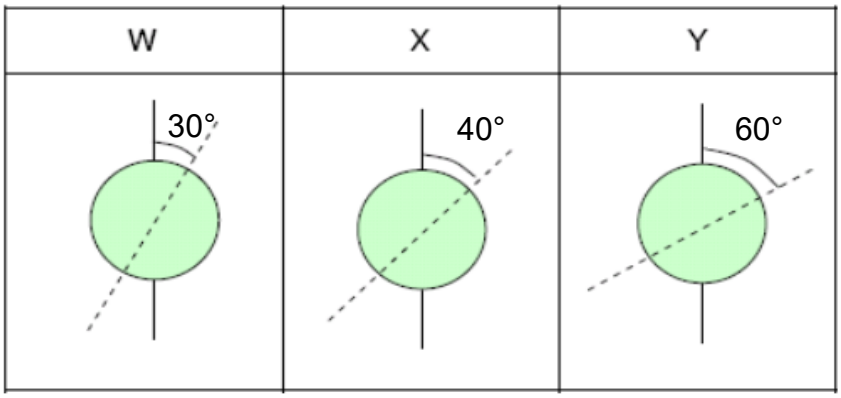
15 The table below shows three polarisers W, X and Y.

A beam of unpolarised light of intensity I_0 is incident normally onto the surface of polariser W, which then passes through polariser X and eventually emerges from polariser Y.

The polarising direction of each polariser is indicated by a dashed line.



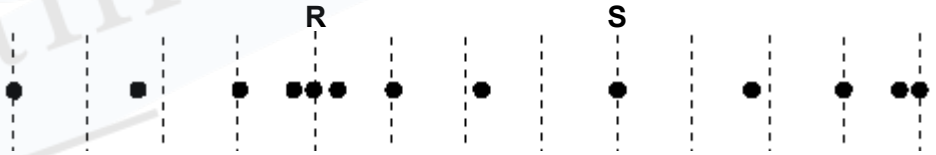
The transmitted intensity of light after the light emerges from polarizer Y is

A 0.32 I_0 **B** 0.43 I_0 **C** 0.64 I_0 **D** 0.86 I_0

16 The figure shows the positions of particles of a medium at a particular instant when a longitudinal wave, travelling from left to right, passes through the medium.

Before the wave arrived, the particles were all spaced equally apart on the vertical dotted lines shown.

At the instant shown, particles R and S are passing through their original undisturbed positions.



Which of the following describes the direction of the velocities of particles R and S at the instant shown?

	velocity direction for R	velocity direction for S
A	right	right
B	right	left
C	left	left
D	left	right

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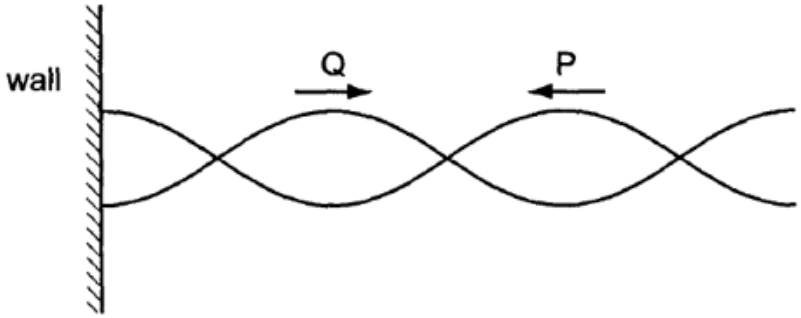
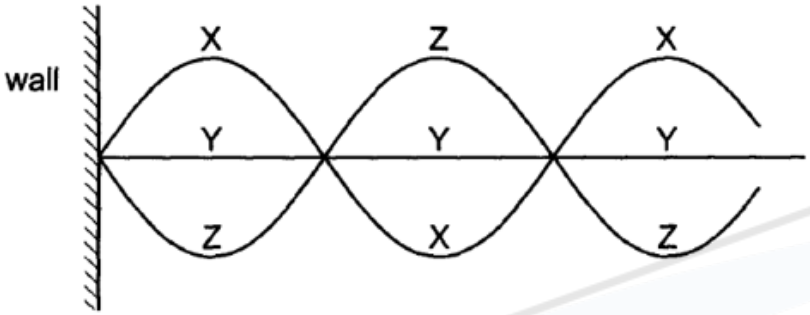
17 A water wave P is incident on a wall. A reflected wave Q moves away from the wall. The diagram illustrates the position of P and Q at time zero.



X, Y and Z represent three positions of the resulting stationary wave.



In which order does the stationary wave have these positions, beginning at time zero?

A X Y Z Y
B Y X Y Z
C Y Z Y X
D Z Y X Y

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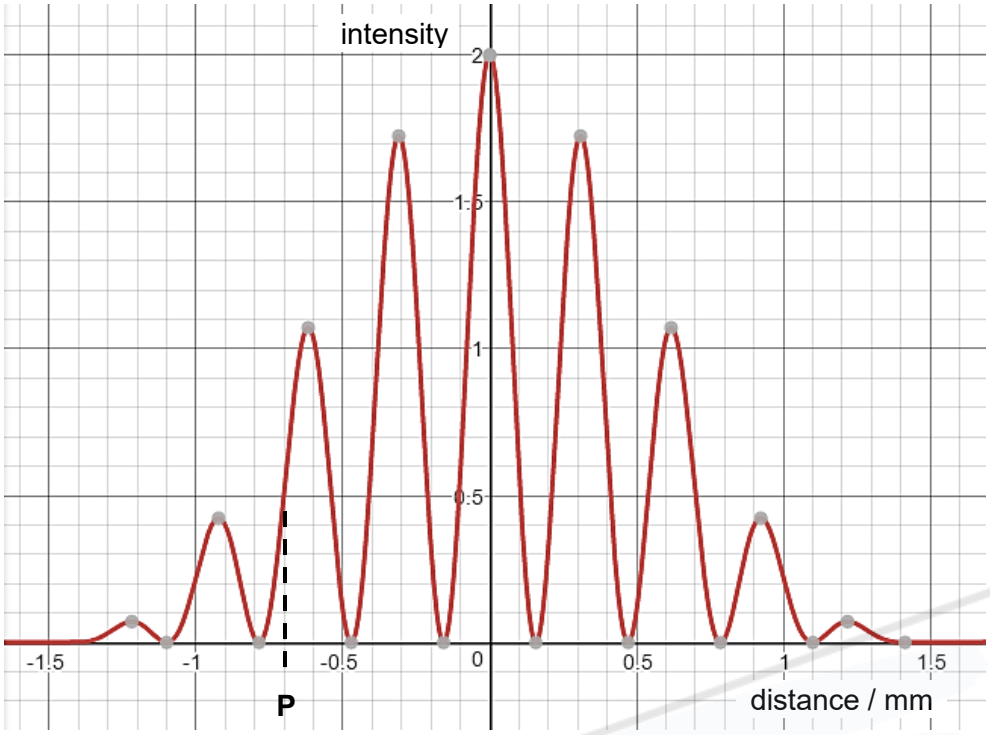
18 Coherent light is incident normally on a double slit. The graph shows the variation of the intensity of light on a screen placed far away from the double slit.



What is the phase angle between the waves from the double slit when the waves meet at point P?

A 0.45 rad **B** 1.43 rad **C** 1.71 rad **D** 4.45 rad

19 In discussing electric fields, the terms 'electric field strength', 'electric potential' and 'potential gradient' are used.

Which statement about these terms is correct?

A Electric field strength at a point is the work done per unit positive charge in bringing a test charge from infinity to the point.

B Electric potential and potential gradient are both scalar quantities.

C The potential gradient at a point is numerically equal to the electric field strength at that point.

D A potential gradient of one volt exists between any two points, if one joule of work is done in transporting one coulomb of charge between the points.

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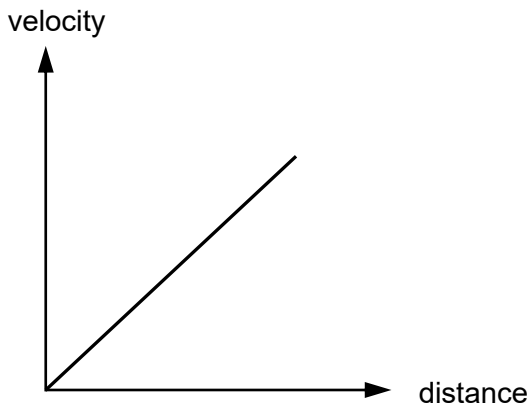
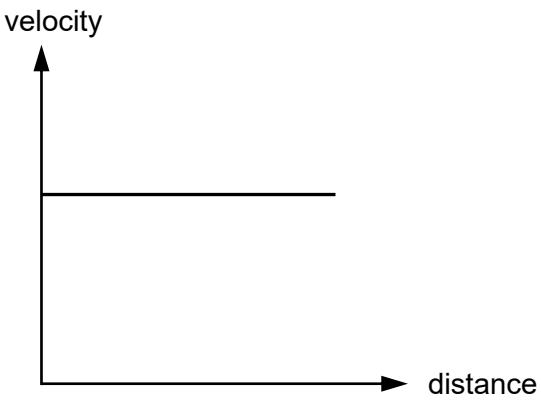
20 An electron is initially at rest in a uniform electric field.

Which graph shows the variation with distance of the velocity of the electron?

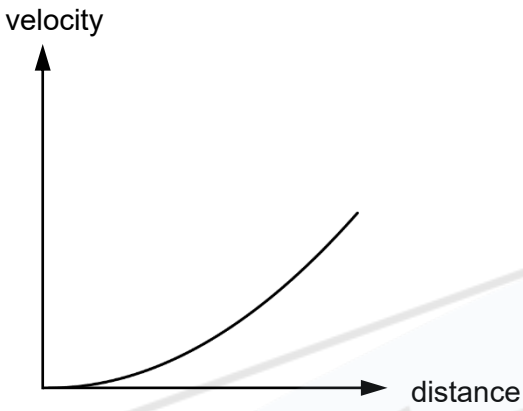
A



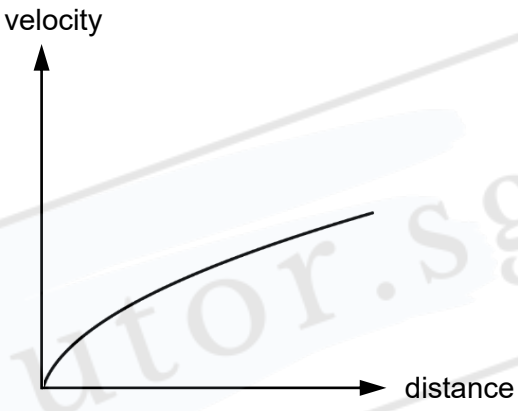
B



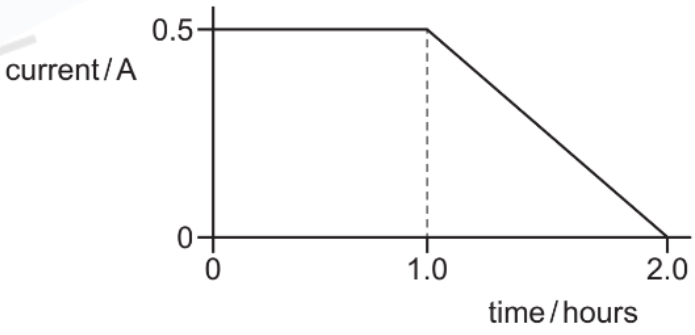
C



D



21 A mobile phone battery is charged by connecting it to a constant potential difference of 5.0V. After a time of 1.0 hour, the initial current of 0.50 A slowly decreases to zero, as shown.



What is the best estimate of the energy transferred to the battery during the time of 2.0 hours shown in the graph?

A 2700 J **B** 9000 J **C** 14 000J **D** 18 000J

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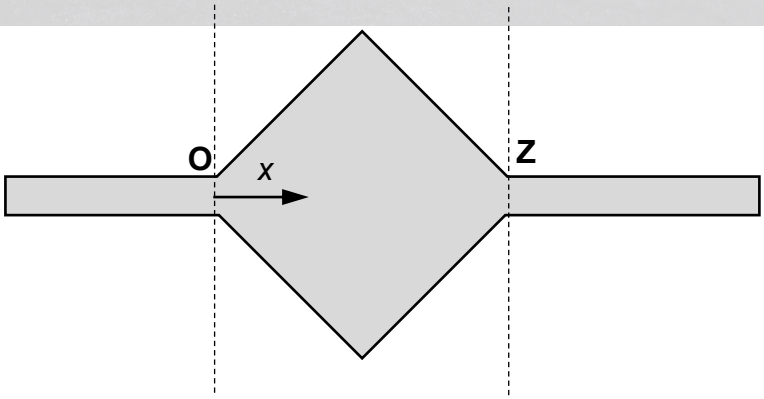
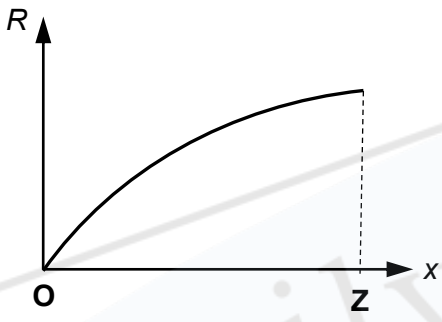
22 A flat conductor which of uniform thickness and resistivity, has the shape shown below.



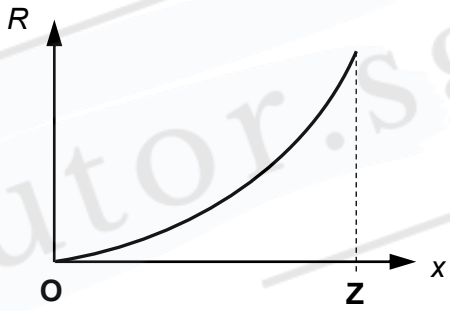
top view

Which of the following graphs best represents the variation of the resistance *R* with the distance *x* from O to Z?

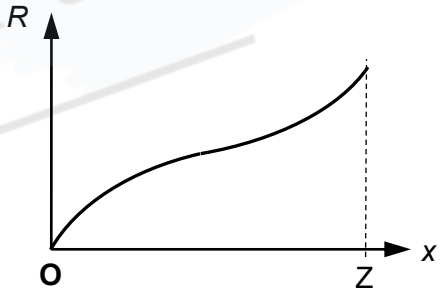
A



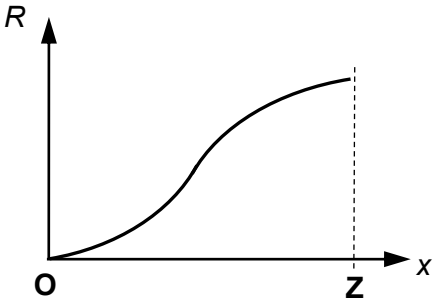
B



C



D



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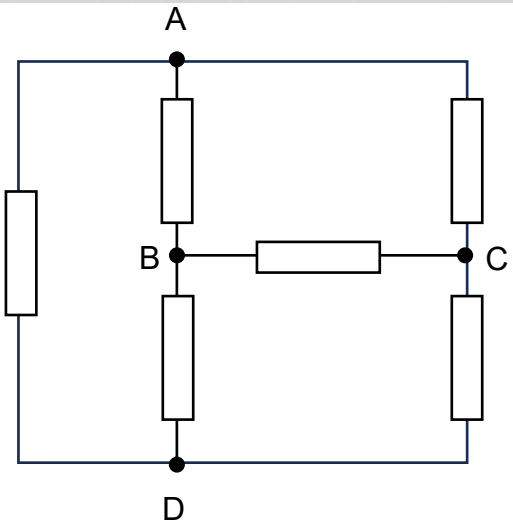
23 Six identical resistors are arranged in a circuit as shown below. Each resistor has a resistance of 6.0 Ω.



What is the effective resistance between points A and D?

A 1.0 Ω **B** 2.0 Ω **C** 3.0 Ω **D** 6.0 Ω

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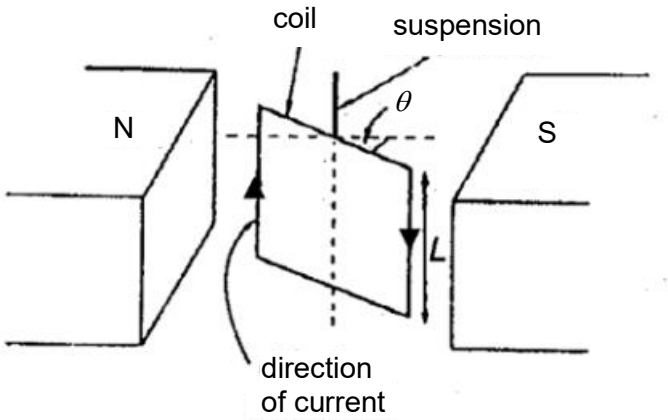
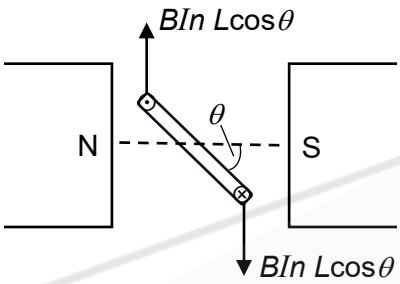
24 A current I is carried by a square coil of n turns and side L, suspended vertically as shown in a uniform horizontal magnetic field of flux density B.

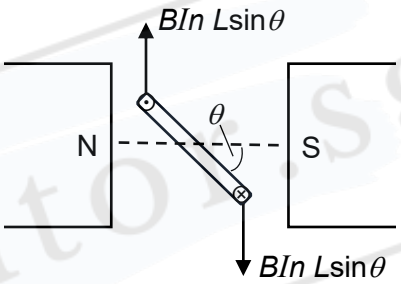


Which one of the plan diagrams correctly shows the magnitude and direction of the forces acting on the vertical sides of the coil?

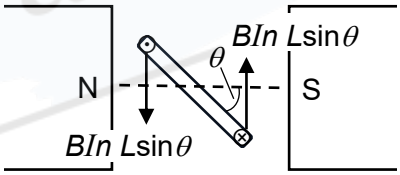
A



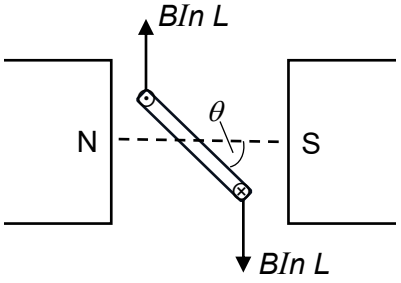
B



C



D



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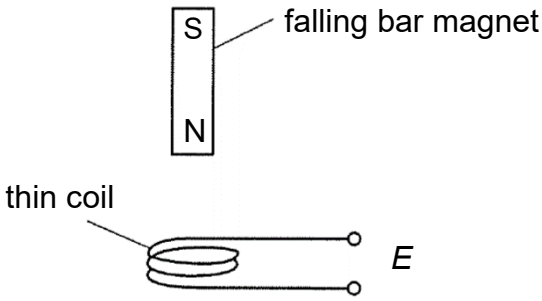
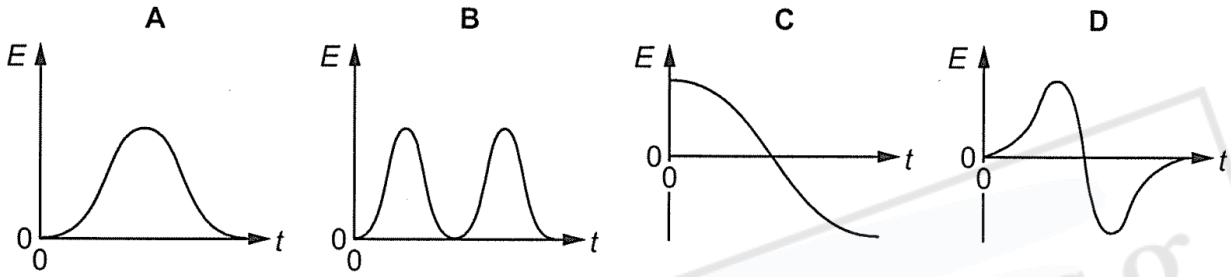
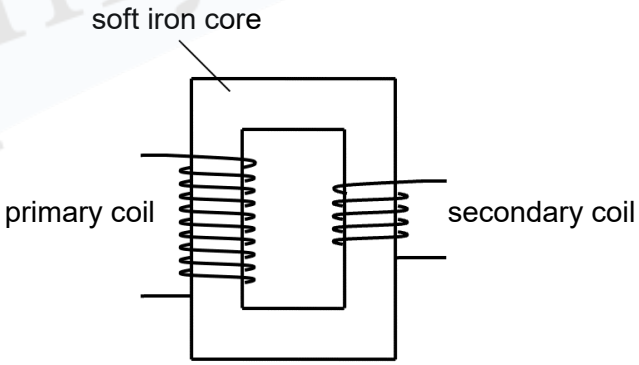
25 In an experiment to record electrical events of short duration, a student drops a bar magnet through a very thin, horizontal coil, as shown.



Which graph best represents how the induced e.m.f. *E* in the coil on the magnet varies with time *t*?



26 The diagram shows a transformer. The primary coil has 100 turns and the secondary coil has 50 turns. The magnetic flux within the primary coil is 0.54 Wb.



What is the average potential difference across the ends of the secondary coil when the flux in the primary coil is reduced to zero in a time of 0.18 s?

A 75 V **B** 150 V **C** 300 V **D** 450 V

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27 Fig. (a) and Fig. (b) show two separate types of alternating potential difference with the same peak voltage (V_P) applied across a load resistor R.

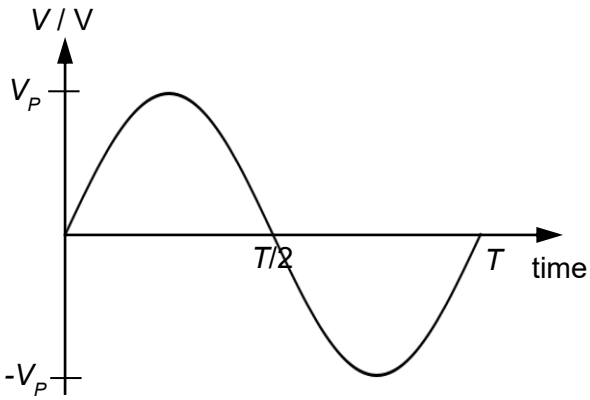

Fig. (a)

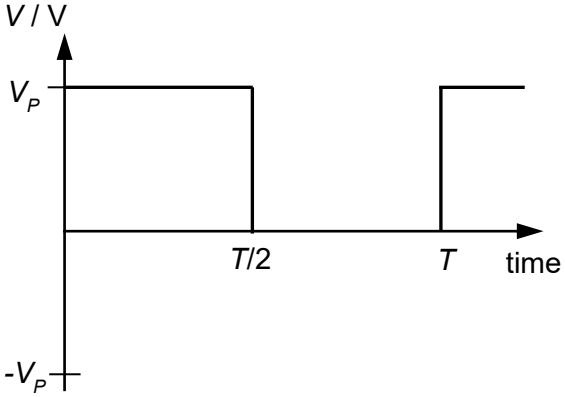

Fig. (b)

What is the ratio of $\frac{\text{root-mean-square potential difference for (a)}}{\text{root-mean-square potential difference for (b)}}$?

A 0.5 **B** 0.7 **C** 1 **D** 1.4

28 When electromagnetic radiation falls on a particular metal surface, photoelectrons may be emitted. The table below gives the maximum kinetic energy of the photoelectrons emitted at a given frequency.

frequency of incident radiation	maximum kinetic energy of photoelectrons
1.0×10^{15} Hz	2.6×10^{-19} J
2.5×10^{15} Hz	E

What is the value of E?

A 1.3×10^{-18} J **B** 9.9×10^{-19} J **C** 7.3×10^{-19} J **D** 6.5×10^{-19} J

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29 A uranium-235 nucleus ($^{235}_{92}U$) undergoes fission, producing nuclei of lanthanum-146 ($^{146}_{57}La$) and bromine-87 ($^{87}_{35}Br$). The binding energies per nucleon of these nuclides are shown below.

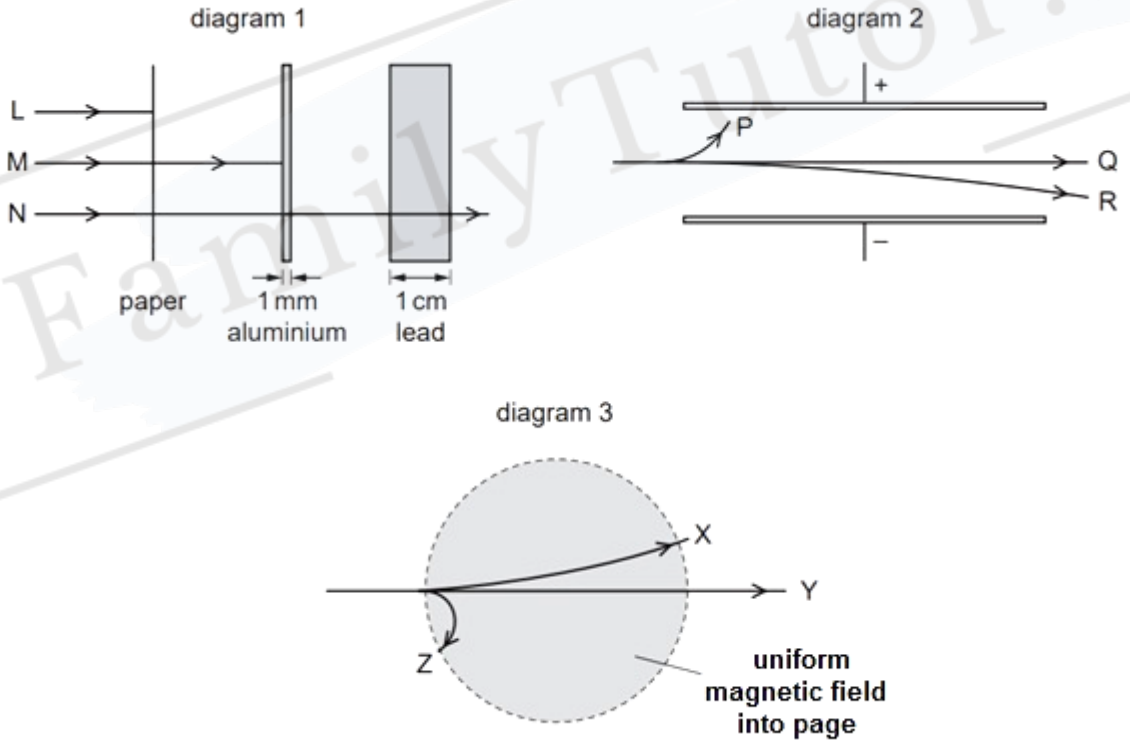
nuclide	binding energy per nucleon / MeV
$^{235}_{92}U$	7.6
$^{146}_{57}La$	8.2
$^{87}_{35}Br$	8.6

What is the energy released from this reaction?

A 9.2 MeV **B** 69.2 MeV **C** 90.2 MeV **D** 159 MeV

30 Alpha, beta and gamma radiations are absorbed to different extents in solids and behave differently in an electric and magnetic field.

The diagrams below illustrate these behaviours.



Which three labels on these diagrams refer to the **same** type of radiation?

A L, P, Z **B** L, R, X **C** M, P, X **D** N, R, X

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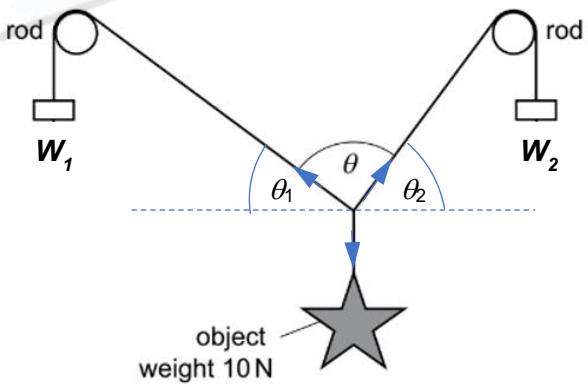
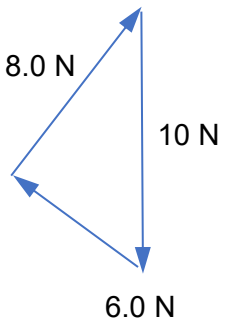
2023 H2 Physics Prelim Paper 1 Suggested Solutions

	ANS	Suggested solutions
1	D	magnetic flux Φ = magnetic flux density B x area A, magnetic flux density, $B = F / I L$ Unit of magnetic flux Φ = unit of $(F / I L) A$ Wb = $(\text{kg m s}^{-2})\ \text{A}^{-1}\ \text{m}^{-1}\ \text{m}^2 = \text{kg m}^2\ \text{s}^{-2}\ \text{A}^{-1}$
2	D	intensity I = (Power P) / (surface area A) $I = \frac{P}{4\pi r^2}$ $P = 4\pi r^2 I = 4\pi (2.0)^2 (0.25) = 12.566$ W $\frac{\Delta P}{P} = \frac{\Delta I}{I} = +2\frac{\Delta r}{r}$ $\frac{\Delta P}{12.566} = \frac{0.05}{0.25} + 2\left(\frac{0.1}{2.0}\right) = 0.3$ $\Delta P = 4$W
3	D	Initially, the speed of the car is increasing in the forward direction. **At X, the car reaches maximum speed (where acceleration is zero).** Beyond X, as the acceleration is in the opposite direction to the velocity, the car slows down in speed at an increasing rate to Y then at a decreasing rate to Z; but the car keeps moving in the forward direction even at Z as the positive change in velocity from O to X (positive area under the *a-t* graph) is still greater than the negative change in velocity from X to Z (negative area under the *a-t* graph). **Therefore, maximum displacement is at Z.**
4	B	The acceleration is downwards, thus resultant force is downwards. The magnitude of the force exerted on the block by the floor (upwards) is always less than the magnitude of the weight of the block (downwards). If the block is placed on a weighing scale in the lift, the scale will read a value less than its original weight.
5	C	The weights W_1 and W_2 provide the tension forces, balancing the weight of the object in equilibrium. Drawing a vector triangle of proportional magnitudes:   Recognize it is a 6-8-10 right-angled triangle. (similar to a 3-4-5). Analysing the horizontal components in equilibrium: $6.0 \cos \theta_1 = 8.0 \cos \theta_2 \quad \Rightarrow \theta_1 < \theta_2$ Thus, $W_1 = 6.0$ N, $W_2 = 8.0$ N

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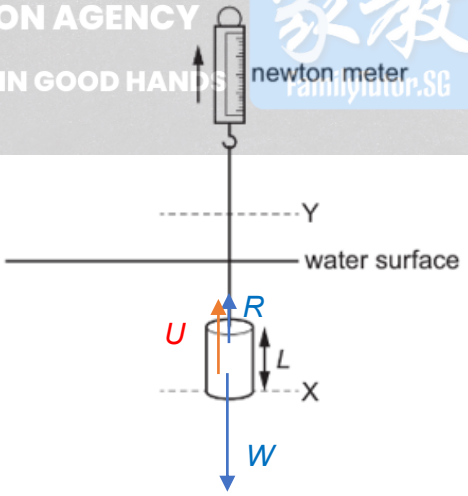
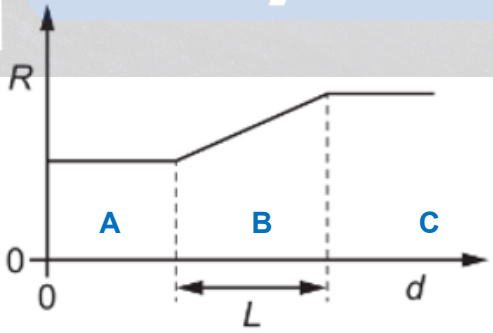
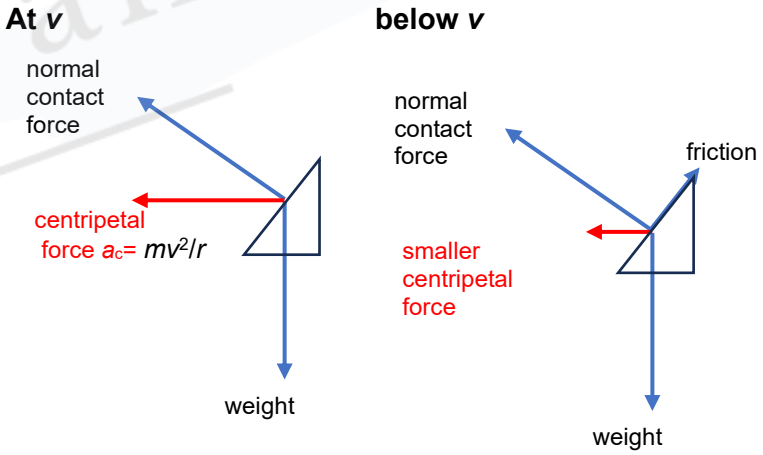
6	C	  At the initial position, the forces acting on the cylinder are weight *W*, upthrust *U* and tension *R*. Magnitude of the sum of upward forces *U* and *R* is equal to downward weight *W*. As the metal cylinder is slowly raised, **In region A:** cylinder is still fully submerged in water hence upthrust *U* remains the same, and weight W always remain the same throughout, hence tension *R* is constant. **In region B:** cylinder is being pulled out of the water so upthrust *U* decreases at a constant rate due to the volume submerged in water decreases at a constant rate. Hence, *R* increases at a constant rate. **In region C:** cylinder is fully out of the water hence upthrust *U* is zero so *W* = *R* remains constant.
7	B	Option A: Wrong because only when the force is reduced and the rubber band follows the path QRO to zero, then Y is the EPE recovered. Option B: Correct as total work done or minimum energy to stretch the rubber band to *e* is the area under the force-extension graph = (X + Y). Option C: Wrong as X is the net work done on the rubber band during the entire process. Option D: Wrong as Y is the EPE recovered when the rubber band is stretched and returned to zero extension.
8	B	The required centripetal force is the vector sum of the horizontal component of friction and the horizontal component of normal contact force.  When the car is moving below *v*, the required centripetal force (which is acting horizontally) is smaller; thus, frictional force should act upwards along incline to oppose the horizontal component of the normal contact force as shown below. When the car is moving above the mentioned speed, the required centripetal force (which is acting horizontally) is larger; thus, frictional force should act downwards along incline to assist the horizontal component of the normal contact force as shown .

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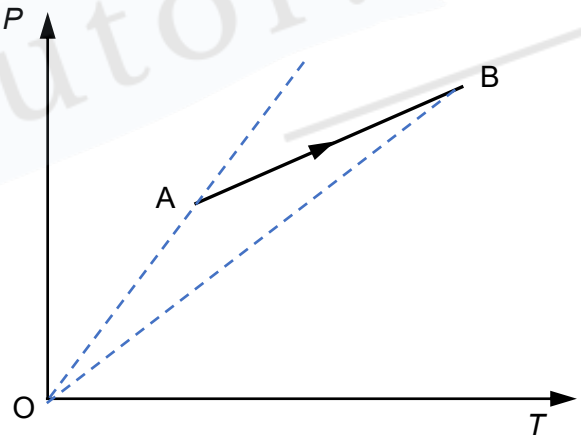
9	**A**	The gravitational force is the **only force** acting on the satellite. This force is providing the centripetal force required to maintain the satellite's orbital motion ($F_G = F_C$).
10	**A**	The gravitational potential at the surface of a planet is directly proportional to the planet's mass, and inversely proportional to its radius (or diameter). Hence, the potential at Mars' surface is approximately (0.1 / 0.5) x (-63 MJ kg^{-1}) = -13 MJ kg^{-1}.
11	**B**	This is an extension from $Q = mc\Delta T$, considering the rate of thermal energy removed. $\frac{dm}{dt} c\Delta T = \frac{dE}{dt} = P$ $\frac{dm}{dt} = \frac{P}{c\Delta T}$ $= \frac{6.7\times10^9 \,/\, 60}{4200\times(14.0-6.0)} = \frac{6.7\times10^9}{4200\times8.0\times60}$ kg s^{-1}
12	**C**	Assume that temperature is constant, then the product of pressure and volume, pV is constant. Further assume that the cross-sectional area of the tube is constant, then pl is constant. When at angle θ, $p = P_{atm} + \rho_{Hg} g l_{Hg} \cos\theta$ When the tube is upright (0°), $p = P_{atm} + \rho_{Hg} g l_{Hg}$, where Hg is mercury, **pressure is maximum, l is minimum.** When the tube is horizontal (90°), and $p = P_{atm}$ When the tube is inverted (180°), $p = P_{atm} - \rho_{Hg} g l_{Hg}$, **pressure is minimum, l is maximum.** As angle varies from 0° to 360°, l varies sinusoidally, following an inverted cosine function.
13	**C**	On the P-T diagram, using $p = \left(\frac{nR}{V}\right)T$, the volume is inversely proportional to the gradient of line passing through the origin. gradient of OA > gradient of OB Thus, volume of the gas increases, and positive work is done <u>by</u> the gas in the process AB (or work done <u>on</u> the gas is negative, $W < 0$). Temperature increases from A to B implies that internal energy of the ideal gas increases in the process, i.e. $\Delta U > 0$. By First Law of Thermodynamics, $\Delta U = W + Q \Rightarrow Q = (\Delta U - W) > 0$ Thus heat is supplied to the gas. 
14	**D**	The pendulum performs simple harmonic motion at small angles. You may see the pendulum swing as a part of a non-uniform vertical circular motion. Let angular displacement be θ. Thus, linear displacement $x \approx r\theta = (1.0)\theta = \theta$ At angular displacement is 0.050 rad, horizontal amplitude x_0 = 0.050 m. At angular displacement is 0.030 rad, horizontal displacement x = 0.030 m. Using the equation given in the formula list,

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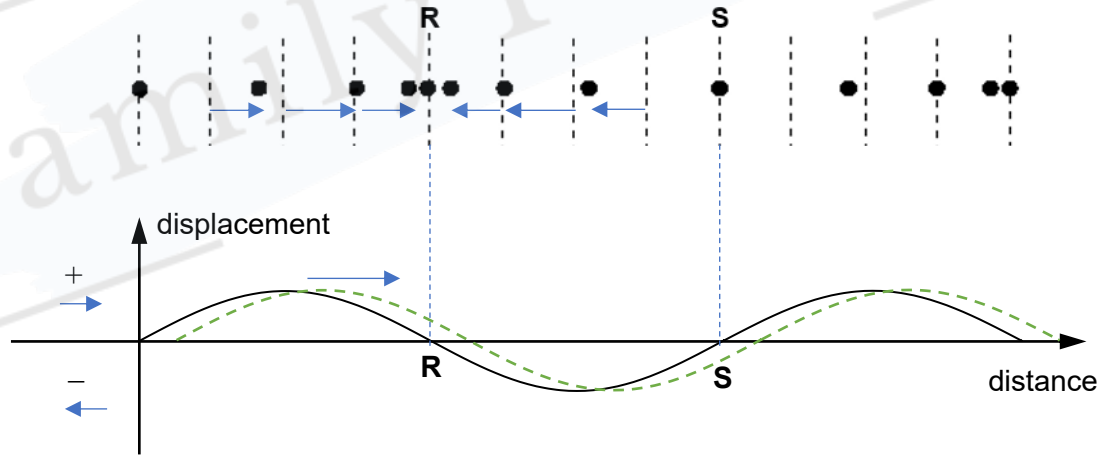
		linear velocity, $v = \pm\omega\sqrt{x_0^2 - x^2}$ $= \pm\frac{2\pi}{T}\sqrt{x_0^2 - x^2}$ $= \pm\frac{2\pi}{2.0}\sqrt{0.050^2 - 0.030^2}$ $= \pm 0.13$ m s^{-1} $\because v = r\omega = (1.0)\omega = \omega$ angular speed, $\omega = v = 0.13$ rads^{-1}
15	**B**	Using Malus' law, the intensity of transmitted light (I) through polarisers is proportional to $I_0 \cos^2\theta$, where I_0 is the intensity of transmitted through the first polariser, θ is the angle between two polarisers. Unpolarized light loses exactly half of its intensity after it passes through polariser W no matter what the direction of polarising for polariser X is: 0.50 I_0. The angle between polariser W and X is 10°, the transmitted intensity after X would be $0.50I_0 \times \cos^2(40° - 30°) = 0.48I_0$. The angle between polariser X and Y is 20°, the transmitted intensity after Y would be $0.48I_0 \times \cos^2(60° - 40°) = 0.43I_0$.
16	**B**	Since the wave is travelling from left to right, at the next instant, every particle will "copy" what its current left neighbour is doing. Hence, R is moving to the right, while S is moving to the left. Alternatively, drawing the displacement-distance graph,  Sketching in the wave profile for the next moment, wave particle at R goes into the positive region, meaning that it is moving to the right; wave particle at Q goes into the negative region, meaning that it is moving to the left.
17	**C**	P is travelling towards left and Q is travelling towards right. Let their amplitudes be *A*. Given that at *t* = 0, P has a negative cosine profile and Q has a positive cosine profile, hence, the resulting stationary wave would produce zero amplitude, Y. *T*/4 later, both P and Q have a negative sine profile, the resultant amplitude would correspond to Z. *T*/2 later, the resultant amplitude would be zero. 3*T*/4 later, the resultant amplitude would correspond to X. Hence, the correct answer is Y Z Y X.

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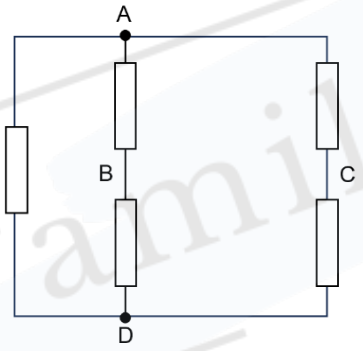
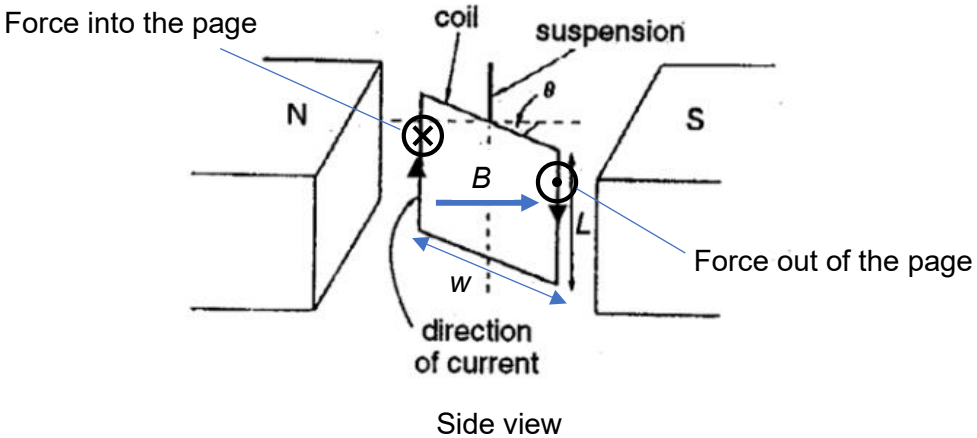
18	**B**	Reading from the graph, a distance on the screen of 1.10 mm corresponds to a phase difference of 3.5 x 2π radians. Since point P is 0.70 mm away from the central maximum, the phase difference there is (0.70 / 1.10) x (3.5 x 2π) = 14.0 radians. The reduced phase difference (i.e., modulo 2π, to get a value between 0 and 2π radians) is 14.0 - 4π = 1.4 radians.
19	**C**	Option A is the definition of electric potential not electric field strength. Option B is incorrect because the potential gradient is the electric field strength, hence a vector quantity. Option C is correct. Option D is about potential difference not potential gradient.
20	**D**	The acceleration on the electron is constant under the influence of the uniform E-field. Applying equations of motion for uniform acceleration in Kinematics: $v^2 = u^2 + 2as, \ \ u = 0$ $v = \sqrt{2as}$ $v \propto \sqrt{s}$ The graph in D correctly depicts this relationship.
21	**C**	Charge Q = Area under I-t graph = ½(0.5)(1+2)(60 x60) = 2700 C Energy transferred i.e. work done on charge = QV = 5.0 x 2700 = 13500 J
22	**C**	Initially, when distance x (less than mid-way of OZ from O) increases, with a small change in distance x, the cross-sectional area increases, resulting in smaller increases in R. Later, when distance x (more than mid-way of OZ from O) increases, with a small change in distance x, the cross-sectional area decreases, resulting in larger increases in R.
23	**C**	Since potentials at points C and B are equal, we can remove the resistor between them.  $\frac{1}{R_{AD}} = \frac{1}{6.0} + \frac{1}{12.0} + \frac{1}{12.0}$ $\frac{1}{R_{eff}} = \frac{4}{12.0}$ $R_{eff} = 3.0\ \Omega$
24	**D**	The forces acting on the vertical sides of the coil = $nBIL$, since the current in the vertical wires are always perpendicular to the horizontal magnetic field.  Side view

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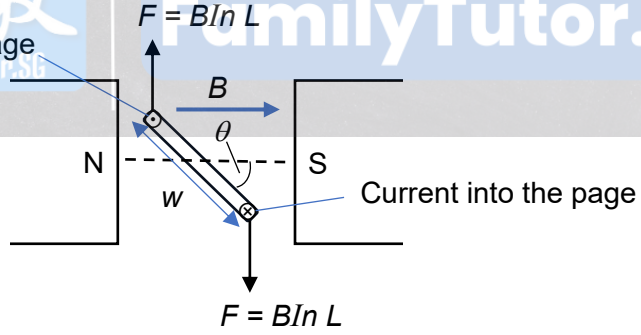
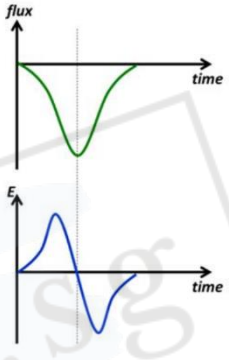


Plan view (or top view)

The angle is required only for the perpendicular distance between the lines of action of the forces $w\cos\theta$.
The moment of the couple is $F \times d_{\perp} = nBIL\, w\cos\theta$.

25 **D**

Take the upper side of the coil as our reference area.
As the north pole of the magnet approaches this area from far, the magnetic flux linkage across this area increases from zero to a maximum (negative value). Then drop to zero as the north pole leaves this area.



The graph of flux against time is as shown.
The negative of the gradient of this graph is the *E* - *t* graph.

26 **B**

The magnetic flux (BA) through the tranformer is the same for both primary and secondary coils.
By Faraday's Law,
the average induced emf in the secondary coil = change of flux linkage/ time

$$|\varepsilon| = \frac{\Delta\Phi}{\Delta t} = \frac{N\Delta\phi}{\Delta t} = \left|\frac{(50)(0.00-0.54)}{0.18}\right| = 150 \text{ V}$$

27 **C**

In Fig. (a), for sinusoidal a.c., $V_{r.m.s.\ for\ (a)} = \frac{V_P}{\sqrt{2}}$

In Fig. (b), for the case of full square wave ac, $V_{peak} = V_{r.m.s.}$,
the mean power is $\langle P\rangle_{full} = \frac{V_{Peak}^2}{R}$
But Fig. (b) represents a half-wave rectified square wave, $\langle P\rangle_{half} = \frac{V_{Peak}^2}{2R}$

$$\frac{V_{r.m.s.for\ (b)}^2}{R} = \frac{V_{Peak}^2}{2R} \rightarrow V_{r.m.s.\ for\ (b)} = \frac{V_P}{\sqrt{2}}$$

Thus, the ratio

$$\frac{V_{r.m.s.\ for\ (a)}}{V_{r.m.s.\ for\ (b)}} = \frac{\frac{V_P}{\sqrt{2}}}{\frac{V_P}{\sqrt{2}}} = 1$$

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28	**A**	By Photoelectric Equation: $hf = \Phi + \text{KE}_{max}$ Work function of the metal, $\Phi = hf - \text{KE}_{max} = (6.63\times10^{-34})(1.0\times10^{15}) - (2.6\times10^{-19}) = 4.03\times10^{-19}$ J $E = hf' - \Phi = (6.63\times10^{-34})(2.5\times10^{15}) - (4.03\times10^{-19}) = 1.3\times10^{-18}$ J
29	**D**	Energy released = $\text{BE}_{products} - \text{BE}_{reactants}$ = (8.2 × 146) + (8.6 × 87) – (7.6 × 235) = 159.4 MeV
30	**B**	L, R, X are all alpha particles (i.e. having charge of +2e and least penetration power through solid).

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HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		CT GROUP	22S
CENTRE NUMBER		INDEX NUMBER	

PHYSICS

9749/02

Paper 2 Structured Questions

13 September 2023

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre Number, index number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

The number of marks is given in brackets [ ] at the end of each question or part question.
You are reminded of the need for good English and clear presentation in your answers.

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For Examiner's Use		
Paper 2		
1		11
2		9
3		7
4		10
5		10
6		12
7		21
Deductions		
Total		80

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

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Data

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

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

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
$\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}

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

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

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

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

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

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

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

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

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

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

Formulae

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

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1 (a) A wooden block placed on a weighing scale on a table registers 1.6 kg.

The same block and the weighing scale are now placed on a rough slope as shown in Fig. 1.1.

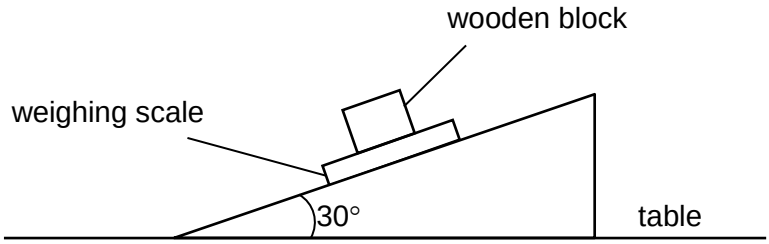

Fig. 1.1

The slope is at an angle of 30° to the horizontal.

Determine the new reading on the weighing scale. Show your working clearly.

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new reading on the weighing scale = …….. kg [3]

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(b) The same block is now suspended from the ceiling by a cord of length 1.3 m.

A tennis ball of mass 58 g is shot from a launcher and strikes the block horizontally.

The ball is in contact with the block for a time of 0.20 s during which it reverses its direction and moves off with a speed of 19 m s^{-1}. After the collision, the block swings to a maximum angle of 37° from its initial vertical position.

Assume that during the collision, vertical motions are negligible.

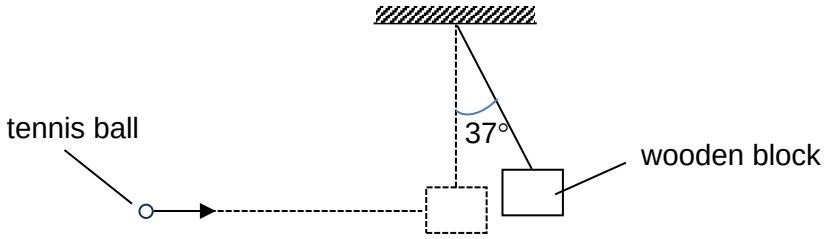

Fig. 1.2

(i) Show that the speed of the block immediately after the collision is 2.3 m s^{-1}.

[2]

(ii) Calculate the average force F between the ball and the block during the collision.

F = ... N [2]

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(iii) Determine the horizontal speed of the ball before the collision.

initial speed of the ball = …….. m s^{-1} [2]

(c) Using your answers in **(b)**, deduce whether the collision is elastic.

……

……[2]

[Total: 11]

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2 **(a)** State Newton's Law of Gravitation.

……

…… [1]

(b) A geostationary satellite is placed in orbit around the Earth.

(i) Explain why the satellite must be above the equator.

……

……

…… [2]

(ii) Given that the mass of the Earth is 6.0×10^{24} kg and the radius of the Earth is 6.4×10^{6} m,

1. show that the altitude of the satellite above the surface of the Earth is 3.6×10^{7} m,

[4]

2. calculate the linear speed of the satellite.

linear speed = …… m s^{-1} [2]

[Total: 9]

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3 A string, tied to a sinusoidal oscillator at P and running over a support at Q, is stretched by a block of mass *m* as shown in Fig. 3.1. The amplitude of the motion at P is small enough for that point to be considered a node. A node also exists at Q.

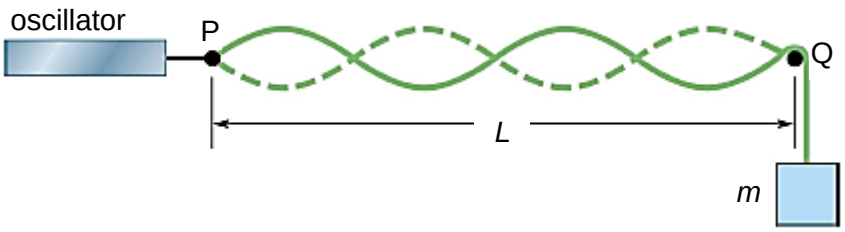

Fig. 3.1

(a) Explain how a stationary wave is formed along the string.

.....

.....

..... [2]

(b) Explain why the incident wave must undergo a phase change of 180° at point Q.

.....

..... [1]

(c) The frequency of the oscillator is set at 120 Hz. A stationary wave is formed when the length *L* is 1.20 m. The length is slowly increased and the stationary wave disappears. The stationary wave is again formed when *L* is increased by 0.30 m.

(i) Calculate the velocity of the wave in the string.

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

(ii) Given that the amplitude of the antinodes is 0.80 cm, calculate the maximum *vertical* velocity for a point on the string.

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

[Total: 7]

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4 **(a)** Define electric potential at a point.

……

……

…… [1]

(b) An isolated nucleus in a vacuum produces electric potential V at a distance r from its centre. Fig. 4.1 shows the variation with r of V.

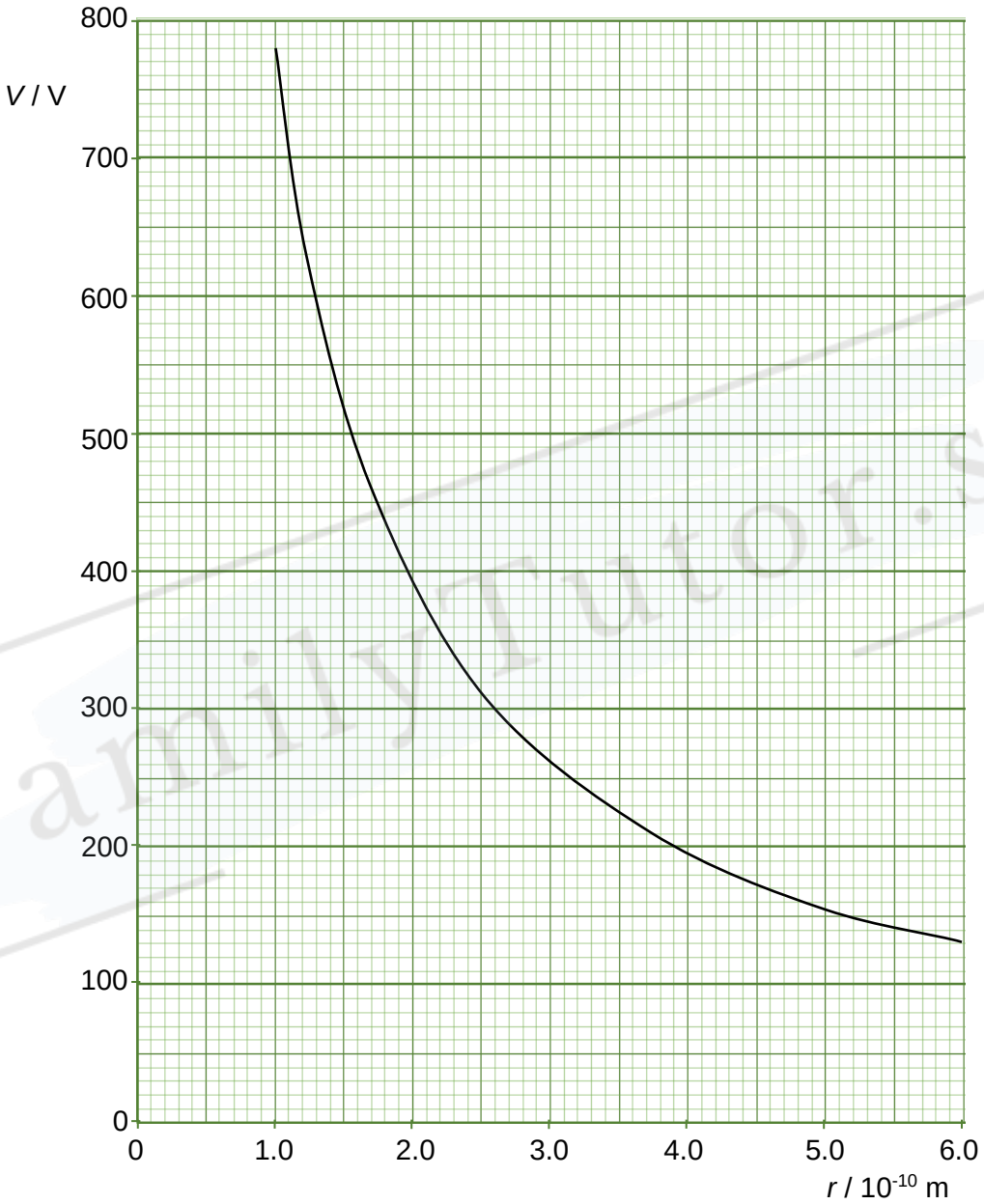

Fig. 4.1

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(i) Use data from Fig. 4.1 to show that there are 54 protons in the nucleus.

[3]

(ii) A single proton is placed at a distance of 2.0×10^{-8} m from the centre of the nucleus.

Suggest why it may be assumed that the proton and the nucleus behave as point charges.

……...

……...

…… [1]

(iii) **1.** Explain how the magnitude of the electric field strength at a distance *r* between 1.0 x 10^{-10} m and 6.0 x 10^{-10} m from the centre of the nucleus can be obtained from the curve in Fig. 4.1.

……..

…… [1]

2. Hence or otherwise, determine the electric force on a proton that is at 2.6 x10^{-10} m from the centre of the nucleus.

magnitude of the force = …… N

direction of the force = ……..

[4]

[Total: 10]

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5 **(a)** Distinguish between electromotive force and potential difference.

……

……

……

……

…….. [2]

(b) The circuit in Fig 5.1 consists of one battery with an e.m.f. of 12.0 V connected to a resistance wire of uniform resistivity and uniform cross-sectional area.

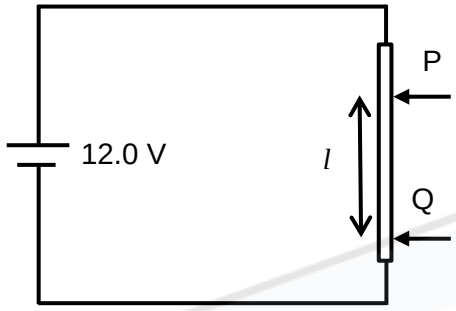

Fig 5.1

Explain why the potential difference between two points P and Q on the resistance wire is proportional to the distance between P and Q.

……

……

……

……

…….. [2]

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(c)

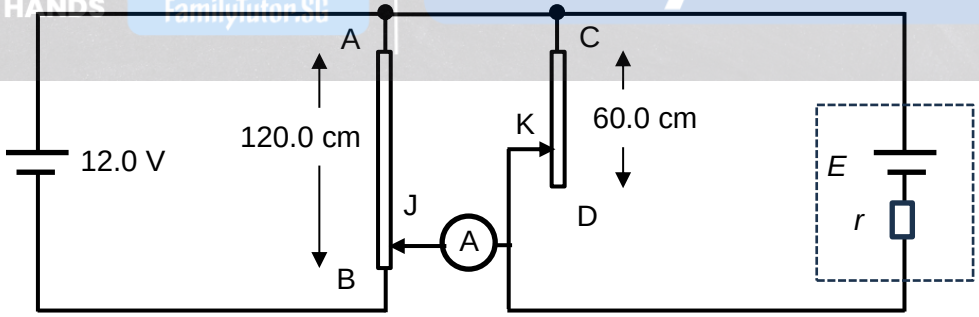

Fig 5.2

Fig 5.2 shows a circuit consisting of two parts.

The part on the left consists of a battery having an e.m.f. of 12.0 V, with negligible internal resistance, connected to a uniform resistance wire of length 120.0 cm.

The part on the right consists of a battery having an unknown e.m.f. *E,* with internal resistance *r*, connected to another uniform resistance wire of different resistivity and cross-sectional area, 60.0 cm in length.

The two jockeys J and K, which are connected to each other through an ideal ammeter, are free to move along the resistance wires AB and CD respectively.

The ammeter shows zero reading when the distance AJ is 54.0 cm and CK is 60.0 cm, and also when AJ is 45.0 cm and CK is 20.0 cm.

(i) Show that the potential difference (p.d.) across CK is 5.4 V when the length CK is 60.0 cm.

[2]

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(ii) Given that the p.d. across CK is 4.5 V when the length CK is 20.0 cm, and the resistance of the resistance wire CD is 4.5 Ω.

Determine E and r.

E = ... V

r = ... Ω

[4]

[Total: 10]

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6 **(a)** In the α-particle scattering experiment, α-particles travelling in a vacuum are incident on a gold foil. The α-particles are shot at the gold foil one at a time.

On Fig 6.1, complete the path of each α-particle as it passes the gold nucleus.

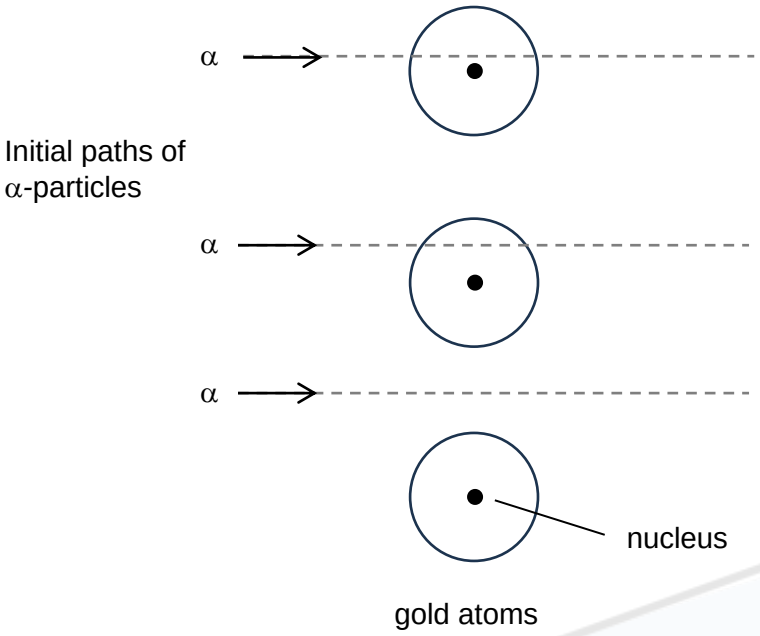

Fig. 6.1

[3]

(b) Describe and explain how the α-particle scattering experiment which you have illustrated in part **(a)** gives evidence for the existence and small size of the nucleus.

.....

.....

.....

.....

.....

.....

.....

..... [4]

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(c) The structure of the nucleus was clarified further by an experiment in which α-particles were fired at a piece of beryllium. A nuclear reaction took place in the beryllium and the reaction is now known to be

$$^{4}_{2}\text{He} + {}^{9}_{4}\text{Be} \rightarrow {}^{1}_{0}\text{n} + {}^{12}_{6}\text{C}$$

(i) What information does the symbol, $^{4}_{2}\text{He}$ give about the α-particle?

……. [1]

(ii) Data for the particles in the reaction in part **(c)** are given as follows.

particle	mass / u
$^{4}_{2}\text{He}$	4.00260
$^{9}_{4}\text{Be}$	9.01212
$^{1}_{0}\text{n}$	1.00867
$^{12}_{6}\text{C}$	12.00000

Calculate the energy associated with the change in mass in the reaction.

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energy = …… J [3]

(iii) Explain whether the products in the reaction have a higher or lower total binding energy than the reactants.

……

……. [1]

[Total :12]

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7 Read the passage and answer the questions that follow.

In World War II, Nazi Germany fought a bombing campaign against the British. The Germans developed a radio navigation system called *X-Gerät* ("X-Apparatus") to help their bombers find their targets more accurately. In turn, the British developed countermeasures, aiming to jam the German signals or lead the bombers off-course. This period of the war came to be known as the "Battle of the Beams."

X-Gerät consists of radio arrays called *Knickebein* ("crooked leg"). Each *Knickebein* array had eight radio antennae, which behave like point sources of radio waves, suspended 6.0 m apart, transmitting radio waves at a frequency of 30.0 MHz. The waves from these antennae superpose to produce a single beam of radio waves, which spreads out with an angle α as shown in Fig. 7.1. This guides an aircraft equipped with a radio receiver, to fly in a straight line towards their target.

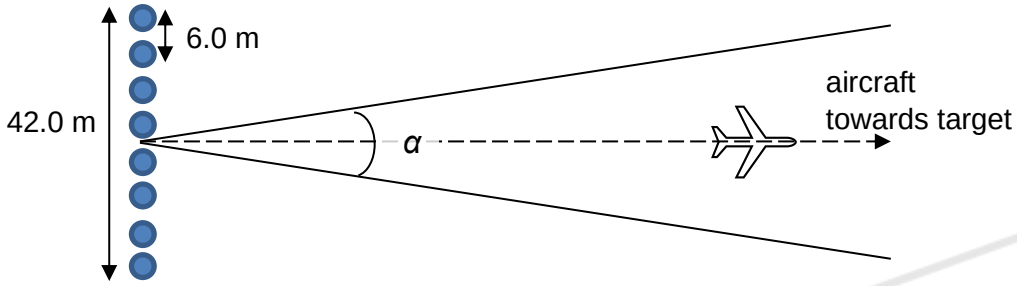

Fig. 7.1

The accuracy of this method of navigation is limited by the width of the beam, especially at long ranges. The narrower the beam, the more accurate the guidance system – but it is difficult to make the angle α small enough to be practical at the long ranges required. However, the German engineers managed to come up with a solution that significantly reduced the *Knickebein* beam's actual angular width.

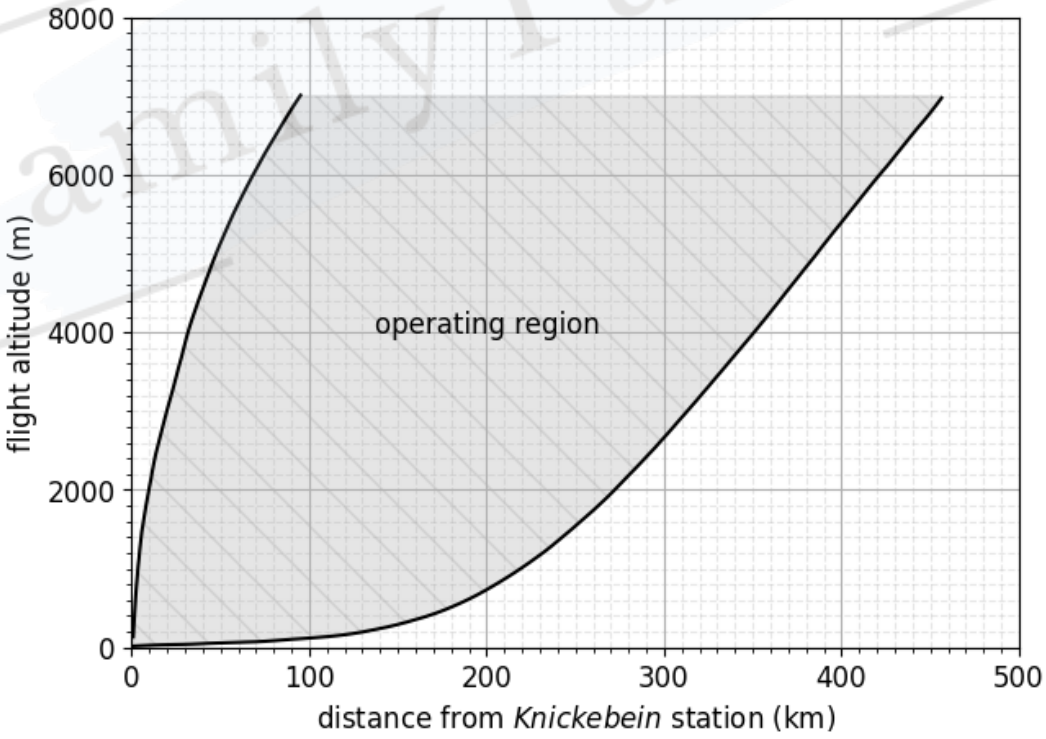

Fig. 7.2

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Whether the signal can be detected by the aircraft depends on its altitude and distance from the *Knickebein* station. Fig. 7.2 is a graph of flight altitude against distance from the *Knickebein* station. The shaded "operating region" between the two curves represents the region where the intensity of the radio waves is large enough for the aircraft to detect it.

In the *X-Gerät* system, the bomber flies along one *Knickebein* beam (the "guide beam") in a straight line towards its target at a constant speed and altitude. As the bomber approaches the target, it flies through two more *Knickebein* beams (*Oder* and *Elbe*), which are perpendicular to its path, as shown in Fig. 7.3. These beams are used to control when the bomb should be released.

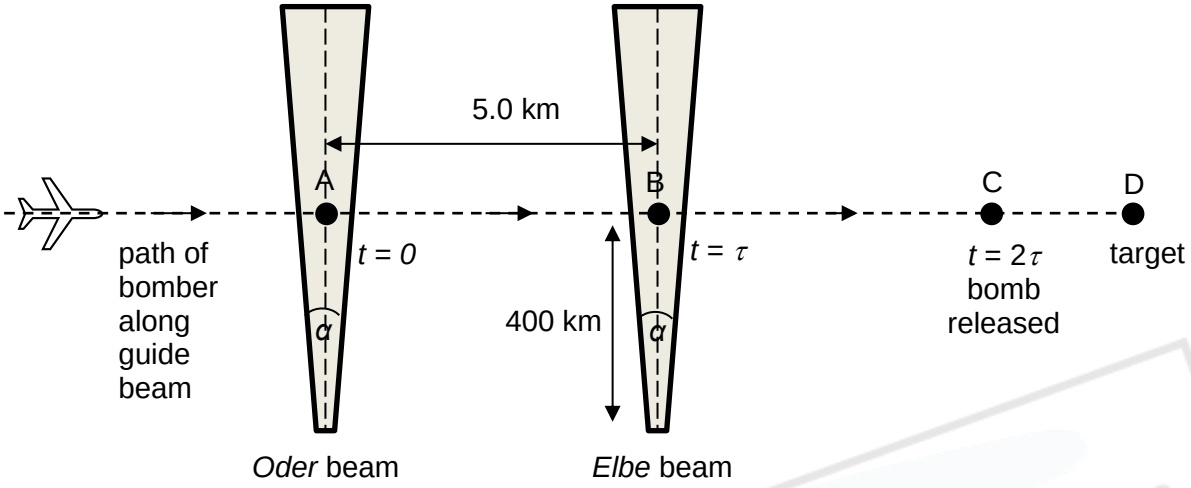

Fig. 7.3

When the bomber detects the *Oder* beam (at point A), a stopwatch is started. After travelling 5.0 km, the bomber detects the *Elbe* beam (at point B), and the stopwatch reading τ is noted. At point C, the stopwatch reading is 2τ, and the bomb is released, which falls and lands on the target at D. The *Oder* and *Elbe* beams originate from *Knickebein* stations in occupied Europe, about 400 km away, and thus have non-negligible widths. This contributes some uncertainty that may cause the bomb to miss.

(a) **(i)** The *Knickebein* array of radio antennae results in interference of radio wave, similar to visible light that has been passed through a diffraction grating.

Using the data from Fig. 7.1, show that the *Knickebein* array produces only a single beam.

[2]

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(ii) This beam of radio wave spreads out as it travels, like a wave passing through a single slit of the same width as the entire array of radio antennae.

For the arrangement of sources in Fig. 7.1, calculate α, the angular width of the beam.

α = ……° [3]

(b) **(i)** The bomber is flying at the minimum altitude for it to have a detectable signal 400 km from the *Knickebein* station.

State this altitude.

altitude = …… m [1]

(ii) The time shown on the stopwatch when the bomber crosses the Elbe beam is τ = 51.4 s.

Show that the speed of the bomber is 97.3 m s^{-1}.

[1]

(iii) Determine CD in Fig. 7.3, the horizontal distance from the release point to the target.

CD = …… m [3]

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(iv) Now, the bomber is flying at a greater speed than your answer to **(b)(ii)**, but the same altitude as in **(b)(i)**; the positions of the *Elbe* and *Oder* beams (A and B respectively) are unchanged.

Explain whether the bomb released at point C will still hit the target.

……

……

…… [2]

(v) The German engineers managed to reduce the angular width α of the beam to 0.3° instead of the value you found in **(a)(ii)**.

Determine the uncertainty in the position of point A due to the angular width of the *Oder* beam.

uncertainty = …… m [2]

(c) The German bomber used with the *Knickebein* was the Heinkel He 111H, which had the technical specifications in Table 7.1.

Crew	5
Propulsion for propellers	2 piston engines
Power of one piston engine	990 kW
Maximum speed	435 km/h
Service ceiling	6700 m
Range	1950 km
Empty weight	8680 kg
Maximum take-off weight	14000 kg

Table 7.1

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Forces acting on a Heinkel He 111H flying at constant speed and altitude are shown in Fig. 7.4.

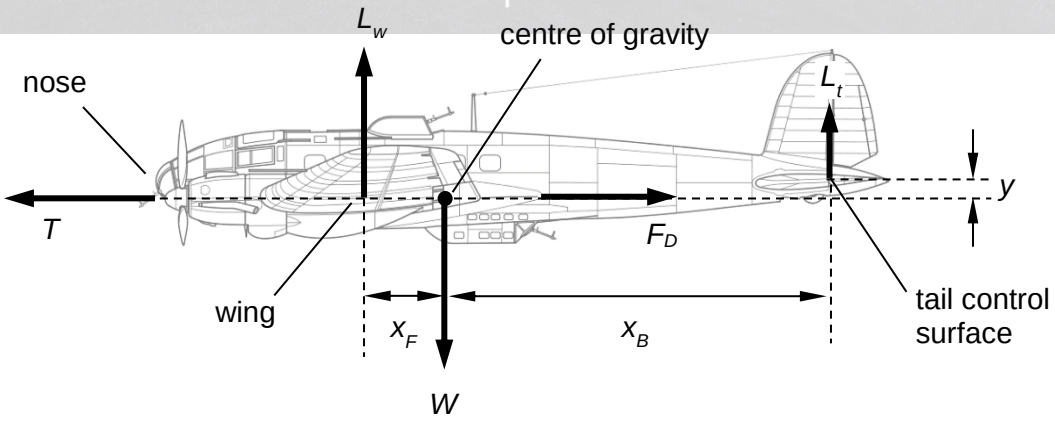

Fig. 7.4

T is the thrust from the propellers, L_w is the lift from the wings, L_t is the lift from the tail control surfaces, W is the weight of the aircraft, and F_D is the drag force.

The centre of gravity is a distance x_F away from the centre of lift of the wings and a distance x_B from the tail control surfaces.

The centre of lift of the tail control surfaces is at a perpendicular distance y above the centre of gravity.

(i) Take moments about the centre of gravity, to show that, when the aircraft is level and flying at constant speed and altitude,

$$L_t = \frac{Wx_F}{x_F + x_B}$$

[2]

(ii) Explain clearly why the drag force F_D does not appear in the relationship in **(c)(i).**

.....

..... [1]

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(iii) Using data from Table 7.1, determine the magnitude of the drag force F_D on the bomber when it is travelling at a constant speed of 200 km h^{-1}.

F_D = ... N [4]

[Total: 21]

End of paper

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JC2 Preliminary Examination
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CANDIDATE NAME		**CT GROUP**	**22S**
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS

9749/03

Paper 3 Longer Structured Questions

18 September 2023

SECTION A BOOKLET

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **Centre number**, **index number, name** and **CT class** clearly on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paperclips, highlighters, glue or correction fluid.

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

Section A

Answer **all** questions.

Section B

Answer **one** question only. **Circle** the question number on the cover page.

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

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

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
Section A		
1		8
2		8
3		9
4		8
5		8
6		7
7		12
Section B		
8		20
9		20
Deductions		
P3		80

This paper consists of **17** printed pages.

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Data

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

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

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
$\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}

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

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

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

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

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

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

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

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

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

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

Formulae

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

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Section A

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

1 **(a)** Define gravitational potential at a point.

……

…… [1]

(b) A satellite is orbiting the Earth with an orbital radius of 6610 km at a speed of 7780 m s^{-1}. The satellite is boosted into a higher orbit of radius 6890 km by firing its thrusters.

(i) State and explain the effect on the gravitational potential energy of the satellite.

……..

…… [1]

(ii) Show that the linear speed v of a satellite in a circular orbit of radius R about the centre of the Earth is given by

$$v = \sqrt{\frac{GM}{R}}$$

where G is the gravitational constant and M is the mass of the Earth.

Explain your working.

[1]

(iii) Show that the speed of the satellite in the new orbit is 7620 m s^{-1}.

[1]

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(iv) The satellite has a mass of 120 kg. Using your result in **(b)**, calculate the **change** in

1. kinetic energy,

change in kinetic energy = ... J [2]

2. total energy.

change in total energy = ... J [2]

[Total: 8]

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2 **(a)** **(i)** The pressure p in an ideal gas is given by the expression

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

State the meaning of each of the symbols in the equation.

N : .....

m : .....

V : .....

$\langle c^2 \rangle$: .....

[2]

(ii) Using the equation in **(i)** and the equation of state of an ideal gas, $pV = NkT$, derive an expression for the relationship between the internal energy of the ideal gas and the thermodynamic temperature T.

[2]

(b) **(i)** The gravitational field is relatively weak on the surface of the Moon. The escape speed (i.e. the minimum speed which a body must have in order to escape to an infinite distance) from the Moon is 2.38 km s^{-1}.

Argon-40 may be assumed to be an ideal gas. Calculate the temperature of argon-40 gas at which the r.m.s speed of its atoms is equal to the escape speed from the Moon.

temperature = ... K [2]

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(ii) An appreciable amount radioactive potassium-40 is discovered below the lunar surface. It is known that potassium-40 decays to form argon-40 gas.

With reference to your answer in **(b)(i)**, discuss the likelihood of argon-40 being present in the Moon's atmosphere.

……...

……...

……...

…….. [2]

[Total: 8]

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3 A spring hangs vertically from a fixed point.

A mass of 1.2 kg is attached to the free end of the spring, as shown in Fig. 3.1.

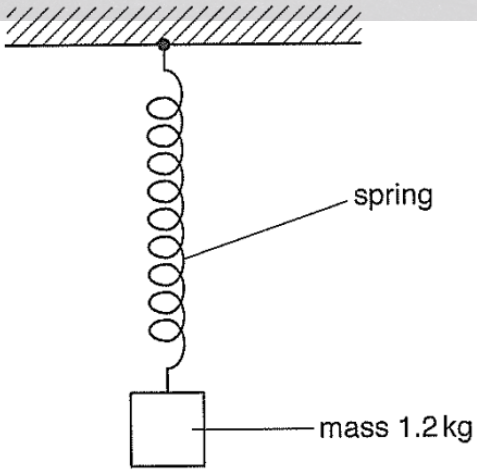

Fig. 3.1

The mass is at the maximum displacement below the equilibrium position at t = 0 s.

It undergoes vertical oscillations with frequency 2.5 Hz and amplitude 3.4 cm.

Take upwards as positive.

(a) The variation with the vertical displacement x of the velocity v of the mass on the spring is shown in Fig. 3.2.

On Fig. 3.2.

(i) indicate the values where the graph cuts the axes,
(ii) mark the starting position at t = 0 s and label this point **A**.

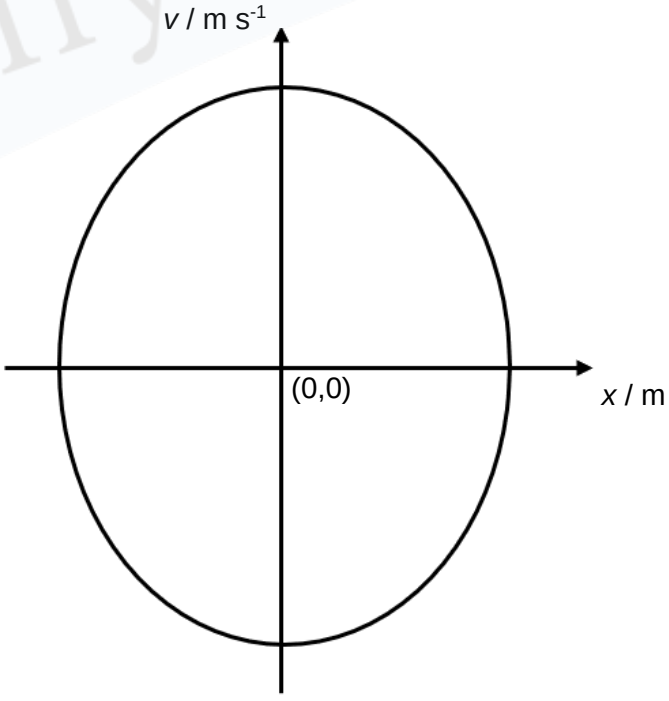

Fig. 3.2

[2]

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(b) For the oscillations of the mass, determine the total energy E_T.

E_T = ... J [2]

(c) **(i)** On Fig. 3.2, mark the position where the potential energy E_P is equal to the kinetic energy E_K for the first time upon releasing the mass. Label this point **B**. [1]

(ii) Determine the displacement d of the mass at **B**.

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d = ... m [2]

(d) Calculate the phase difference between the positions **A** and **B**.

phase difference = ... rad [2]

[Total: 9]

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4 An optical telescope detects light in the visible spectrum. It has an aperture of width 20.0 cm which is 1.50 m from the eyepiece. It is pointed at a binary star system 8.14 x 10^{16} m away, as shown in Fig. 4.1.

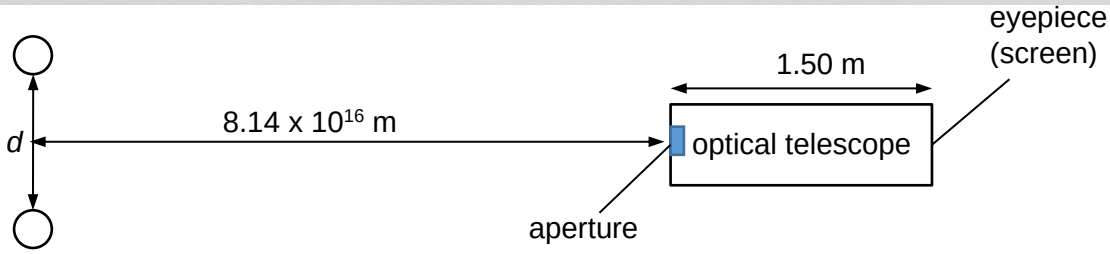

Fig. 4.1 (not drawn to scale)

(a) State Rayleigh's Criterion.

……

……

…… [2]

(b) The two stars are **just** resolvable on this telescope for wavelength of 600 nm.

Calculate the separation *d* of the stars if the plane of the stars' orbits is perpendicular to the earth (i.e. "face-on") as shown in Fig. 4.1.

Show your working clearly.

d = …… m [2]

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(c) The light of the entire visible spectrum (400 nm to 700 nm) collected by the telescope is passed through a diffraction grating with 500 lines per mm.

(i) Find the angular width of the second order spectrum.

angular width = …… ° [3]

(ii) State an advantage of using the second order spectrum instead of the first order spectrum to determine the wavelength of a radiation.

……

…….. [1]

[Total: 8]

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5 (a) A thermistor and a filament bulb are connected in parallel to a battery as shown in Fig 5.1. The e.m.f. E of the battery is unknown and its internal resistance is negligible.

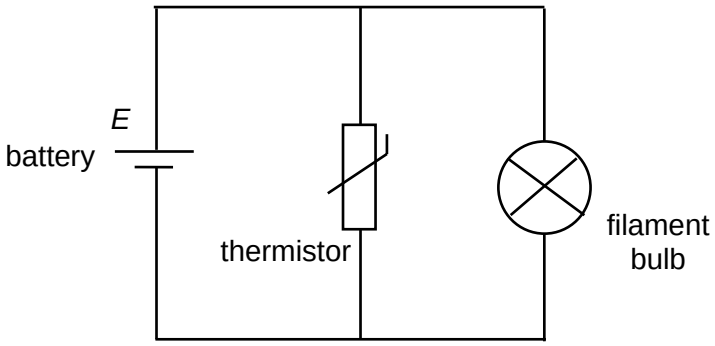

Fig 5.1

Fig. 5.2 shows the current-voltage (I-V) characteristics of the filament bulb and the thermistor.

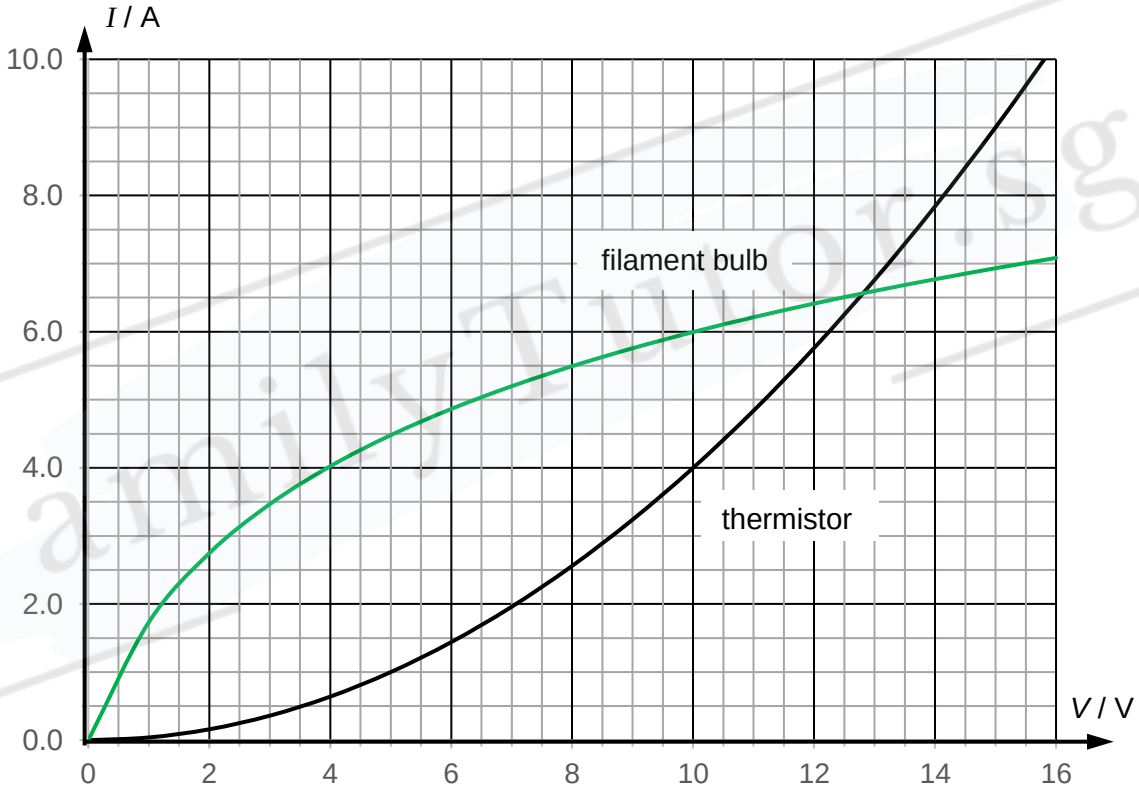

Fig 5.2

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(i) Describe the main features of Fig. 5.2 that show the characteristics of the negative temperature coefficient thermistor in terms of current, voltage and resistance.

……..

……..

……..

…… [2]

(ii) The current through the battery is 8.0 A.

Using Fig. 5.2, determine

1. the current through the filament bulb and the thermistor

current through the filament bulb = …… A [1]

current through the thermistor = …… A [1]

2. the e.m.f. of the battery.

e.m.f. = …… V [1]

(b) The filament bulb is now connected in series with a fixed resistor of 2.5 Ω and a battery, as shown in Fig 5.3. The e.m.f. *E* of the battery is 14.0 V and its internal resistance is negligible.

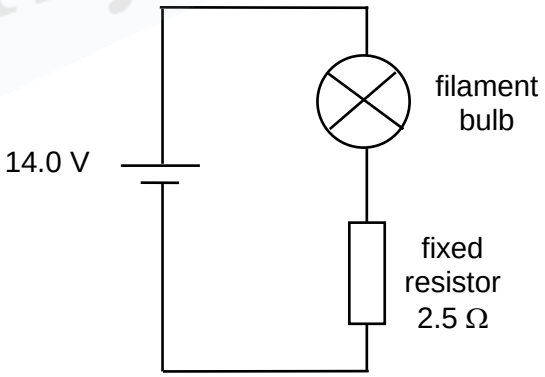

Fig. 5.3

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The variation with the potential difference V of the current I for the filament bulb is shown in Fig. 5.4.

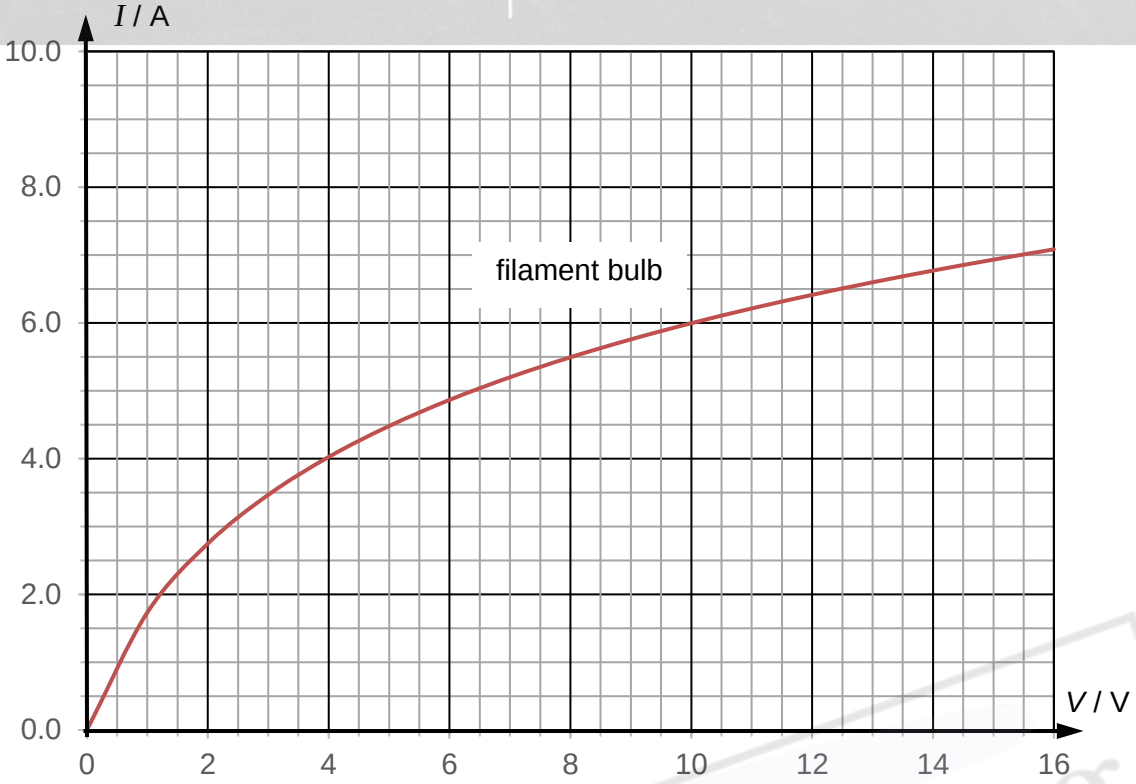

Fig 5.4

(i) On Fig 5.4, draw a line to show the variation with the potential difference V of the current I through the fixed resistor. [1]

(ii) Using Fig. 5.4, determine the current through the filament bulb.

current = ... A [1]

(iii) Using Fig. 5.4, determine the potential difference across the fixed resistor.

potential difference = ... V [1]

[Total: 8]

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

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

The alternating voltage V_P is connected to the primary coil of an ideal transformer as shown in Fig. 6.1. An electric heater with resistance 130 Ω is connected to the secondary coil of the transformer.

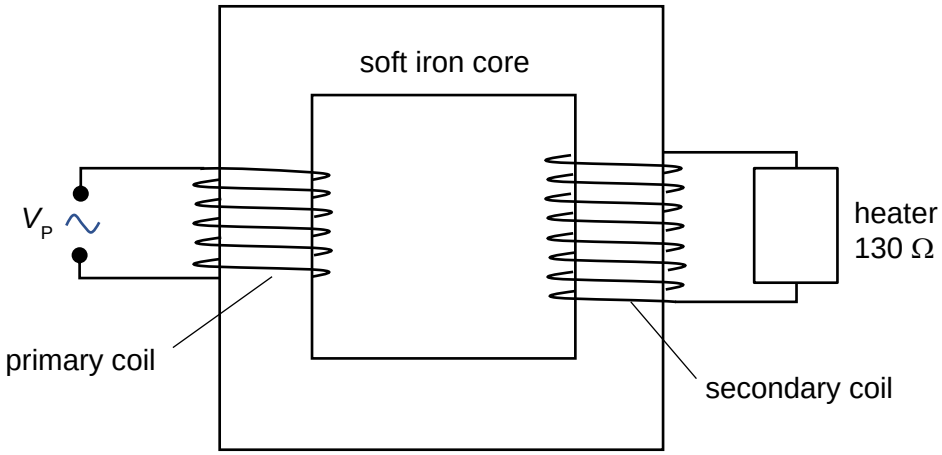

Fig. 6.1

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

(i) Determine r.m.s. potential difference, $V_{S,\,r.m.s.}$ of the secondary coil.

$V_{S,\,r.m.s}$ = ... V [2]

(ii) Determine the peak current, $I_{P,\,peak}$ in the primary coil.

$I_{P,\,peak}$ = ... A [3]

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(b) In Fig. 6.1, the mean power dissipated in the heater is P.

The number of turns in secondary coil is halved while keeping the V_P and the number of turns in primary coil constant.

Determine the new mean power dissipated in the heater in terms of P. Explain your answer.

……

……

……

…… [2]

[Total: 7]

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7 Fig. 7.1 shows the energy levels of a hydrogen atom. Transitions A, B, C and D represent some of the possible transitions of an excited electron of the atom.

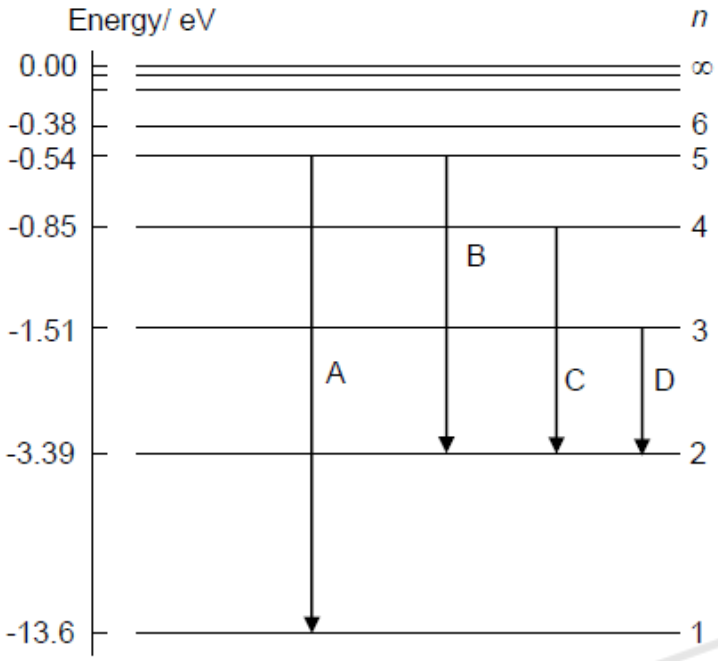

Fig. 7.1

(a) Explain why the energy levels are negative.

.....

.....

.....

.....

.....

..... [3]

(b) Which of the transitions A, B, C, or D would lead to the emission of radiation of the shortest wavelength?

..... [1]

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(c) Using your answer in **(b)**, calculate the wavelength of the radiation and state the region of the electromagnetic spectrum in which this radiation lies.

wavelength = ……. nm [2]

region = ……..…… [1]

(d) List all possible transition(s) in an emission spectrum if an unexcited hydrogen atom is separately bombarded by the following. Explain your answer.

In the case where no transitions are possible, state so clearly and explain your answer.

(i) An incoming electron with energy 12.6 eV

……..

……..

…… [2]

(ii) An incoming photon with energy 12.6 eV

……..

……..

…… [2]

(e) Suggest an application of emission spectrum.

……

……... [1]

[Total: 12]

End of Paper 3 Section A

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HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	**22S**
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS

9749/03

Paper 3 Longer Structured Questions

18 September 2023

SECTION B BOOKLET

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **Centre number**, **index number, name** and **CT class** clearly on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paperclips, highlighters, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only. **Circle** the question number on the cover page.

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

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

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
SECTION B (circle 1 question)		
8		**20**
9		**20**
Deductions		

This document consists of **11** printed pages.

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Data

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

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

permittivity of free space,
$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
$\approx (1/(36\pi)) \times 10^{-9}\ \mathrm{F\,m^{-1}}$

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

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

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

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

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

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

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

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

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

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

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\,\Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/\mathrm{K} = T/^{\circ}\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{(x_0^2 - x^2)}$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section B

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

8 **(a)** State the conditions required for a body to be in equilibrium.

.....

..... [2]

(b) A uniform beam AB of mass 1.5 kg is placed on a horizontal bench and held in equilibrium by a support cable. The beam is at an angle of 42° to the horizontal bench and the support cable is at an angle of 25° to the horizontal platform, as shown in Fig. 8.1.

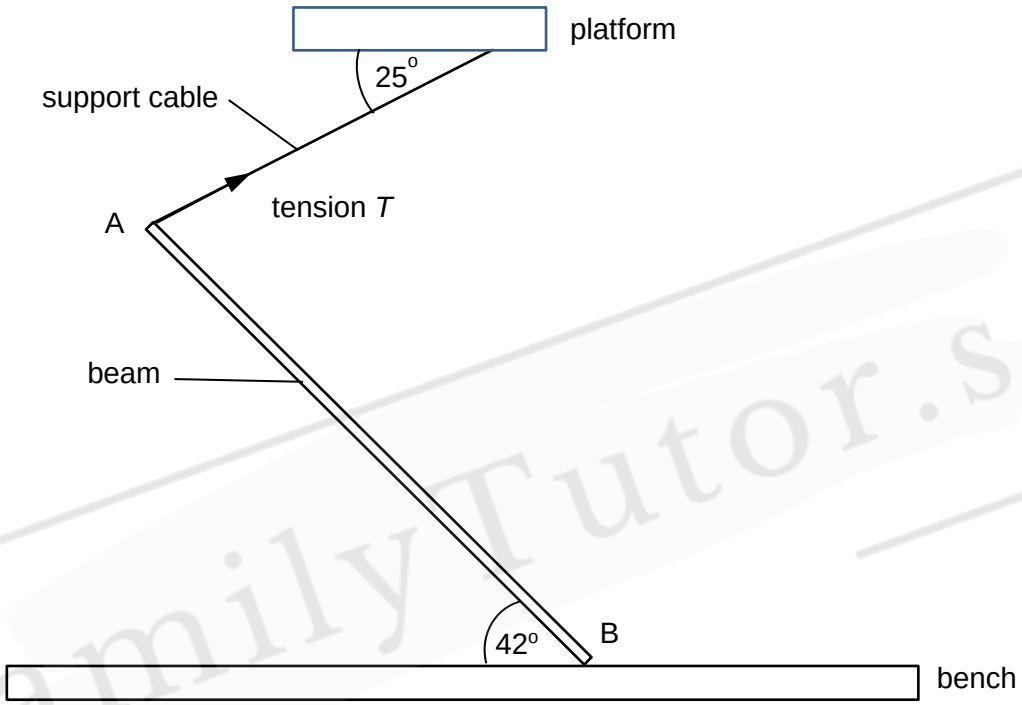

Fig. 8.1 (not drawn to scale)

(i) On Fig. 8.1, draw the forces acting on the beam. [2]

(ii) Show that the magnitude of tension T exerted on the beam by the cable is 5.94 N.

[2]

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(iii) Determine the force exerted on the beam by the bench.

magnitude = ... N [3]

direction = ... [1]

(c) In a child's toy, a small ball moves along a smooth track. The ball moves down a straight slope and then travels around a vertical circular loop, as shown in Fig. 8.2

The loop has diameter of 34 cm. The slope has a length of 58 cm and is inclined at an angle of 42° to the horizontal. Initially, the ball is at rest at the top of the slope.

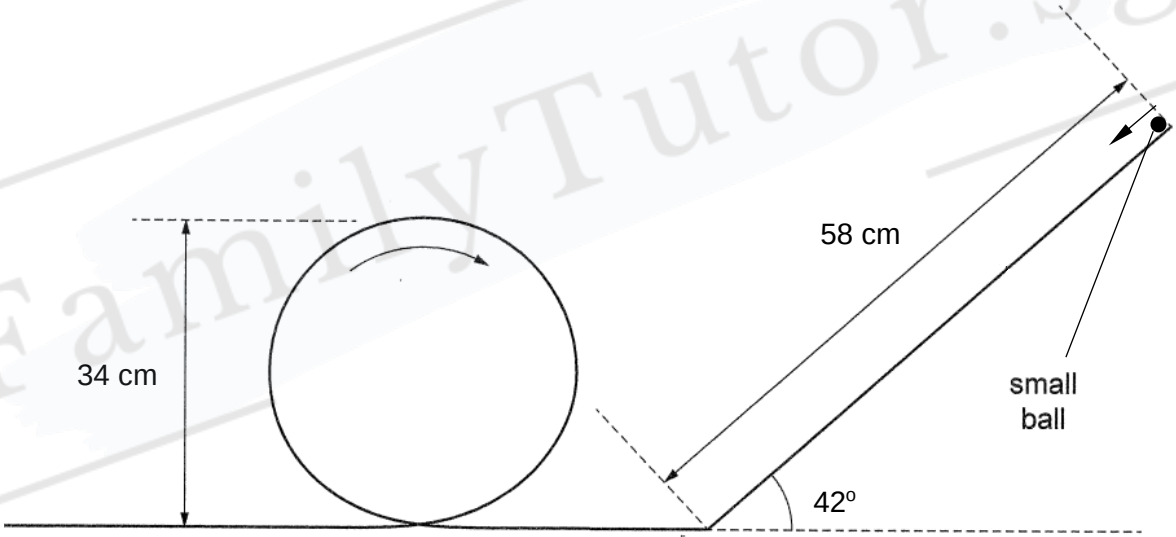

Fig 8.2

(i) Calculate the acceleration of the ball moving down the slope.

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

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(ii) State and explain what happens to the acceleration of the ball moving down the slope when it is replaced with another ball of the same size but twice the original weight.

……..

……..

……..... [2]

(iii) Determine whether the ball is able to make a complete loop around the circular track when released at the top of the slope. Show your working clearly.

Assume there is negligible air resistance and friction between the slope, the bench and the circular track with the ball.

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……..

……..

…… [4]

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(iv)

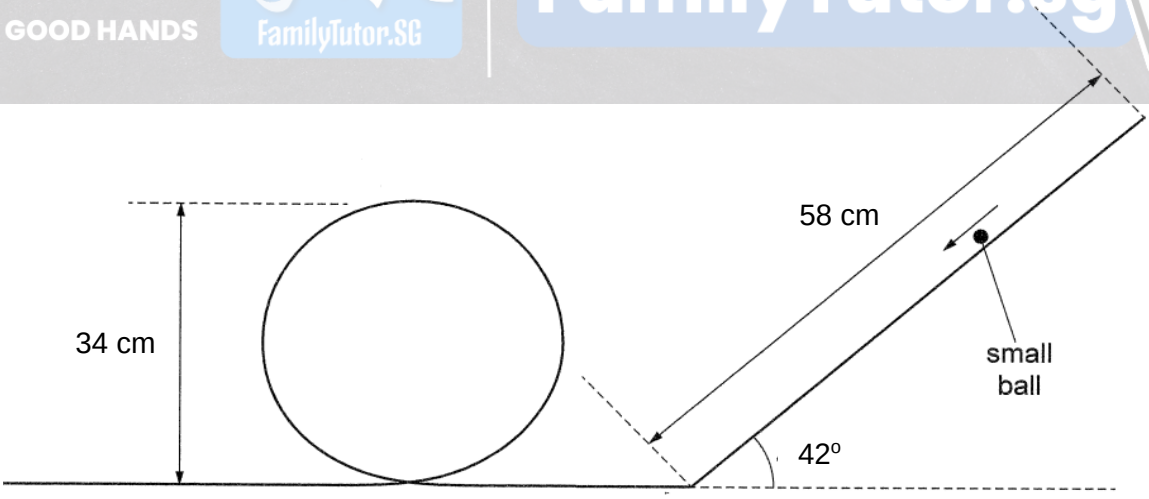

Fig. 8.3

The ball is now released from a new position as shown in Fig. 8.3.

Describe the subsequent path of the ball.

……..

……

…… [2]

[Total: 20]

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9 **(a)** Define magnetic flux linkage.

.....

.....

..... [2]

(b) A solenoid of length 30.0 cm is wound evenly with 900 turns of insulated wire. The cross-sectional area of the solenoid is 3.2×10^{-4} m^2.

A flat coil having 250 turns of wire is wound tightly around the centre of the solenoid. A resistor of 35 Ω is connected to the coil as illustrated in Fig. 9.1.

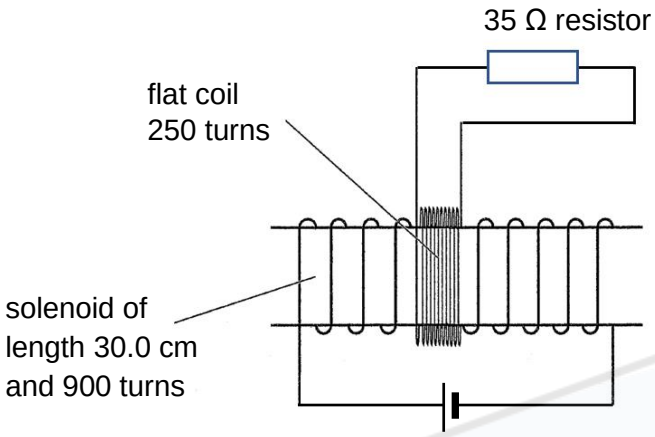

Fig. 9.1

(i) At a particular instant in time, the current through the solenoid is 2.0 A. Show that the magnetic flux through the coil is 2.41×10^{-6} Wb at that instant.

[2]

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(ii) The current in the solenoid increases at a uniform rate from 0.0 A to 2.0 A in 0.45 s.

1. Calculate the magnitude of the e.m.f. induced in the flat coil during this period.

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

2. Hence, calculate the amount of charge that flows through the resistor during this period.

charge = ... C [2]

3. Determine the amount of charge that passes through the solenoid during this period.

charge = ... C [2]

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(c) A potential difference is applied between two horizontal plates, each 15.0 cm long and separated by 4.0 cm.

A uniform magnetic field is directed perpendicularly into the page between the two plates.

A beam of electrons moves in a straight line between the plates along a horizontal path halfway between the two plates as shown in Fig. 9.2.

Each electron has a velocity of 4.50×10^6 m s^{-1}.

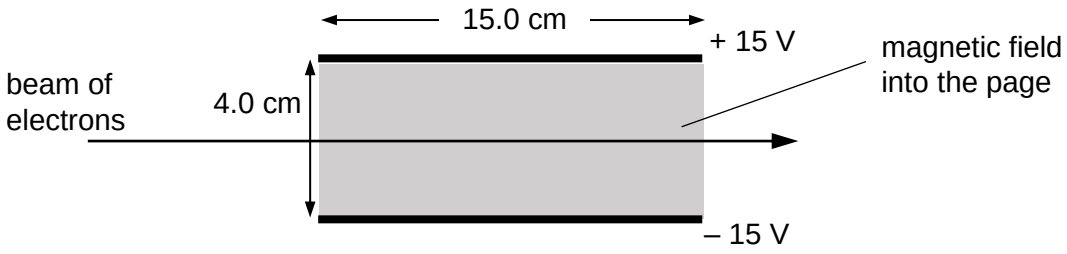

Fig. 9.2 (not drawn to scale)

(i) Determine the magnetic flux density of the magnetic field.

magnetic flux density = …….. T [2]

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The undeflected beam of electrons enters a second region of uniform magnetic field as shown by the shaded region in Fig. 9.3. A magnetic flux density of 0.50 x 10^{-3} T is directed perpendicularly into the page.

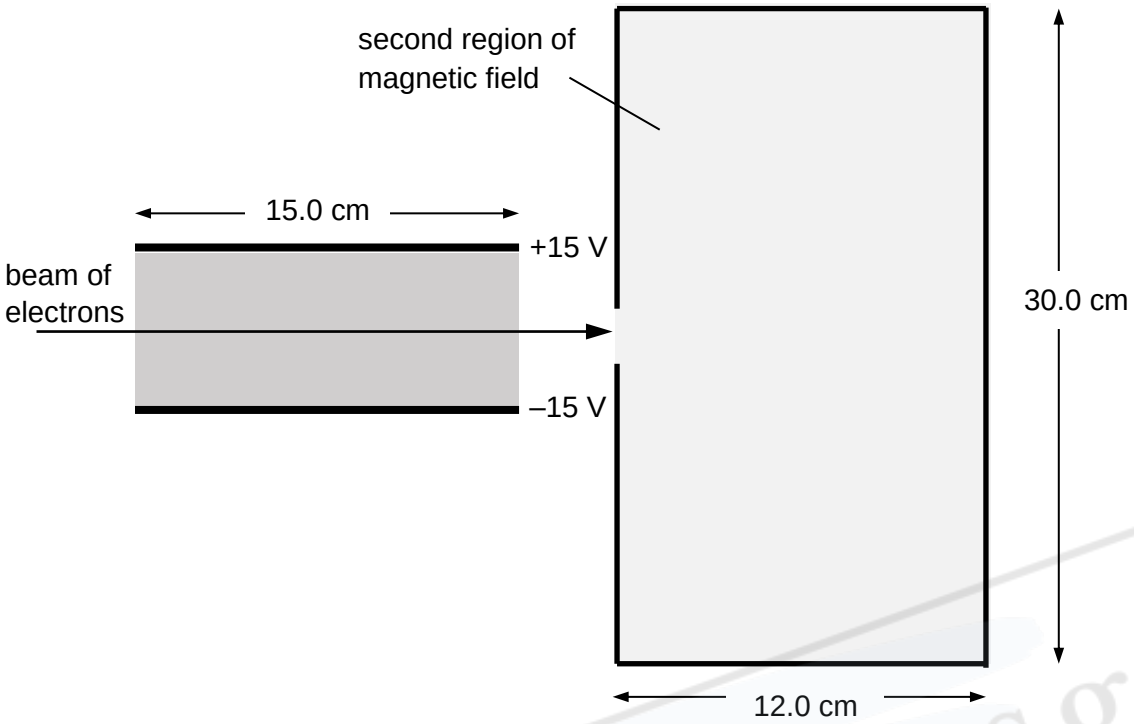

Fig. 9.3

(ii) Explain why the electrons move in a uniform circular motion inside the second region of magnetic field.

……

……

……

…… [2]

(iii) Calculate the radius of the path.

radius = …… m [2]

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(iv) The beam of electrons is now replaced by a beam of protons. The velocities of the protons before going between the two parallel plates ranges from of 3.00×10^6 m s^{-1} to 6.00×10^6 m s^{-1}.

Determine the speed of the protons that enters the second region of magnetic field.

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

(v) Sketch and label the respective paths of the electrons and protons inside the second magnetic field in Fig. 9.3.

[3]

[Total: 20]

End of Paper 3 Section B

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Answer:

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

Suggested Solutions:

Qn	Ans	Solution
1	B	$R = \sigma T^4 \rightarrow \sigma = \frac{R}{T^4}$ Unit of $\sigma = \frac{\text{J s}^{-1}\ \text{m}^{-2}}{\text{K}^4}$ $= (\text{kg m}^2\ \text{s}^{-2})\ \text{s}^{-1}\ \text{m}^{-2}\ \text{K}^{-4}$ $= \text{kg s}^{-3}\ \text{K}^{-4}$
2	B	$Z = X - Y \rightarrow X = Z + Y$
3	C	By conservation of energy, $\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + mg\Delta h$ Since, the magnitude of the loss in gravitational potential energy is the same for stones P and Q, with the same initial kinetic energy, the stones will end up with the same magnitude of kinetic energy, implying they will hit the ground with the same speed.
4	C	Using $s = ut + \frac{1}{2}at^2$, distance travelled in first 10 s is 24 m, $24 = \frac{1}{2}a(10)^2$ $\therefore a = 0.48\ \text{m s}^{-2}$ Distance travelled in the first 25 s, $s = \frac{1}{2}(0.48)(25)^2$ $= 150\ \text{m}$ Distance travelled from $t = 10$ s to $t = 25$ s $= 150 - 24$ $= 126\ \text{m}$
5	A	For A: $T = (2.0)a$ ..... (1) For B: $(5.0)(9.81) - T = (5.0)a$ ..... (2) Sub (1) into (2): $49.05 - 2a = 5a$ $a = 7.0\ \text{m s}^{-2}$

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Qn	Ans	Solution
6	A	By principle of conservation of linear momentum, $m(2v)+3m(-v)=(m+3m)V$ $V=-\frac{1}{4}v$ The speed of mass m is $\frac{1}{4}v$ after the collision.
7	D	Weight of boat = upthrust = weight of fresh water displaced = 35.6 kN Weight of boat = weight of salt water displaced = $mg = \rho Vg$ = 35.6 kN $V=\frac{35.6\times10^3}{\rho g}=\frac{35.6\times10^3}{(1024)(9.81)}$ $=3.54\ \text{m}^3$
8	B	Extension for spring X, $x_1=\frac{F}{k_1}=\frac{1.5}{5.0}=0.30$ m Extension for spring Y, $x_2=\frac{F}{k_2}=\frac{1.5}{10.0}=0.15$ m Elastic P.E. stored = $\frac{1}{2}kx^2$ Total elastic P.E. stored = $\frac{1}{2}(5)(0.3)^2+\frac{1}{2}(10)(0.15)^2$ J = 0.34 J
9	C	Loss in G.P.E. by Y = gain in G.P.E. by X + gain in K.E. by X and Y $3.0\times9.81\times3.0\sin40°=2.0\times9.81\times3.0\sin30°+\frac{1}{2}(2.0+3.0)v^2$ $v\approx3.3\ \text{m s}^{-1}$
10	B	For mass m_1: $\frac{m_1v^2}{L+e}=ke$ $v^2=\frac{ke(L+e)}{m_1}$ For mass m_2: $\frac{m_2v^2}{2(L+e)}=k(2L+2e-L)$ $\frac{m_2v^2}{2(L+e)}=k(L+2e)$ $m_2=\frac{2k(L+2e)(L+e)}{v^2}$ $=\frac{2k(L+2e)(L+e)m_1}{ke(L+e)}$ $=\frac{2m_1(L+2e)}{e}$

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Qn	Ans	Solution
11	**C**	total energy at top of ramp = total energy at lowest point $mgh = \frac{1}{2}mv^2 \rightarrow v^2 = 2gh$ By Newton's second law of motion, at the lowest point, $R - mg = \frac{mv^2}{r}$ $R = \frac{m(2gh)}{r} + mg$ Since $r = h$, $R = 3mg$
12	**A**	Gravitational potential at infinity is zero. Moving from –30 MJ kg^{-1} to –70 MJ kg^{-1} means moving closer to Earth. Potential energy change = 50 [–70 – (–30)] = –2000 MJ
13	**D**	A is true: From $pV = nRT$, at constant pressure, when volume is doubled, temperature is doubled. B is true: work done $W = p\Delta V = 4P_o(2V_o - V_o)$ C is true: $W = 0 \rightarrow \Delta U = Q$. From $pV = nRT$, since there is a decrease in pressure, there must be a decrease in temperature and hence a decrease in internal energy, i.e. ΔU is negative. This means Q is negative, i.e. heat is removed.
14	**C**	From $pV = nRT$, when p and V are tripled, the temperature would be $9T$ New temperature = (200 + 273) × 9 = 4257 K = 4257 – 273 = 3984 = 4000 °C From $\frac{1}{2}m\langle c^2\rangle = \frac{1}{2}mv^2 = \frac{3}{2}kT \rightarrow v^2 = \frac{3kT}{m} \rightarrow v = \sqrt{\frac{3kT}{m}}$, when the new temperature is $9T$, the new r.m.s. speed = $3v$
15	**D**	Option A: The kinetic energy of the oscillator is proportional to **square of the frequency** of its motion. Incorrect. Option B: The potential energy of the oscillator is **maximum** when the oscillator is momentarily at rest. Incorrect. Option C: The kinetic energy of the oscillator is **maximum** when the oscillator is at the equilibrium position. Incorrect. Option D: When the kinetic energy of the oscillator is equal to its potential energy, the oscillator is neither at the rest position nor at the maximum displacement positions. Correct.

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Qn	Ans	Solution
16	B	Using $v_0 = x_0\omega$, $x_0 = \frac{v_0}{\omega}$ $= \frac{v_0}{\frac{2\pi}{T}}$ $= \frac{3.0 \times 0.063}{2\pi}$ $= 0.03$ m $a_0 = \omega^2 x_0$ $= \left(\frac{2\pi}{T}\right)^2 x_0$ $= \left(\frac{2\pi}{0.063}\right)^2 \times 0.03$ $= 298$ ≈ 300 m s^{-2}
17	A	Let the speed of the wave be v. The wavelength $\lambda = \frac{v}{f} = \frac{v}{12.5} \rightarrow v = 12.5\lambda$ For the displacement to be zero at Q, the wave travels a distance $d = \frac{\lambda}{8} = 0.125\lambda$. The time taken for this $= \frac{d}{v} = \frac{0.125\lambda}{12.5\lambda} = 0.010$ s

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Qn	Ans	Solution
18	D	At lowest frequency, $L = \frac{1}{4}\lambda_1$ $\lambda_1 = 4L$ $f_1 = \frac{v}{\lambda_1} = \frac{v}{4L}$ At next highest frequency, $L = \frac{3}{4}\lambda_2$ $\lambda_2 = \frac{4}{3}L$ $f_2 = \frac{v}{\lambda_2} = \frac{3v}{4L} = 3\frac{v}{4L} = 3f_1$ At third highest frequency, $L = \frac{5}{4}\lambda_3$ $\lambda_3 = \frac{4}{5}L$ $f_3 = \frac{v}{\lambda_3} = \frac{5v}{4L} = 5\frac{v}{4L} = 5f_1$ So the frequencies that can be produced by the instrument are $f_1,\ 3f_1,\ 5f_1,\ 7f_1,\ \ldots$
19	A	Option A: Correct $\theta = \frac{\lambda}{b} \Rightarrow b = \frac{\lambda}{\theta} = \frac{590\times10^{-9}}{2.0\times10^{-6}} = 0.295\text{ m} \approx 0.30\text{ m}$ Option B: Incorrect Red stars give out red light of wavelength of 700 nm. $\theta = \frac{\lambda}{b} = \frac{700\times10^{-9}}{0.30} = 2.3\times10^{-6}$ radians which is larger than the angular separation of 2.0×10^{-6} radians. Hence, the red stars cannot be resolved. Option C: Incorrect The resolving power of the telescope is dependent of the wavelength of light, according to the expression $\theta = \frac{\lambda}{b}$. Option D: Incorrect The angular separation between the stars is 2.0×10^{-6} radians for the telescope to be able to resolve. Hence, the telescope cannot be used to distinguish the stars.

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Qn	Ans	Solution
20	**A**	For the first 2.0 m, the movement is along the direction of increasing potential which resulted in positive work done by the electric field. Positive work done by field = $(5.0)(4.0)(2.0) = 40$ J Thus, work done against electric field = −40 J. For the next 3.5 m, movement is along the same potential, hence, there is zero work done. Therefore, total work done against electric field = −40 J.
21	**C**	By conservation of energy, for the electron to just reach plate AB (that is, $v_y = 0$), work done against electric force = loss in kinetic energy of electron $eV = \frac{1}{2} m_e (v\cos\theta)^2$.
22	**A**	Effective resistance is made up of copper and iron resistors in parallel. Per unit length, Copper resistance $= \frac{1.7\times10^{-8}}{2.0\times10^{-3}} = 8.5\times10^{-6}\,\Omega$ Iron resistance $= \frac{1.0\times10^{-7}}{1.0\times10^{-3}} = 1.0\times10^{-4}\,\Omega$ Effective resistance per unit length $= \left(\frac{1}{8.5\times10^{-6}} + \frac{1}{1.0\times10^{-4}}\right)^{-1} = 7.8\times10^{-6}\ \Omega\,\text{m}^{-1}$
23	**C**	The smallest reading on the ammeter means smallest current passing through it. Ammeter has a resistance of 3 Ω. Option A: Incorrect. Current passing through ammeter, $I = \frac{V}{3}$, because ammeter is in parallel connection with the 1 Ω and 2 Ω resistors. Option B: Incorrect. Current passing through ammeter, $I = \frac{V}{3.67}$. Option C: Correct. Current passing through ammeter, $I = \frac{V}{6}$. Option D: Incorrect. Current passing through ammeter, $I = \frac{V}{4}$.
24	**D**	For zero deflection, magnetic force = electric force $Bqv = qE$ $v = \frac{E}{B}$ perpendicular to both B and E.

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Qn	Ans	Solution
25	**B**	The current in the wire will result in a magnetic field coming out of the coil according to the right hand grip rule. As the current in the wire increases, the B-field through coil increases. Applying Lenz Law and right hand grip rule to the coil, the induced B-field must be into the coil. Thus, induced current in the coil is clockwise.
26	**D**	The a.c. is half-wave rectified with a single diode.. Voltmeter reads the r.m.s. voltage, V = 2.5 V So peak voltage across NB = 2(2.5) = 5.0 V By potential divider principle, $\frac{V_{AB}}{V_{NB}} = \frac{L_{AB}}{L_{NB}} = \frac{100}{40} \rightarrow V_{AB} = V_o = \left(\frac{100}{40}\right)V_{NB} = \left(\frac{100}{40}\right)(5.0) = 12.5 \text{ V}$ Peak power $= \frac{V_o^2}{R} = \frac{12.5^2}{10} = 15.6 = 16 \text{ W}$
27	**B**	By de Broglie's expression, $\lambda = \frac{h}{p}$, Since $E = \frac{p^2}{2m} \Rightarrow p = \sqrt{2mE}$, $\lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2meV}}$ $\therefore \lambda \propto \frac{1}{\sqrt{V}}$
28	**B**	The peaks will remain the same as these are characteristic of the target metal. If the p.d. is increased, the electrons are fired with greater kinetic energy at the target metal, which means that more energetic X-rays can be produced. The cutoff wavelength will decrease, because $eV_{AC} = \frac{hc}{\lambda_{\min}}$.
29	**D**	Original activity is 180 counts s^{-1} after deducting background count. After 10 hours, the radioactive sample decays for 2 half-lives. Hence $\frac{1}{4}$ of its original activity remains giving 45 counts s^{-1}. Adding background counts giving 75 s^{-1}.
30	**A**	$^{111}_{47}\text{Ag} \rightarrow {}^{111}_{48}\text{Cd} + {}^{0}_{-1}\text{e}$

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Name: _____ Class: _____

JURONG PIONEER JUNIOR COLLEGE

JC2 Preliminary Examination 2023

PHYSICS **9749/01**
Higher 2 **19 September 2023**

Paper 1 Multiple Choice **1 hour**

Additional Material: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

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

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

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

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

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Data

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

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{GM}{r}$
temperature	$T\,/\,\mathrm{K} = T\,/\,^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{{x_0}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 The radiancy R is defined as the total energy emitted per unit time per unit area from a black body at thermodynamic temperature T. It is given by

$$R = \sigma T^4$$

where σ is called the Stefan-Boltzmann constant.

What is the correct unit for σ?

A W m^{-2} K^4

B kg s^{-3} K^{-4}

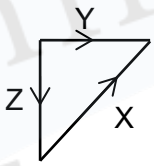
C J s m^{-2} K^{-4}

D J s^{-1} m^{-2} K^4

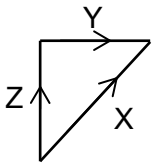
2 Two vectors X and Y are shown in the given diagram.

In which vector diagram does the vector Z represent the difference between X and Y such that Z = X – Y?

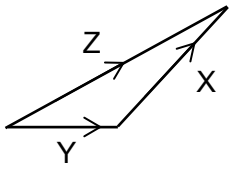
A



B



C



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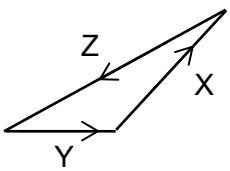

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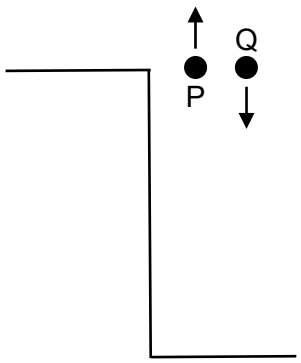
3 Two stones P and Q are thrown from the top of a cliff, one straight up and the other straight down, at the same initial speed. Both eventually hit the ground.



The effect of air resistance on the stones is negligible.

Which statement will be true of the speeds with which the stones hit the ground?

A Stone P hits the ground with the greater speed.

B Stone Q hits the ground with the greater speed.

C Both stones hit the ground with the same speed.

D The comparative speeds of impact depend on the height of the cliff.

4 An object accelerates uniformly from rest in a straight line.

During the first 10 seconds it travels a total distance of 24 m.

What is distance travelled by the object in the next 15 s?

A 36 m

B 54 m

C 126 m

D 150 m

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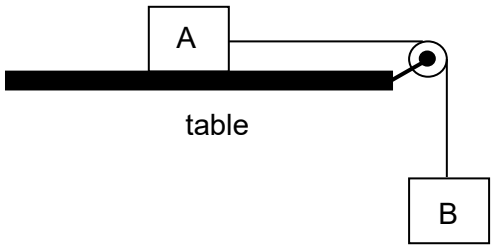
5 Two blocks A and B of masses 2.0 kg and 5.0 kg respectively are connected by an inextensible string as shown.



Both the table and the pulley are frictionless.

When B is released, what is the acceleration of A?

A 7.0 m s^{-2}

B 9.8 m s^{-2}

C 16 m s^{-2}

D 25 m s^{-2}

6 Two masses m and $3m$ move towards each other in opposite directions with speeds $2v$ and v respectively.

The masses collide and stick together.

What is the speed of mass m after the collision?

A $\frac{v}{4}$

B $\frac{v}{2}$

C v

D $\frac{5v}{4}$

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7 A boat floating in fresh water displaces 35.6 kN of water.

The density of sea water is 1024 kg m^{-3}.

What is the volume of sea water it will displace when floating in the sea?

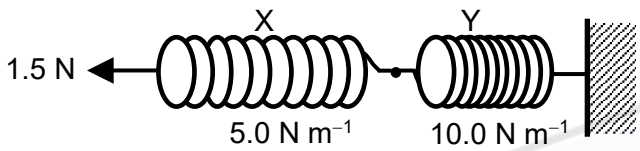
A 3720 m^3

B 34.8 m^3

C 3.63 m^3

D 3.54 m^3

8 A spring X of force constant 5.0 N m^{-1} is connected in series with a spring Y of force constant 10.0 N m^{-1} as shown. A force of 1.5 N is applied to the other end.



What is the total elastic potential energy stored in the springs?

A 0.23 J

B 0.34 J

C 0.68 J

D 1.5 J

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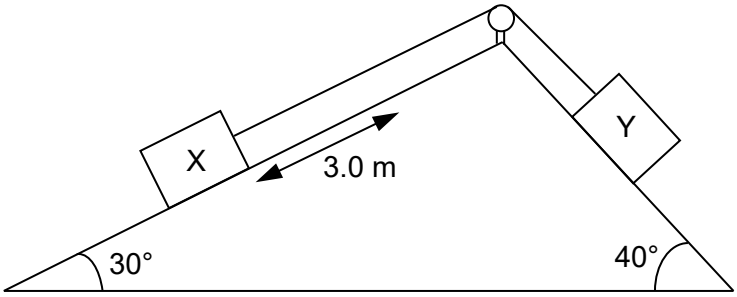
9 Two boxes X and Y of masses 2.0 kg and 3.0 kg respectively are connected by a light inextensible rope passing over a smooth pulley. X and Y are on smooth inclined planes.

X starts from rest and moves up the plane inclined at 30° to the horizontal.



What will be the final speed of Y after X has travelled 3.0 m along the plane?

A 1.6 m s^{-1}

B 2.3 m s^{-1}

C 3.3 m s^{-1}

D 4.3 m s^{-1}

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10 A mass m_1 is attached to one end of an elastic string of an unstretched length L. When the mass is rotating with a linear speed v on a smooth table in a horizontal circle, an extension e is obtained.

A second mass m_2 rotates with the same linear speed v. The radius is twice that produced by m_1.

What is the mass m_2?

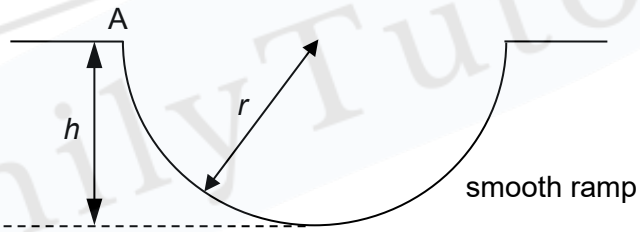
A $\dfrac{2m_1(L+e)}{e}$

B $\dfrac{2m_1(L+2e)}{e}$

C $\dfrac{2m_1(2L+e)}{e}$

D $\dfrac{2m_1(2L+2e)}{e}$

11 A skateboarder rests on top of a smooth ramp of height h and radius of curvature r. He moves off from his position of rest at A and slides down the smooth ramp.



The mass of the skateboarder is m.

What is the magnitude of the contact force R exerted by the ramp on the skateboarder at the lowest point of the ramp?

A mg

B $2mg$

C $3mg$

D $4mg$

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12 A satellite of mass 50 kg moves from a point where the gravitational potential due to the Earth is −30 MJ kg^{-1} to another point where the gravitational potential is −70 MJ kg^{-1}.

During this change of position, it has moved

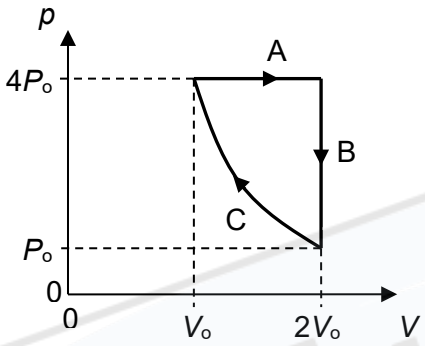
A closer to the Earth and lost 2000 MJ of potential energy.

B closer to the Earth and lost 40 MJ of potential energy.

C further from the Earth and gained 2000 MJ of potential energy.

D further from the Earth and gained 40 MJ of potential energy.

13 A fixed mass of ideal gas undergoes changes in pressure p and volume V starting with process A, as shown.



Which statement about the processes is **not** necessarily true?

A Temperature of the gas is doubled in process A.

B Work done by the gas in process A is $4P_oV_o$.

C Heat is removed from the system in process B.

D There is no heat exchange in process C.

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14 In an ideal gas at 200 °C, the molecules are travelling at a root-mean-square speed v.

Both the pressure and volume of the gas are then tripled.

What are the temperature of the gas and the root-mean-square speed of the molecules?

	temperature / °C	root-mean-square speed of molecules
A	1800	$3v$
B	1800	$9v$
C	4000	$3v$
D	4000	$9v$

15 Which statement about a simple harmonic oscillator is correct?

A The maximum kinetic energy of the oscillator is proportional to the frequency of its motion.

B The potential energy of the oscillator is minimum when the oscillator is momentarily at rest.

C The kinetic energy of the oscillator is zero when the oscillator is at the equilibrium position.

D When the kinetic energy of the oscillator is equal to its potential energy, the oscillator is neither at the rest position nor at the maximum displacement positions.

16 A body performs simple harmonic motion with a period of 0.063 s. The maximum speed of the body is 3.0 m s^{-1}.

What are the values of the amplitude x_0 and maximum acceleration a_0?

	x_0 / m	a_0 / m s^{-2}
A	0.030	3.0
B	0.030	300
C	0.19	19
D	0.19	1900

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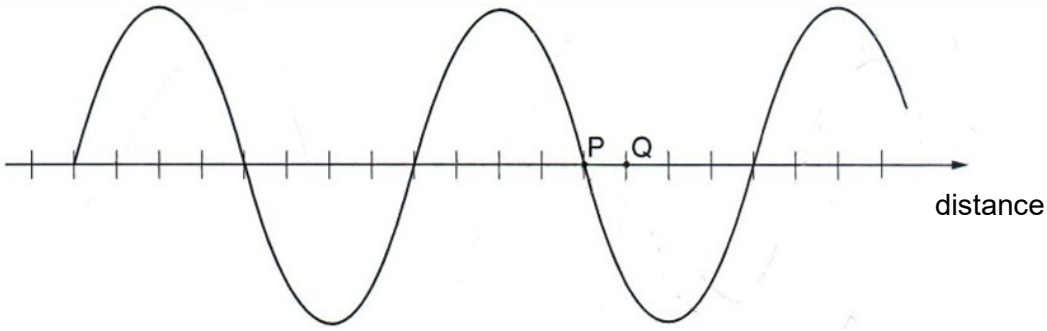
17 The diagram shows a transverse wave at a particular instant. The wave is travelling to the right. The frequency of the wave is 12.5 Hz.



At the instant shown the displacement is zero at the point P.

What is the shortest time to elapse before the displacement is zero at point Q?

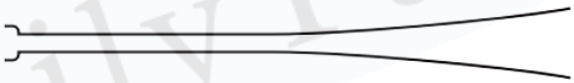
A 0.010 s

B 0.030 s

C 0.080 s

D 0.100 s

18 A musical instrument is made using a long tube with a mouthpiece at one end. The other end is open and flared, as shown.



A musician maintains stationary sound waves with a node at the mouthpiece and an antinode at the other end. The lowest frequency of sound that the instrument can produce is 98 Hz.

Which different frequencies of sound can be produced by the instrument?

A 98 Hz, 147 Hz, 196 Hz, 245 Hz

B 98 Hz, 196 Hz, 294 Hz, 392 Hz

C 98 Hz, 196 Hz, 392 Hz, 588 Hz

D 98 Hz, 294 Hz, 490 Hz, 686 Hz

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19 An optical telescope just resolves two distant yellow stars. They are subtended at an angle of 2.0×10^{-6} radians at the telescope. The wavelength of yellow light is about 590 nm.

Which statement is correct?

A The aperture of the telescope has a diameter of about 0.30 m.

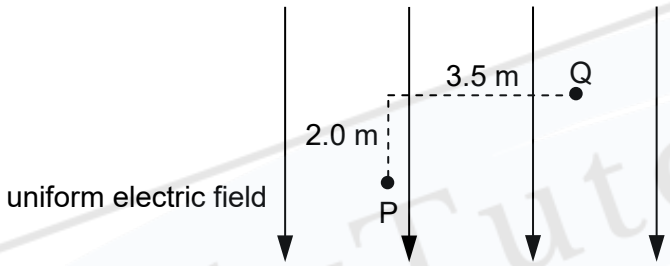
B The telescope can be used to distinguish two red stars at similar distance.

C The resolving power of the telescope is independent of the wavelength of light.

D The telescope can be used to distinguish stars subtended at an angle of 3.0×10^{-7} radians.

20 A −5.0 C point charge is initially stationary at a point P in a uniform electric field of field strength 4.0 V m^{-1}.

It is then moved within the field 2.0 m parallel to the field and 3.5 m perpendicular to the field to a point Q as shown.



What is the work done against the electric field?

A −40 J

B 40 J

C −70 J

D 70 J

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21 An electron of charge *e* and mass m_e enters through a hole into a space between two parallel metal plates AB and CD, separated by a distance *d*.

CD is maintained at a positive potential *V* relative to AB.

The velocity of the electron is *v*.

Which expression is correct for the electron to just reach AB?

A $\frac{1}{2}m_e v^2 = \frac{e}{4\pi\varepsilon_o d}$

B $\frac{1}{2}m_e v^2 = eV$

C $\frac{1}{2}m_e (v\cos\theta)^2 = eV$

D $\frac{1}{2}m_e (v\sin\theta)^2 = eV$

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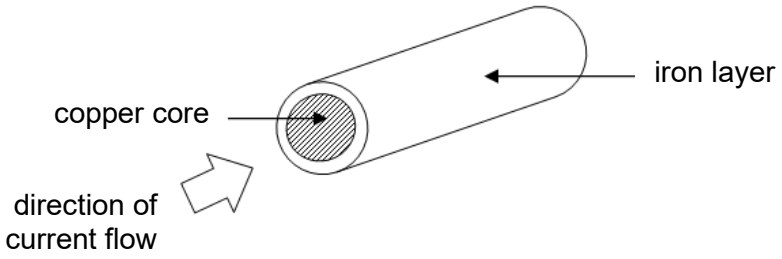
22 A resistor is made of a copper cylindrical core of cross-sectional area $2.0 \times 10^{-3}\,m^2$ which is surrounded by iron of cross-sectional area $1.0 \times 10^{-3}\,m^2$.



The resistivities of copper and iron are $1.7 \times 10^{-8}\ \Omega$ m and $1.0 \times 10^{-7}\ \Omega$ m respectively.

What is the resistance per unit length of such a resistor?

A $7.8 \times 10^{-6}\ \Omega\ m^{-1}$

B $8.5 \times 10^{-6}\ \Omega\ m^{-1}$

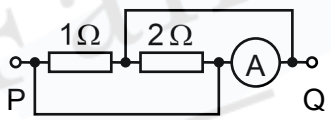
C $8.3 \times 10^{-5}\ \Omega\ m^{-1}$

D $9.2 \times 10^{-5}\ \Omega\ m^{-1}$

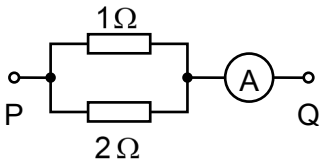
23 In each arrangement of resistors, the ammeter has a resistance of 3 Ω.

Which arrangement gives the smallest reading on the ammeter when the same potential difference is applied between points P and Q?

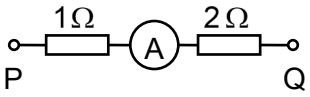
A



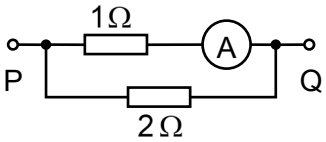
B



C



D



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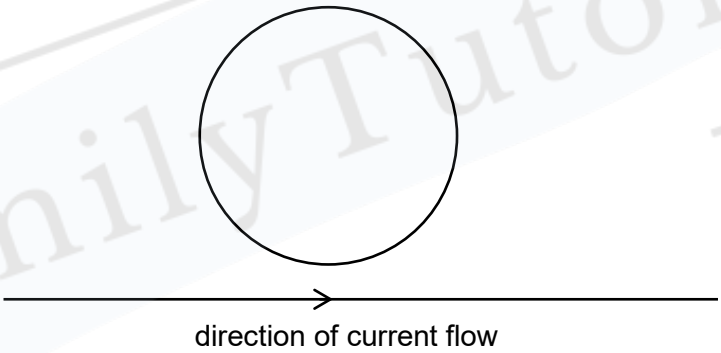
24 A charged particle is projected with velocity v into an evacuated region. A uniform electric field of field strength E and a uniform magnetic field of flux density B are applied perpendicular to each other in the same evacuated region.

If the velocity v is to stay constant, what is its magnitude and direction?

	magnitude	direction
A	$\frac{B}{E}$	parallel to B
B	$\frac{E}{B}$	parallel to E
C	$\frac{B}{E}$	perpendicular to both B and E
D	$\frac{E}{B}$	perpendicular to both B and E

25 A current carrying wire is placed below a vertical coil in its plane, with current flowing towards the right as shown.



Which statement correctly describes the possible effect on the coil when the current in the wire increases?

A No current will be induced in the coil.

B A clockwise current will be induced in the coil.

C An anti-clockwise current will be induced in the coil.

D The current induced in the coil will be first anticlockwise and then clockwise.

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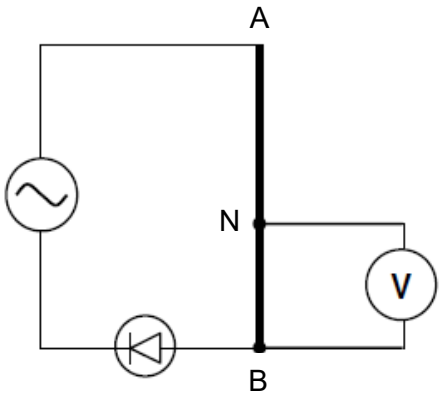
26 The uniform wire AB has length 1.0 m and resistance of 10 Ω. It is connected in series with an a.c. supply and an ideal diode.



When NB is 40 cm, the a.c. voltmeter gives a steady reading of 2.5 V.

What is the instantaneous peak power provided by the supply?

A 0.63 W

B 3.9 W

C 7.8 W

D 16 W

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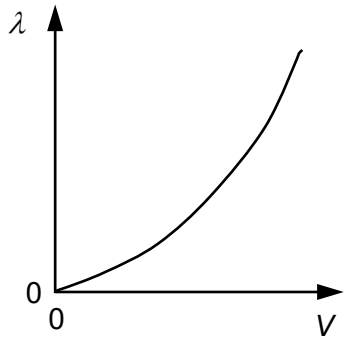
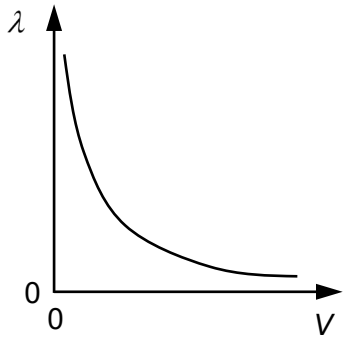
27 Electrons are accelerated from rest through a potential difference V.

Which graph shows the variation of the de Broglie wavelength λ of the electrons with V?

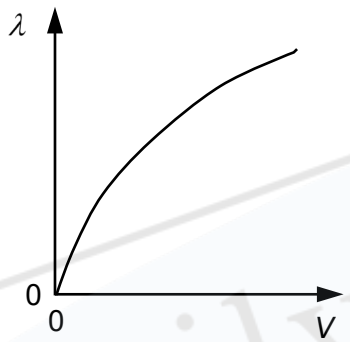
A



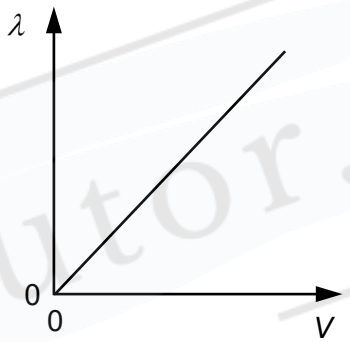
B



C



D



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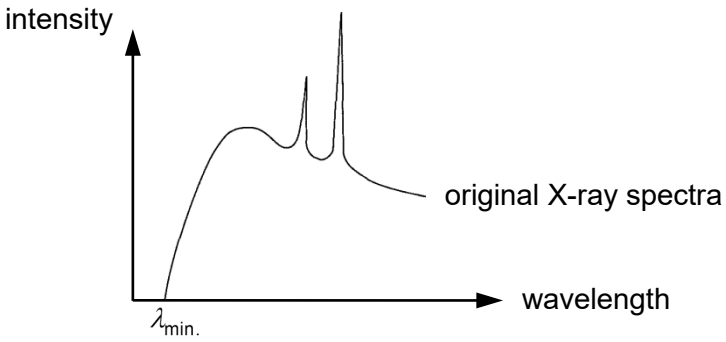
28 The graph shows the spectrum of X-rays emitted from an X-ray tube.



The potential difference between the target and cathode is increased.

How do the minimum wavelength and the wavelengths of the peaks change?

	minimum wavelength	wavelengths of peaks
A	decrease	increase
B	decrease	remain the same
C	increase	increase
D	increase	remain the same

29 In the absence of any radioactive source, the average value of the background radiation is found to be 30 counts per second.

When a radioactive source with half-life of 5 hours is placed at a fixed distance from the counter, the average total count rate is 210 counts per second.

What average count rate is expected with the source in the same position 10 hours later?

A 45 s^{-1}

B 53 s^{-1}

C 60 s^{-1}

D 75 s^{-1}

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30 Which isotope decays by emission of a β-particle to produce $^{111}_{48}Cd$?

A $^{111}_{47}Ag$

B $^{110}_{47}Ag$

C $^{111}_{49}In$

D $^{112}_{50}Sn$

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End of paper

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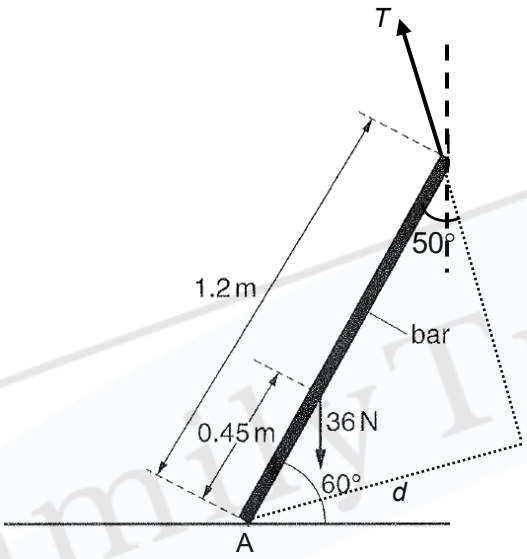
Suggested Solutions:

No.	Solution	Remarks
1(a)(i)	$B = \frac{\phi}{A} = \frac{50 \times 10^{-6}}{4.00 \times 10^{-4}} = 0.125$ T $\frac{\Delta B}{B} = \frac{\Delta \phi}{\phi} + \frac{\Delta A}{A} = \frac{5}{50} + \frac{0.01}{4.00} = 0.1025$ ΔB = (0.125 T)(0.1025) = 0.01 T (1 s.f.) → B = (0.13 ± 0.01) T	[1] value of $\frac{\Delta B}{B}$ [1] value of ΔB to 1 s.f. [1] answer
1(a)(ii)	The percentage (or fractional) uncertainty of ϕ is more significant than that of A.	[1]
1(b)(i)	 The perpendicular distance from A to line of action of T is given by d = 1.2 sin 50° Taking moments about A, (36)(0.45 cos 60°) = T (1.2 sin 50°) $T = \frac{(36)(0.45\cos 60^\circ)}{1.2\sin 50^\circ}$ = 8.8115 = 8.8 N (shown) OR Anti-clockwise moment = T_y (1.2 cos 60°) + T_x (1.2 sin 60°) = (T cos 20°)(1.2 cos 60°) + (T sin 20°)(1.2 sin 60°)	[1] moment equation [1] numerical answer before 8.8 N

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No.	Solution	Remarks
1(b)(ii)	Let F_x and F_y be the horizontal and vertical components of F respectively. Consider vertical forces: 36 N = T cos 20° + F_y → F_y = 36 – 8.81 cos 20° = 27.72 N Consider horizontal forces: $F_x = T_x = T$ sin 20° = 8.81 sin 20° = 3.01 N $F = \sqrt{F_x^2 + F_y^2} = \sqrt{3.01^2 + 27.72^2}$ = 27.9 N	[1] value of F_y [1] value of F_x [1] answer
2(a)	The phase difference is due to the extra distance x travelled by the wave from the student to the wall and back to him (x = 0.60 m) and also the phase change of π rad due to reflection at the wall. Phase difference $\phi = \frac{2\pi x}{\lambda} + \pi$ $= \frac{2\pi(0.60)}{0.40} + \pi$ $= 4\pi$ rad (or 0 or 2π rad)	[1] value of x [1] substitution [1] answer
2(b)(i)	When x_1 = 1.10 m, $A_1 = 1.2 \times 10^{-8}$ m When x_2 = 1.70 m, A_2 = ? $\frac{A_2}{A_1} = \frac{x_1}{x_2} \rightarrow A_2 = A_1\left(\frac{x_1}{x_2}\right) = 1.2\times10^{-8}\left(\frac{1.10}{1.70}\right)$ $= 0.78\times10^{-8}$ m Assumption: no energy is absorbed by the wall upon reflection	[1] substitution [1] answer [1] assumption
2(b)(ii)	Since $\phi = 4\pi$ rad, they are in phase, so Amplitude of resultant wave = (1.2 + 0.78) × 10^{-8} m = 2.0 × 10^{-8} m	[1] answer
2(c)	$\frac{I_r}{I_1} = \left(\frac{A_r}{A_1}\right)^2 \rightarrow I_r = I_1\left(\frac{A_r}{A_1}\right)^2 = 1.0\times10^{-6}\left(\frac{2.0\times10^{-8}}{1.2\times10^{-8}}\right)^2$ $= 2.8\times10^{-6}$ W m^{-2}	[1] substitution [1] answer
3(a)(i)	The electric field strength E at a point is the <u>negative of the potential gradient</u> $-\frac{dV}{dx}$ at that point.	[1]
3(a)(ii)	The <u>equipotential lines are equally spaced</u> with the same potential difference between consecutive lines.	[1]

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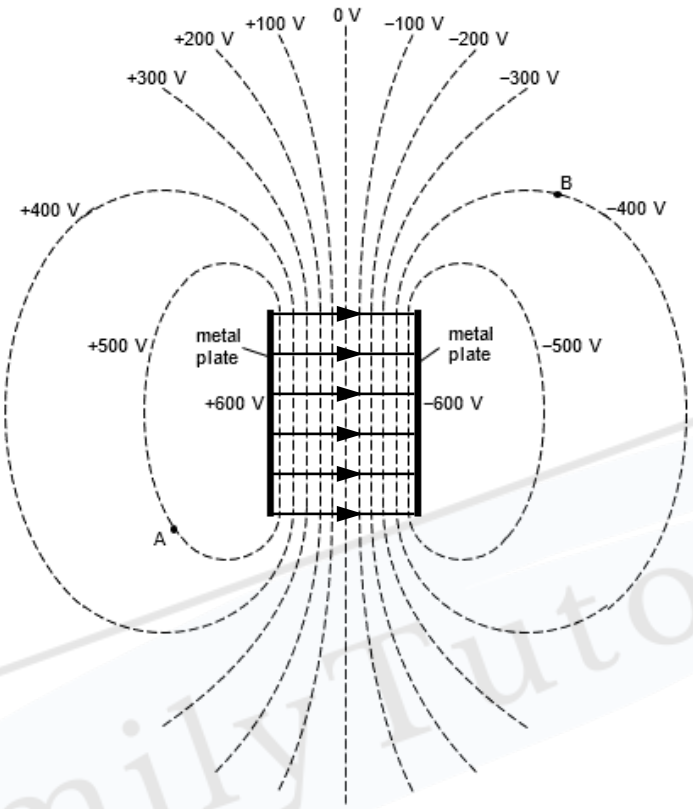
No.	Solution	Remarks
3(a)(iii)	Since $E = \frac{V}{d}$, we have $E = \frac{600 - (-600)}{2.5 \times 10^{-2}}$ $E = 4.8 \times 10^{4}$ N C^{-1}	[1] for correct substitution [1] for correct answer
3(b)		[1] for six uniform field lines between the plates [1] for correct direction of field lines
3(c)(i)	Since the gain in electric potential energy of the particle is $q\Delta V$, we have $q \times (-400 - 500) = 1.44 \times 10^{-16}$ $q = -1.60 \times 10^{-19}$ C	[1] for correct substitution [1] for correct answer
3(c)(ii)	The particle is an electron.	[1] No e.c.f. from **(c)(i)**
3(c)(iii)	By conservation of energy, loss in k.e. = gain in e.p.e. $\frac{1}{2} \times 9.11 \times 10^{-31} \times \left[(3.50 \times 10^{7})^{2} - v_f^{\,2} \right] = 1.44 \times 10^{-16}$ $v_f \approx 3.01 \times 10^{7}$ m s^{-1}	[1] for applying conservation of energy [1] for correct answer

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No.	Solution	Remarks
4(a)(i)	p.d. across LDR $= \frac{400}{400+8400}\left[4.0-(-2.0)\right] = 0.27273$ V p.d. across LDR $= V_p - (-2.0)$ $0.27273 = V_p + 2.0$ $V_p = 0.27273 - 2.0$ ≈ -1.7 V	[1] for p.d. across LDR [1] for correct answer
4(a)(ii)	When a burglar blocks the laser beam, the resistance of the LDR will be high (or increases). Hence the p.d across the LDR and alarm will be high (or increases). This will turn on the alarm.	[1] [1]
4(b)(i)	There will be no deflection in the galvanometer when the p.d across JY = 1.5 V. Let the balance length (between J and Y) be L_{JY}. Then $V_{JY} = \frac{L_{JY}}{1.00}\left(\frac{1.6}{1.6+0.50}\right)(4.0)$ $1.5 = \frac{L_{JY}}{1.00}\left(\frac{1.6}{1.6+0.50}\right)(4.0)$ $L_{JY} = 0.4922$ ≈ 0.49 m	[1] for correct substitution [1] for correct answer
4(b)(ii)	When 1.5 Ω resistor is connected across points A and B, the terminal p.d across cell E is $V_{terminal} = \frac{1.5}{1.5+0.50}(1.5)$ $= 1.125$ V There will be null deflection when $V'_{JY} = 1.125$ V $V'_{JY} = \frac{L'_{JY}}{1.00}\left(\frac{1.6}{1.6+0.50}\right)(4.0)$ $1.125 = \frac{L'_{JY}}{1.00}\left(\frac{1.6}{1.6+0.50}\right)(4.0)$ $L'_{JY} = 0.3691$ ≈ 0.37 m	[1] for correct $V_{terminal}$ [1] for correct substitution [1] for correct answer
5(a)	Gain in kinetic energy = Loss in electric potential energy $\frac{1}{2}mv^2 - 0 = eV - 0$ $\frac{1}{2}\left(9.11\times10^{-31}\right)v^2 = \left(1.60\times10^{-19}\right)(200)$ $v = 8.382\times10^6$ $\approx 8.38\times10^6$ m s^{-1}	[1] statement [1] correct answer before rounding off

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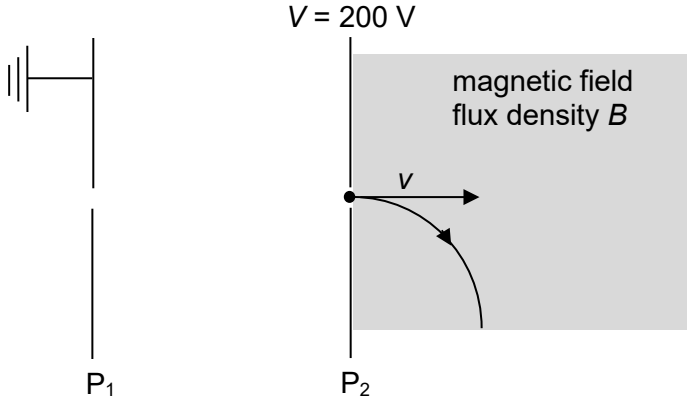
No.	Solution	Remarks
5(b)(i)		[1] path
5(b)(ii)	For circular motion, $Bqv = \frac{mv^2}{r}$ $B = \frac{mv}{qr}$ $B = \frac{9.11\times10^{-31}\left(8.38\times10^{6}\right)}{1.60\times10^{-19}\left(2.8\times10^{-2}\right)}$ $= 1.7\times10^{-3}$ T	[1] for correct substitution [1] for correct answer
5(c)(i)	The component of the velocity parallel to the magnetic field, is unaffected by the magnetic field. The component of the velocity perpendicular to the magnetic field results in a magnetic force acting on the electron perpendicular to its motion. Combining these 2 effects produces a helical path of the electron.	[1] for correct effect [1] for correct effect [1] correct path
5(c)(ii)	Radius of curvature, $r = \frac{mv_{\perp}}{Bq}$ $= \frac{9.11\times10^{-31}\left(8.38\times10^{6}\sin30^{\circ}\right)}{1.60\times10^{-19}\left(1.7\times10^{-3}\right)}$ $= 1.4\times10^{-2}$ m	[1] for correct substitution [1] for correct answer

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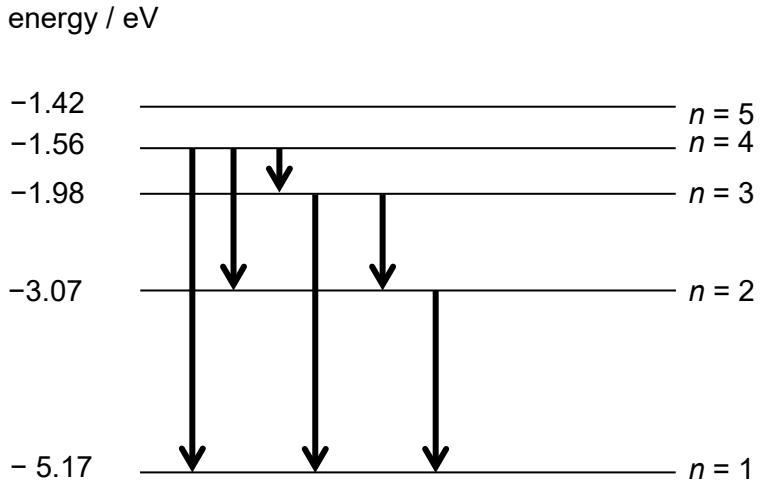
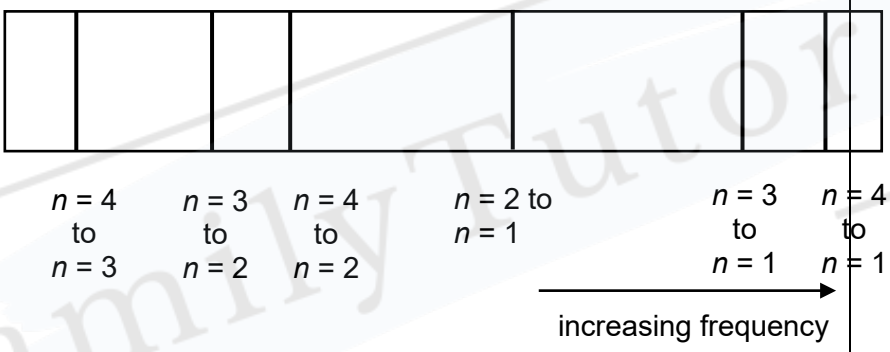
No.	Solution	Remarks
6(a)(i)	If all the electron's energy is absorbed, the electron could reach −5.17 + 3.7 = −1.47 eV level. Since there are no such energy level, the electron can only excite to −1.56 eV or n = 4 level. 	[1] for transitions to n = 1 [1] for transitions to n = 2 and n = 3
6(a)(ii)	 [1] for 3 spectral lines to the left and 2 spectral lines to the right [1] for correct spacing for the extreme 2 spectral lines on the right	
6(a)(iii)	If the electron absorbed the incoming photon, there is no energy levels for it to excite to. As such, there will be no emission lines observed.	[1]
6(b)(i)	The X-ray tube is evacuated so that the electrons emitted from the filament can move towards the metal target without colliding with air molecules and getting scattered.	[1]
6(b)(ii)	A photon is a quantum of electromagnetic radiation having a discrete amount of energy $E = hf$ where h is the Planck constant and f the frequency of radiation.	[1]
6(b)(iii)	From Fig. 6.3, $\lambda_{min} = 0.40 \times 10^{-11}$ m ,	

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No.	Solution	Remarks
	$E = \frac{hc}{\lambda_{min}}$ $= \frac{\left(6.63\times10^{-34}\right)\left(3.00\times10^{8}\right)}{\left(0.40\times10^{-11}\right)}$ $= 4.97\times10^{-14}$ J	[1] correct substitution [1] correct answer
6(b)(iv)	$qV = 4.97\times10^{-14}$ $\left(1.60\times10^{-19}\right)V = 4.97\times10^{-14}$ $V = 310.6$ ≈ 310 kV	[1] substitution
7(a)(i)	The engine takes in air at a rate of 1300 kg s^{-1} $\frac{\Delta m}{\Delta t} = \rho A \frac{\Delta s}{\Delta t}$ $= \rho\left(\frac{\pi}{4}D^2\right)v_{in}$ $v_{in} = \frac{1300}{1.2\times\frac{\pi}{4}\times3.0^2}$ $= 153.3$ ≈ 150 m s^{-1} (shown)	[1] for correct substitution [1] for correct calculated value before 150 m s^{-1}
7(a)(ii)	Thrust, $F = \left(m_{air} + m_{fuel}\right)v_{exhaust} - m_{air}v_{in}$ $= (1300+17)(410) - (1300)(150)$ $= 344970$ ≈ 345 kN	[1] for correct substitution [1] for correct answer
7(a)(iii)	By Newton's second law, $F = ma$ $a = \frac{F}{m}$ $= \frac{344970\times2}{\frac{2.75\times10^6}{9.81}}$ (because of 2 engines) $= 2.461$ ≈ 2.46 m s^{-2}	[1] for correct substitution [1] for correct answer
7(b)	As air is deflected upwards upon contact with the stabiliser, it experiences a rate of change of momentum. By Newton's second law, this is the resultant force on the air by the stabiliser.	[1] for application of Newton's 2nd law

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No.	Solution	Remarks
	By Newton's third law, the air will exert a force of equal magnitude but in opposite direction, causing a downward force on the stabiliser and enabling the aircraft to take off.	[1] for application of Newton's 3rd law
7(c)(i)	Consider vertical forces in equilibrium, $N_R + N_F = W$ $N_F = W - N_R$ Take moments about the centre of gravity, $N_R X_R = N_F X_F + Fd$ $= (W - N_R) X_F + Fd$ $N_R (X_R + X_F) = WX_F + Fd$ $\therefore\ N_R = \frac{WX_F + Fd}{X_R + X_F}$ (shown)	[1] for vertical forces in equilibrium [1] for correct expression taking moments [1] for substitution
7(c)(ii)	$N_F = W - N_R$ $= W - \frac{WX_F + Fd}{X_R + X_F}$ $= \frac{W(X_R + X_F) - WX_F - Fd}{X_R + X_F}$ $= \frac{WX_R - Fd}{X_R + X_F}$	[1] for correct substitution
7(c)(iii)	When at rest without the thrust F, the contact force on the front landing gears is $\frac{WX_R}{X_R + X_F}$ and the contact force on the rear landing gears is $\frac{WX_F}{X_R + X_F}$. When accelerating, the thrust F results in the contact force on the front gears to decrease by $\frac{Fd}{X_R + X_F}$, while the contact force on the rear gears is increased by $\frac{Fd}{X_R + X_F}$, causing the weight transfer from the front gears to the rear gears.	[1] for explanation of contact forces without acceleration [1] for explanation of the transfer of force from front gears to the rear gears
7(d)(i)	Total energy used	[1] for correct substitution

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No.	Solution	Remarks
	$= (5.5 \times 10^3)(12)(42 \times 10^6)$ $= 2.772 \times 10^{12}$ $\approx 2.77 \times 10^{12}$ J	[1] for correct answer
7(d)(ii)	The amount of energy that the battery stores per kilogram of its mass is 0.260 kilowatt-hours.	[1]
7(d)(iii)	Mass of lithium battery $= \frac{2.772 \times 10^{12}}{0.260 \times 10^3 \times 60 \times 60}$ $= 2.962 \times 10^6$ $\approx 2.96 \times 10^6$ kg	[1] for correct substitution [1] for correct answer
7(e)(i)	The total weight of the battery (2.9×10^7 N) will be greater than the maximum take-off weight (MTOW) of 2.75×10^6 N of the aircraft, which is not possible.	[1]
7(e)(ii)	Any two: 1. Jet fuel has a higher energy density (42 MJ kg^{-1}) compared to battery (0.260 kW h kg^{-1}, i.e. 9.36×10^5 J kg^{-1}), hence more suitable for long-haul flights. 2. Electric aircrafts need batteries with high enough specific energy, so the mass penalty means they cannot fly long distances. 3. Lithium batteries can overheat and ignite, posing fire hazard on electric aircrafts. 4. Jet engine aircraft uses jet fuel which gets depleted over the course of the flight causing the aircraft to be lighter and hence burns less fuel whereas the mass of the battery-powered electric aircraft remains constant throughout the flight. 5. Jet engine aircraft takes a shorter time to refuel compared to the duration needed to recharge the lithium battery.	[2] Any other logical answer

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Name: _____ Class: _____

JURONG PIONEER JUNIOR COLLEGE

JC2 Preliminary Examination 2023

PHYSICS **9749/02**
Higher 2 **29 August 2023**

Paper 2 Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

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

For Examiner's Use	
1	/ 9
2	/ 9
3	/ 11
4	/ 9
5	/ 10
6	/ 10
7	/ 22
Total	/ 80

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

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Data

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

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{GM}{r}$
temperature	$T/\mathrm{K} = T/{}^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 (a) (i) Magnetic flux density B generated by a magnet may be found by determining the magnetic flux ϕ passing normally through an area A according to the expression

$$\phi = BA$$

In one experiment, ϕ and A were determined to be (50 ± 5) μWb and $(4.00 \pm 0.01) \times 10^{-4}$ m^2 respectively.

Determine the value of B along with its associated uncertainty.

B = ... ± ..... T [3]

(ii) Explain why the value of B cannot be more precisely determined even if the precision in the instrument used to measure A is improved.

.....

..... [1]

(b) A non-uniform bar AB makes an angle of 60° with a horizontal surface, as shown in Fig. 1.1.

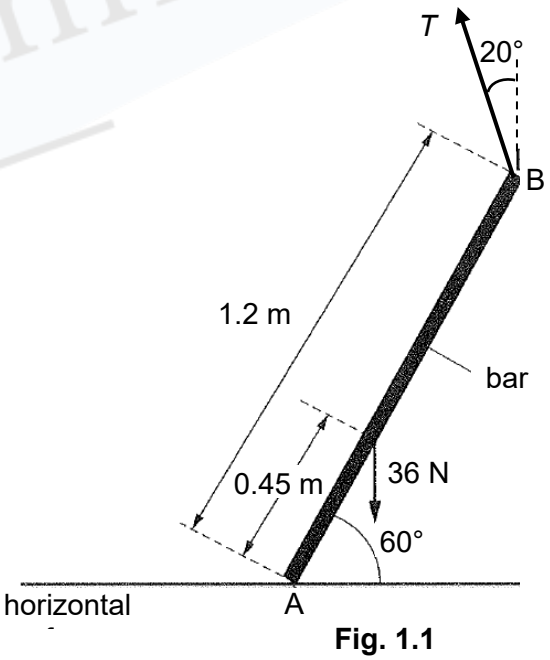

Fig. 1.1

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The bar is hinged as A and is supported by a light string at B. The string is inclined at an angle of 20° to the vertical. The bar has a length of 1.2 m and a weight of 36 N. The centre of gravity of the bar is 0.45 m from A.

(i) Show that the magnitude of the tension T in the string is 8.8 N.

[2]

(ii) A force F acts on the bar at A.

Calculate the magnitude of F.

F = ... N [3]

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2 As part of a physics lesson demonstration, a student stands between a sound speaker and a wall, such that he is 1.10 m from the speaker and 0.30 m from the wall as shown in Fig. 2.1. The speaker emits a sound wave of a single wavelength of 0.40 m. The sound wave hits the wall perpendicularly and is reflected back.

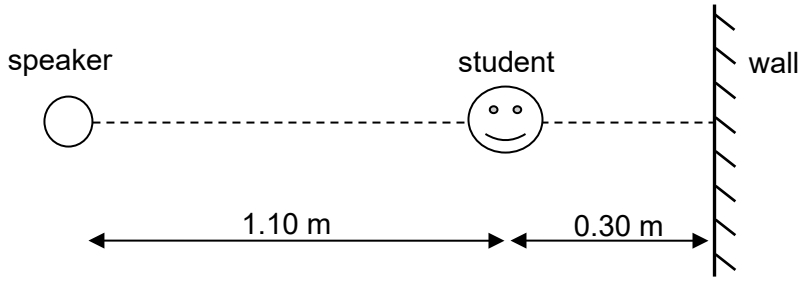

Fig. 2.1

The reflection at the wall causes the wave to undergo a phase change of π rad.

(a) Calculate the phase difference between the waves that come directly from the speaker and the one that is reflected back from the wall, when they meet at the student's location. Leave your answer in multiples of π.

phase difference = ... rad [3]

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(b) The sound wave is emitted uniformly in all directions by the speaker. When the wave reaches the student directly from the speaker, it has an amplitude of 1.2×10^{-8} m.

(i) Calculate the amplitude of the wave that reaches the student after reflection from the wall. State an assumption made in your calculation.

amplitude = ... m [2]

Assumption: .....

..... [1]

(ii) Hence calculate the amplitude of the resultant wave experienced by the student.

amplitude = ... m [1]

(c) The intensity of the sound wave that reaches the student directly from the speaker is 1.0×10^{-6} W m^{-2}.

Calculate the intensity of the resultant wave that reaches him.

intensity = ... W m^{-2} [2]

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3 Fig. 3.1 shows lines joining points at the same potential in and around a pair of parallel, charged metal plates. The plates have a separation of 2.5 cm.

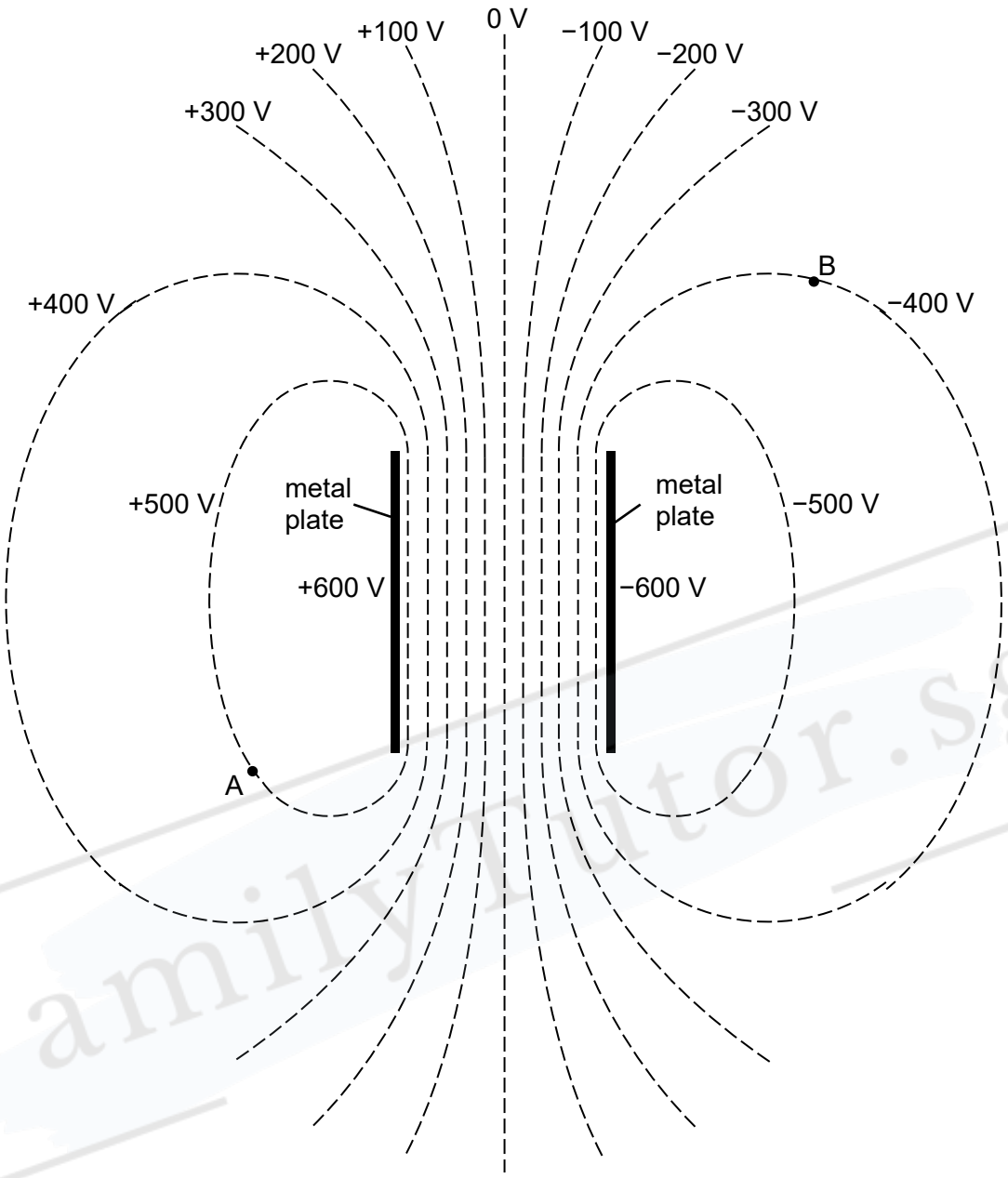

Fig. 3.1

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

.....

..... [1]

(ii) By reference to Fig. 3.1, suggest why the electric field between the plates is uniform.

.....

..... [1]

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(iii) Determine the value of the electric field strength between the plates.

electric field strength = ... NC^{-1} [2]

(b) On Fig. 3.1, draw six lines to represent the electric field between the plates. [2]

(c) A particle moves from point A to point B. As a result, there is a loss in potential but the particle gains electric potential energy of 1.44×10^{-16} J.

(i) Calculate the charge of the particle.

charge = ... C [2]

(ii) Suggest a particle that might have this value of charge.

..... [1]

(iii) Hence, calculate the speed of the particle at B, given that its initial speed at A is 3.5×10^{7} m s^{-1}.

speed = ... ms^{-1} [2]

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4 **(a)** A resistor of resistance of 8.4 kΩ and a LDR (light dependent resistor) are connected in series, as shown in Fig. 4.1. The resistance of the LDR when light is shone on it is 400 Ω.

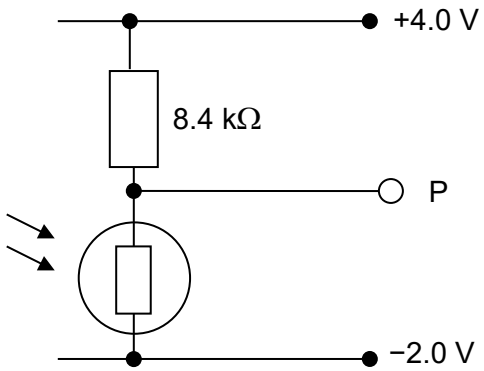

Fig. 4.1

(i) Calculate the potential at point P when light is shone on the LDR.

potential = ……..…….. V [2]

(ii) An alarm is now connected in parallel with the LDR in Fig. 4.1 and a laser beam is directed continuously at the LDR in a simple burglar alarm system. When a burglar blocks the laser that is shining on the LDR, the alarm is triggered. Assume that the resistance of the alarm is very large.

Explain how the LDR is used to trigger the alarm in such a system.

……

……

……

…… [2]

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(b) A circuit is set up as shown in Fig. 4.2. The potentiometer wire XY has a resistance of 1.6 Ω and is 1.00 m long. The movable contact J can be connected to any point along wire XY.

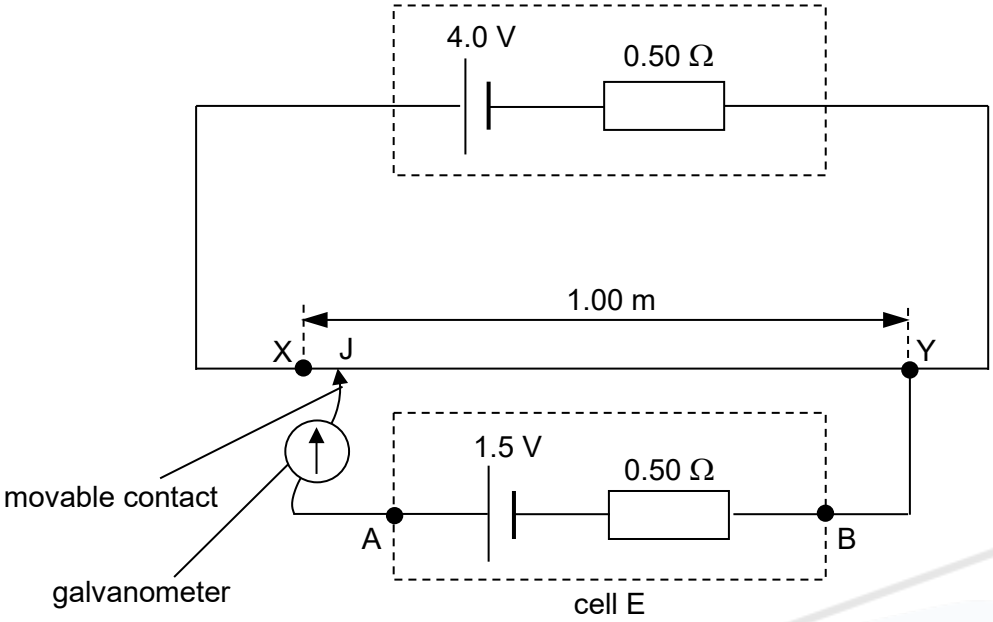

Fig. 4.2

(i) Determine the distance of the contact J from Y, such that there is no deflection in the galvanometer.

distance = ……..…….. m [2]

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(ii) A 1.5 Ω resistor is then connected across points A and B.

Determine the distance of the contact J from Y, such that there is no deflection in the galvanometer.

distance = ……..…….. m [3]

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5 Fig. 5.1 shows an electron passing an earthed vertical plate P_1 with negligible speed and accelerates horizontally towards vertical plate P_2 which is at a potential 200 V.

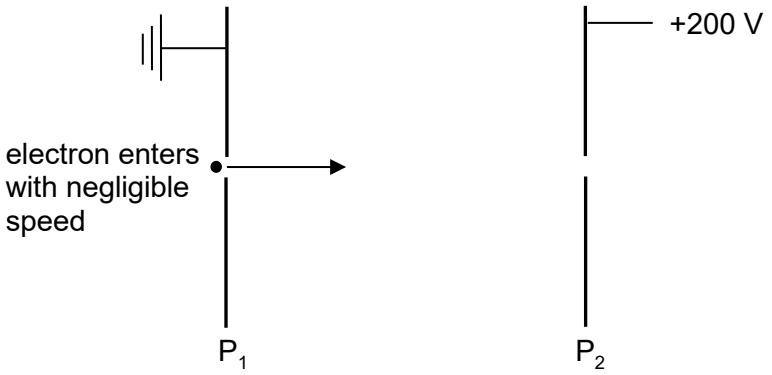

Fig. 5.1

(a) Show that the speed of the electron when it reaches plate P_2 is 8.38×10^6 m s^{-1}.

[2]

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(b) After emerging from plate P_2, the electron enters a region of uniform magnetic field of flux density B, directed into the plane of the paper as shown in Fig. 5.2.

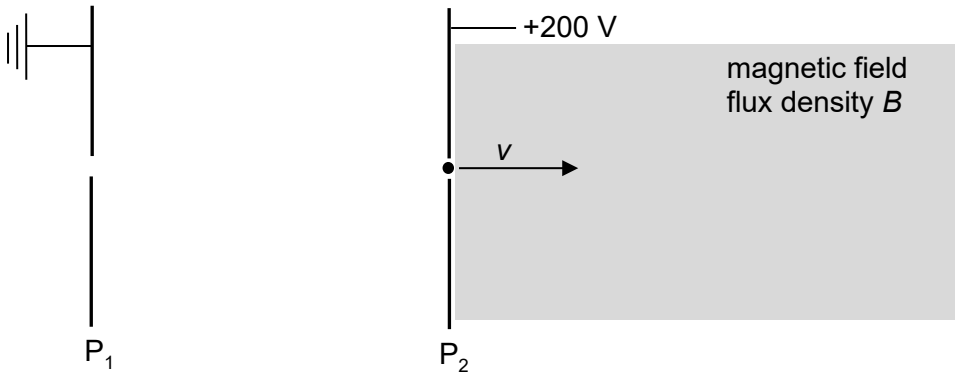

Fig. 5.2

(i) On Fig. 5.2, draw a solid line to represent a possible path of the electron. [1]

(ii) The electron moves in a path with a radius of curvature of 2.8 cm.

Calculate the magnitude of the magnetic flux density B.

B = ... T [2]

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(c) The direction of the magnetic field is now changed such that it is at an angle of 30° below the horizontal, as shown in Fig. 5.3.

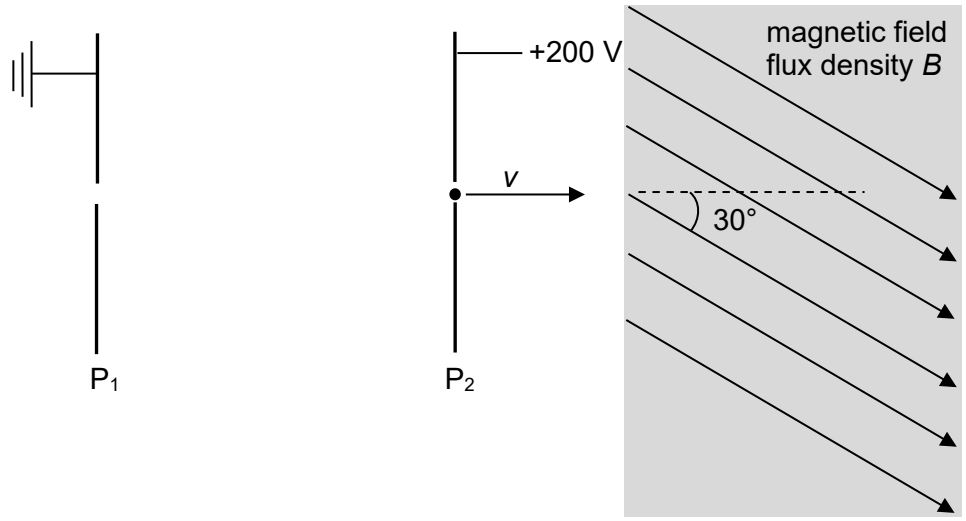

Fig. 5.3

(i) By considering the components of the velocity parallel to the magnetic field and at right-angle to the magnetic field, describe and explain qualitatively the motion of the electron in the field.

.....

.....

.....

.....

.....

..... [3]

(ii) Calculate the radius of curvature of this new path.

radius = ... m [2]

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6 **(a)** Fig. 6.1 shows the energy levels of sodium gas.

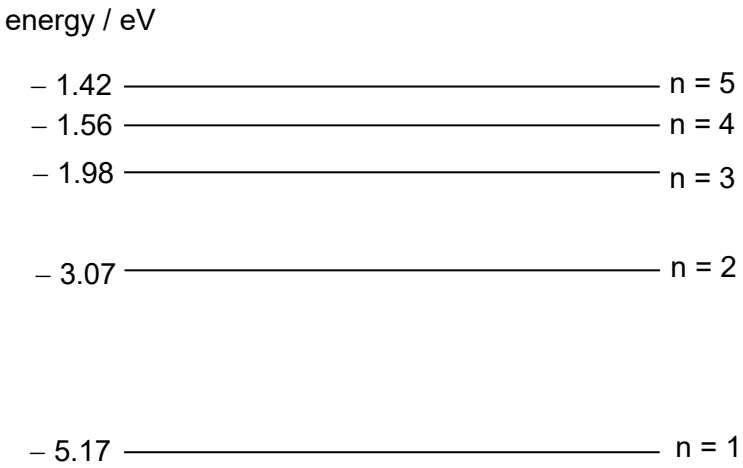

Fig. 6.1

The cool sodium gas at low pressure is bombarded by incoming electrons with kinetic energy of 3.70 eV.

(i) On Fig. 6.1, draw arrows to show all the possible de-excitation transitions that will be observed if all the sodium atoms are at ground state initially. [2]

(ii) Fig. 6.2 shows the emission line due to the transition from $n = 2$ to $n = 1$.

On Fig. 6.2, sketch the positions of all the other possible emission lines observed.

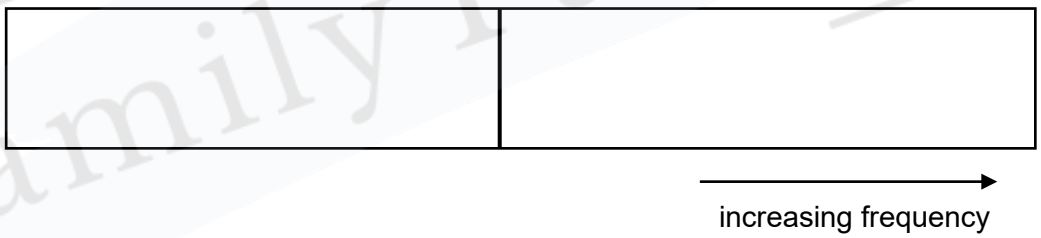

Fig. 6.2

[2]

(iii) The cool sodium gas is now bombarded by incoming photons of energy of 3.70 eV instead.

State and explain the number of emission lines observed, if any.

.....

..... [1]

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(b) Fig. 6.3 shows the variation against wavelength of the relative intensity of emitted X-rays radiation from an X-ray tube. In the evacuated X-ray tube, electrons emitted at the cathode are accelerated from rest using an accelerating voltage to hit a target made of a metal at the anode and produce X-rays as a result.

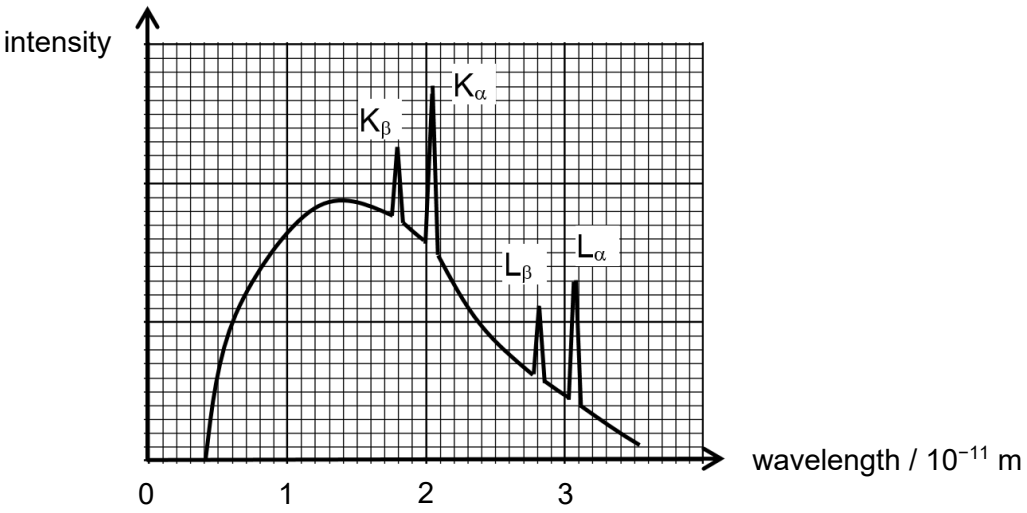

Fig. 6.3

(i) Explain why the X-ray tube is evacuated.

.....

..... [1]

(ii) Explain what is meant by a *photon*.

.....

..... [1]

(iii) Determine the maximum energy of the X-ray photons emitted.

energy = ... J [2]

(iv) Hence, show that the accelerating voltage required to accelerate the electrons in the tube is 310 kV.

[1]

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

Modern aircrafts operated by airlines use jet engines. A jet engine is a type of reaction engine, drawing in air and discharging a fast-moving jet of heated exhaust gas (air mixed with jet fuel) that generates thrust by jet propulsion.

Fig. 7.1 shows an engine designed for modern passenger aircraft that draws in a maximum mass of air of 1300 kg per second. The diameter of the engine intake fan is 3.0 m. The air drawn into the engine is compressed, or "squeezed", and then in the combustion chamber, it is heated to a very high temperature. Finally, the engine blows the heated exhaust gas back out of its nozzle producing thrust.

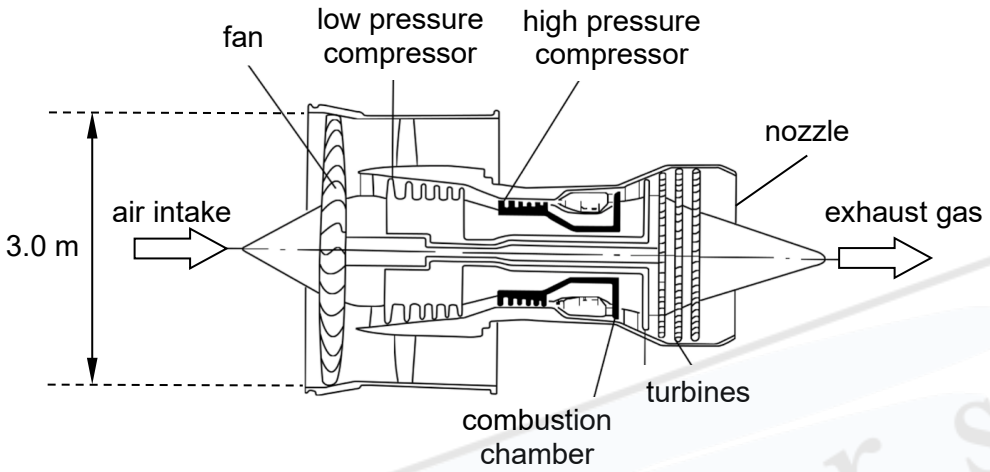

Fig. 7.1

The thrust F produced by such an engine is given by the expression

$$F = (m_{air} + m_{fuel})v_{exhaust} - m_{air}v_{in}$$

where m_{air} is the mass of air intake per second, m_{fuel} is the mass of fuel consumed per second, v_{in} is the velocity of air intake, and $v_{exhaust}$ is the velocity of exhaust gas.

Table 7.1 show data for the engine operating during take-off.

Table 7.1

m_{air}	1300 kg s^{-1}
m_{fuel}	17 kg s^{-1}
$v_{exhaust}$	410 m s^{-1}

A modern passenger aircraft is fitted with two such engines. When operating at maximum thrust, the aircraft with the maximum take-off weight (MTOW) of 2.75×10^6 N is accelerated from rest to an airspeed that provides sufficient lift to be airborne in 45 s.

At take off, the aircraft performs a rotation to point its nose upwards for take off as shown in Fig. 7.2. This is accomplished with the aid of its rear horizontal stabilisers as shown in Fig. 7.3.

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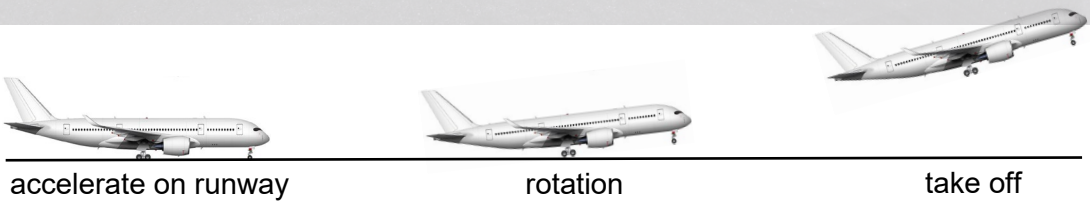

Fig. 7.2

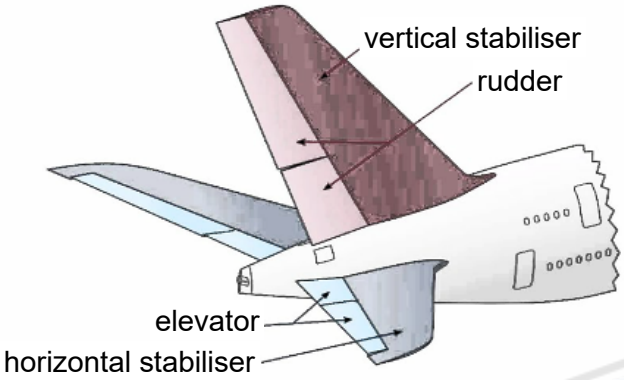

Fig. 7.3

The energy density of jet fuel is 42 MJ kg^{-1}.

Aviation accounts for about 2.5% of global carbon dioxide emissions, so transitioning the sector away from its dependence on fossil fuels to clean electric power is seen as a priority. While battery-powered electric aircraft is far from being able to replace the large passenger aircraft used on long-haul routes, they may be able to take on city-to-city hops of several hundred kilometres.

The electrical energy onboard aircrafts is stored in lithium-ion batteries. When fully charged, the battery has a specific energy of 0.260 kW h kg^{-1}.

(a) (i) The density of air is 1.2 kg m^{-3}.

Show that the velocity of air intake of the engine is 150 m s^{-1}.

[2]

[Turn over

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(ii) Calculate the maximum thrust F.

F = ... kN [2]

(iii) Determine the maximum acceleration of the aircraft.

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

(b) A cross-section of the rear horizontal stabiliser on the aircraft during rotation for take off is shown in Fig. 7.4.

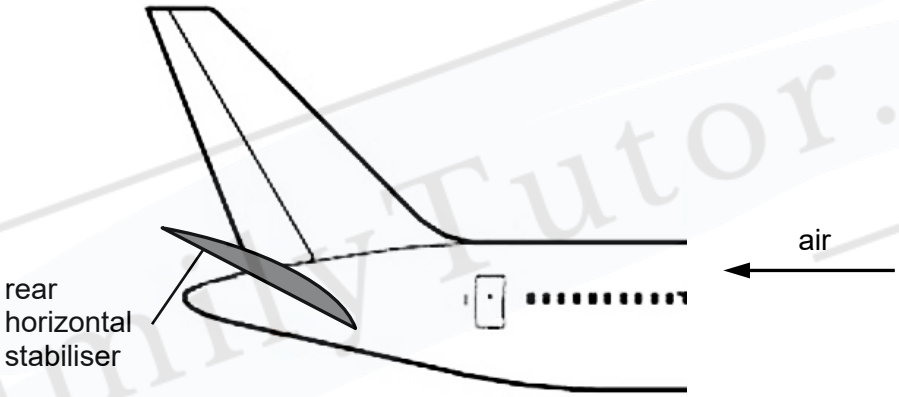

Fig. 7.4

The stabiliser deflects air when the aircraft is moving along the runway.

Explain, by reference to the change in momentum of the air, why this air flow causes the aircraft to rotate for take off.

……..

……..

……..

……..

……..

…… [2]

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(c) Some of the forces acting on the aircraft while accelerating from rest are shown in Fig. 7.5.

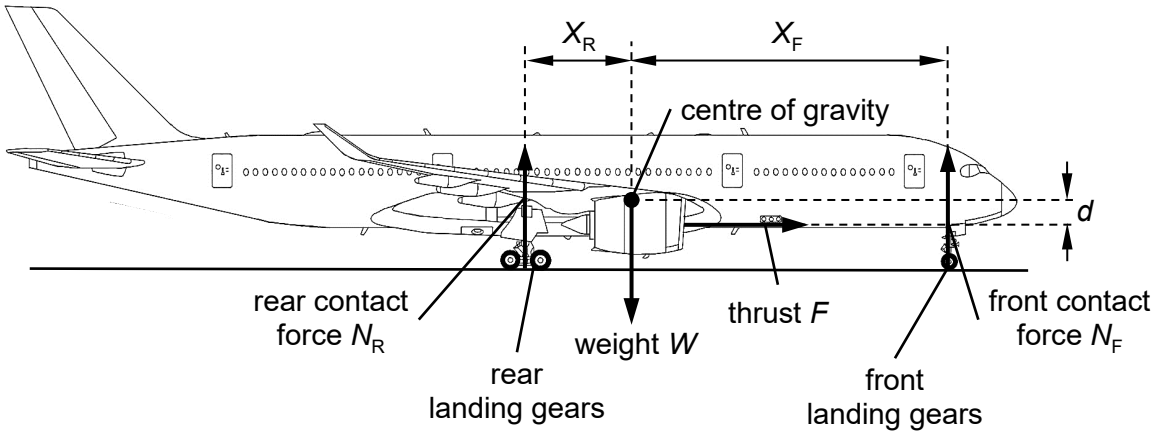

Fig. 7.5

N_F and N_R are the contact force acting on the rear and front landing gears respectively. W is the weight of the aircraft. F is the thrust acting on the aircraft by the exhaust gas.

The centre of gravity is a vertical distance d above the line of action of F. The centre of gravity is a horizontal distance X_R from the rear landing gears and a horizontal distance X_F from the front landing gears.

For the aircraft accelerating from rest:

(i) take moments about the centre of gravity, to show that

$$N_R = \frac{WX_F + Fd}{X_F + X_R}$$

[3]

[Turn over

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(ii) determine a similar expression to that in **(c)(i)** for N_F.

[1]

(iii) Use your expressions in **(c)(i)** and **(c)(ii)** to show that there is weight transfer between the front and rear landing gears when the aircraft is accelerating from rest.

.....

.....

.....

..... [2]

(d) A passenger aircraft consumes jet fuel at a rate of 5.5×10^3 kg h^{-1} when cruising. A flight from Singapore to Munich takes 12 hours.

(i) Calculate the total energy used during cruising flight of 12 hours.

total energy = ... J [2]

(ii) Suggest what is meant by a specific energy of 0.260 kW h kg^{-1}.

.....

.....

..... [1]

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(iii) Determine the mass of the lithium battery needed to supply the total energy in **(d)(i)**.

mass = …….. kg [2]

(e) (i) Use your answer in **(d)(iii)** to explain if the aircraft can be purely battery-powered for a flight from Singapore to Munich.

……

…… [1]

(ii) Suggest two advantages that the jet engine aircraft has over the battery-powered electric aircraft.

1. ……

……

2. ……

…… [2]

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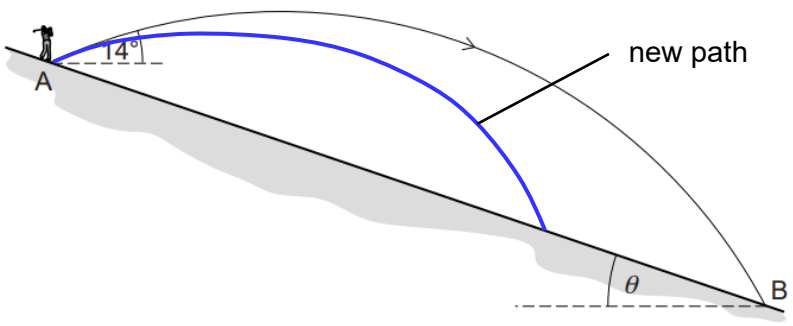
Suggested Solutions:

No.	Solution	Remarks
1(a)(i)	horizontal component $= 67\cos 14^\circ$ $= 65.01$ $\approx 65.0 \text{ m s}^{-1}$ vertical component $= 67\sin 14^\circ$ $= 16.21$ $\approx 16.2 \text{ m s}^{-1}$	[1] for correct answer [1] for correct answer
1(a)(ii)	horizontal displacement $= 65.01 \times 4.9$ $= 318.5$ $\approx 319 \text{ m}$	[1] for correct substitution and answer
1(a)(iii)	Using $s_y = u_y t + \frac{1}{2} a_y t^2$, Taking downward as positive, $s_y = (-16.21)(4.9) + \frac{1}{2}(9.81)(4.9)^2$ $= 38.34$ $\approx 38.3 \text{ m}$	[1] for correct substitution [1] for correct answer
1(a)(iv)	angle of the slope to the horizontal $\theta = \tan^{-1}\left(\frac{38.34}{318.5}\right)$ $= 6.864$ $\approx 6.86^\circ$	[1] for correct substitution [1] for correct answer
1(b)(i)	 [1] for correct new path Note: new path under present path	

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No.	Solution	Remarks
1(b)(ii)1.	The path of the ball at the start is determined by the direction of the force of the club acting on the ball **or** air resistance has acted only for a short period of time.	[1] for correct answer
1(b)(ii)2.	The horizontal velocity is much reduced by air resistance.	[1] for correct answer
2(a)(i)	Gravitational force on satellite provides for centripetal force to keep satellite in orbit. $\frac{GM_EM_S}{r^2} = M_S r\omega^2$ $\frac{GM_E}{r^2} = r\left(\frac{2\pi}{T}\right)^2$ $T = \sqrt{\frac{4\pi^2 r^3}{GM_E}} = \sqrt{\frac{4\pi^2(9.0\times10^6)^3}{(6.67\times10^{-11})(5.97\times10^{24})}}$ $= 8500s$	[1] correct substitution [1] correct answer
2(a)(ii)	Work done = increase in total energy of satellite $= E_{T,f} - E_{T,i}$ $= \left(-\frac{GM_EM_s}{2r_f}\right) - \left(-\frac{GM_EM_s}{2r_i}\right)$ $= \frac{(6.67\times10^{-11})(5.97\times10^{24})(500)}{2}\left(-\frac{1}{1.0\times10^7} + \frac{1}{9.0\times10^6}\right)$ $= 1.1\times10^9$ J	[1] correct substitution [1] correct answer
2(b)(i)	The gravitational force <u>acts towards centre of Earth</u> provides the centripetal force and thus, <u>gravitational force must lie on the plane of orbit which passes through centre of Earth</u>. Additionally, in order for the satellite to orbit such that it remains at a fixed relative position above the Earth, <u>its axis of rotation must coincide with Earth's axis of rotation</u> and thus it has to orbit in the equatorial plane.	[1] [1] [1]
2(b)(ii)	Geostationary satellites move in orbits where they are at a fixed relative position above the Earth. This allows the satellites to <u>constantly receive and transmit telecommunication signals to and from the same position</u> on the Earth's surface.	[1]
3(a)(i)	The internal energy of a system is the sum of a random distribution of kinetic and potential energies associated with the molecules of a system.	[1]

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No.	Solution	Remarks
3(a)(ii)	$\Delta U = Q + W$ ΔU – increase in internal energy Q – heat supplied to the system W – work done on the system	[1] equation [1] correct definition of symbols
3(a)(iii)	There is work done by gas against the atmosphere during expansion for gas at constant pressure. Using $\Delta U = Q + W \rightarrow Q = \Delta U + W_{BY}$, amount of heat supplied has to be larger for the same amount of increase in internal energy. Since ΔT depends on ΔU, therefore a larger amount of heat must be supplied to have the same amount of ΔT.	[1] [1] [1]
3(b)	Let θ be the equilibrium temperature. $m_w\ c_w\ (90 - \theta) = m_{ice}\ L_f + m_{water\ at\ 0\ ^\circ C}\ c_w\ (\theta - 0)$ $(0.5)\ (4200)\ (90 - \theta) = (0.1)\ (3.34 \times 10^5) + (0.1)\ (4200)\ (\theta)$ $\theta = 61.7\ ^\circ C$	[1] substitution [1] answer
4(a)	Simple harmonic motion is defined as an oscillatory motion in which the acceleration of an object is directly proportional to the displacement of the object from its equilibrium position, and the acceleration is always directed towards that position.	[1]
4(b)(i)	Angular frequency $\omega = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$ $= \sqrt{\frac{18.5}{0.400}} = 6.80\ \text{rad s}^{-1}$ Amplitude $x_0 = \frac{v_{max}}{\omega} = \frac{1.40}{6.80} = 0.206\ \text{m}$	[1] value for ω [1] answer
4(b)(ii)	Maximum tension of the spring occurs at the lowest position. At the lowest position, acceleration is maximum $= (6.80)^2(0.206)$ $= 9.53\ \text{m s}^{-2}$ At lowest point, $T - mg = ma$ $T = mg + ma$ $= (0.400)(9.81) + (0.400)(9.53)$ $T = 7.74\ \text{N}$	[1] value for max acceleration [1] sub [1] ans

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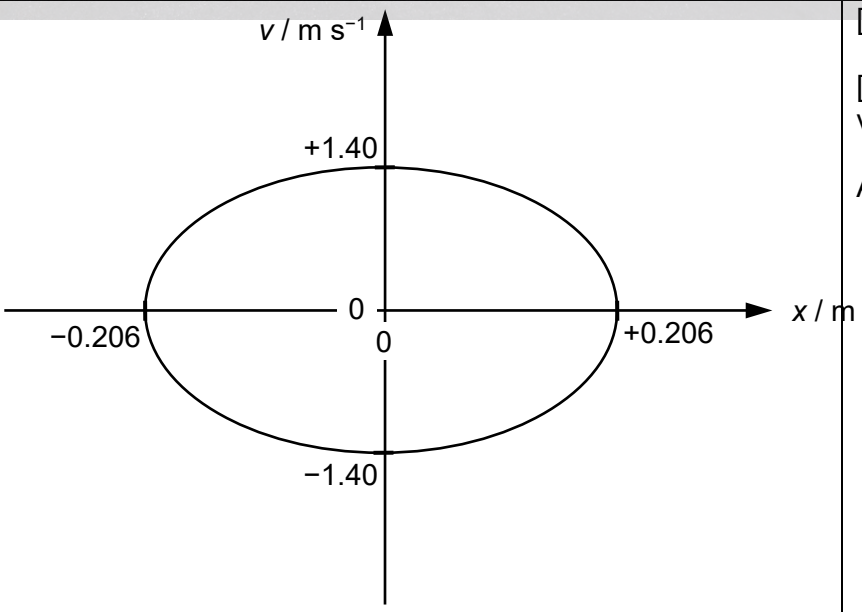
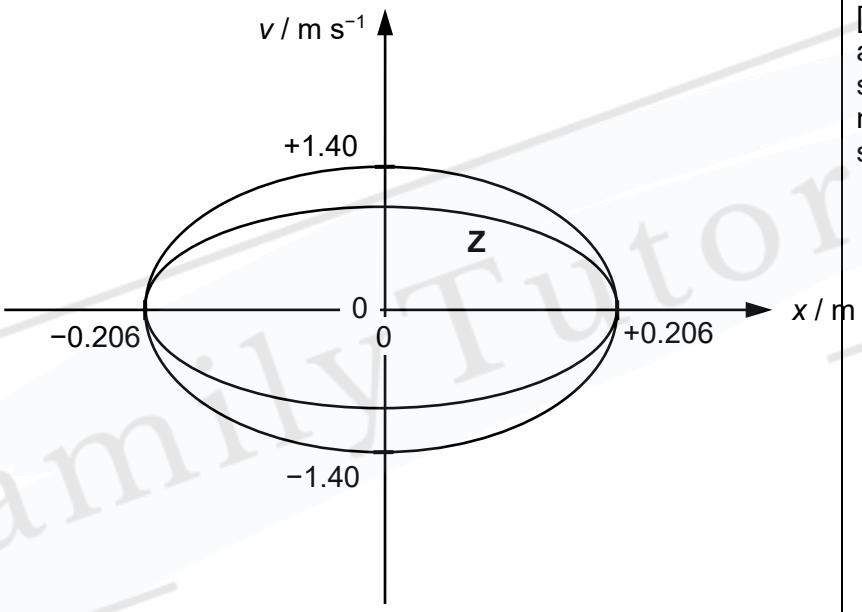
No.	Solution	Remarks
4(c)(i)		[1] shape [1] 4 numerical values Allow e.c.f.
4(c)(ii)		[1] for same amplitude and smaller maximum speed
5(a)(i)	Since copper has one conduction electron per atom, the number density of charge carriers is equal to the number of atoms per unit volume. $\text{number of mole} = \frac{\text{mass}}{\text{molar mass}}$ number of mole per unit volume $= \frac{\text{density}}{\text{molar mass}}$ $= \frac{8.9 \times 10^{3}}{63.5 \times 10^{-3}}$ $= 1.40157 \times 10^{5}\ \text{m}^{-3}$	[1]

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No.	Solution	Remarks
	number of atoms per unit volume $=$ number of mole per unit volume $\times N_A$ $=1.40157\times10^{5}\times6.02\times10^{23}$ $=8.44\times10^{28}$ $\approx 8.4\times10^{28}$ m^{-3} Hence number density of charge carriers $=8.4\times10^{28}$ m^{-3}	[1] answer before rounding off
5(a)(ii)	Using $I = Anvq$ $17\times10^{-3} = \pi\times\left(\frac{1.8\times10^{-3}}{2}\right)^2\times8.4\times10^{28}\times v\times1.60\times10^{-19}$ $v = 4.97\times10^{-7}$ $\approx 5.0\times10^{-7}$ m s^{-1}	[1] for correct substitution [1] for correct answer
5(b)	Current is the same in all segments of the wire, including the thinner segment. For the thinner segment, the cross-sectional area is smaller. The charge carriers hence move with a higher drift velocity (number density of charge carriers does not change).	[1] same current and smaller cross-sectional area [1] higher drift velocity
6(a)	Faraday's law of electromagnetic induction states that the induced e.m.f. in a coil is directly proportional to the rate of change of magnetic flux linkage through the coil.	[1]
6(b)(i)	$B = \mu_0 nI$ $=4\pi\times10^{-7}\times\left(\frac{400}{1.6}\right)\times3.8$ $=1.19\times10^{-3}$ T $\Phi = NBA$ $=80\times\left(1.19\times10^{-3}\right)\times\pi\times\left(\frac{0.040}{2}\right)^2$ $=1.2\times10^{-4}$ Wb	[1] value of B [1] sub [1] ans
6(b)(ii)	$E_{mean} = \frac{\Delta\Phi}{\Delta t}$ $=\frac{2\times1.2\times10^{-4}}{0.30}$ $=8.0\times10^{-4}$ V	[1] sub [1] ans

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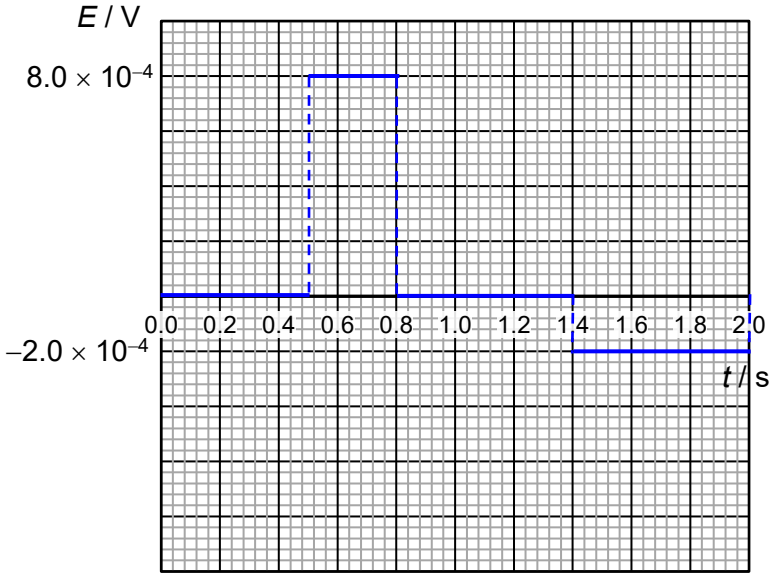
No.	Solution	Remarks
6(b)(iii)		[1] E = 0 V from t = 0 to 0.5 s & 0.8 s to 1.4 s [1] $E = 8.0 \times 10^{-4}$ V from t = 0.5 s to 0.8 s [1] $E = -2.0 \times 10^{-4}$ V from t =1.4 s to 2.0 s
6(b)(iv)	The magnitude of the <u>maximum e.m.f. induced in the coil increases</u>, The iron core in the solenoid <u>increases the magnetic flux density in the coil</u>, resulting in <u>increase in the magnetic flux linkage in the coil</u>. Hence by Faraday's law, the magnitude of the maximum e.m.f. induced in the coil increases,	[1] state [1] explain
7(a)(i)	r.m.s. current $I_{rms} = \frac{I_o}{\sqrt{2}} = \frac{2}{\sqrt{2}}$ $= 1.4$ A	[1] substitution [1] answer
7(a)(ii)	r.m.s. voltage $V_{rms} = \frac{V_o}{\sqrt{2}}$ $= \frac{240}{\sqrt{2}}$ V Mean power supplied $\langle P \rangle = I_{rms} V_{rms}$ $\langle P \rangle = \left(\frac{2}{\sqrt{2}}\right)\left(\frac{240}{\sqrt{2}}\right)$ $= 240$ W **OR** Peak power $P_o = V_o I_o = (240)(2)$ 480 W $\langle P \rangle = \frac{P_o}{2} = \frac{480}{2} = 240$ W	[1] substitution [1] answer

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No.	Solution	Remarks
7(b)(i)	$\frac{V_2}{V_1} = \frac{N_2}{N_1} \rightarrow \frac{V_2}{240} = \frac{10}{500} \rightarrow V_2 = 4.8$ V $\frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2} \rightarrow \frac{I_2}{2} = \frac{500}{10} \rightarrow I_2 = 100$ A Assumption: Transformer is 100% efficient / ideal with zero ohmic, magnetic leakage, copper and core losses. The output power is equal to the input power of the transformer.	[1] answer [1] answer [1] reasonable answer
7(b)(ii)	Welding Induction furnace Smelting scrap metal	[1] reasonable answer
8(a)(i)	When the vibrator oscillates the string, the waves travel along string and <u>get reflected at fixed points A and B</u>. The incident and reflected waves along the string, superpose and interfere to form stationary waves on the string. OR The two waves along the string travel with same speed in opposite directions, superpose and interfere to form stationary waves on the string.	[1] reflection at fixed ends [1] incident and reflected waves superpose and interfere
8(a)(ii)	 Line has an approximate sinusoidal shape with maximum downward displacement at P and zero displacement at each node. [1] for correct shape	
8(a)(iii)	Using $v = f\lambda = \frac{\lambda}{T}$, $\lambda = vT$ $= 35 \times 0.040$ $= 1.4$ m Distance AB $= 2.5\lambda$ $= 2.5 \times 1.4$ $= 3.5$ m	[1] for correct wavelength [1] for correct answer

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No.	Solution	Remarks
8(a)(iv)	No. of periods $= \frac{t}{T}$ $= \frac{0.060}{0.040}$ $= 1.5$ Amplitude $= \frac{72}{6}$ $= 12$ mm	[1] for correct substitution [1] for correct answer
8(b)(i)	Constant phase difference between the waves.	[1] for correct answer
8(b)(ii)1.	Path difference $= 1.5\lambda$ $= 1.5 \times 640$ $= 960$ nm	[1] for correct answer
8(b)(ii)2.	Phase difference $= 360^\circ \times 1.5$ $= 540^\circ$	[1] for correct answer. Accept 180°
8(b)(iii)	Distance OR $= 1.5x$ $= 1.5\frac{\lambda D}{a}$ $= 1.5 \times \frac{\left(640 \times 10^{-9}\right)(1.8)}{0.44 \times 10^{-3}}$ $= 3.928 \times 10^{-3}$ $\approx 3.9 \times 10^{-3}$ m	[1] for correct substitution [1] for correct answer
8(b)(iv)	The bright fringes are brighter due to the increased intensity. No change to the intensity of the dark fringes. The fringe separation remains unchanged.	[1] [1] [1]
8(b)(v)	Since the fringe separation is directly proportional to the wavelength of the incident light and inversely proportional to the slit separation. Blue light has a shorter wavelength. So decrease the slit separation in order to maintain the same fringe separation.	[1] for correct explanation [1] for correct answer

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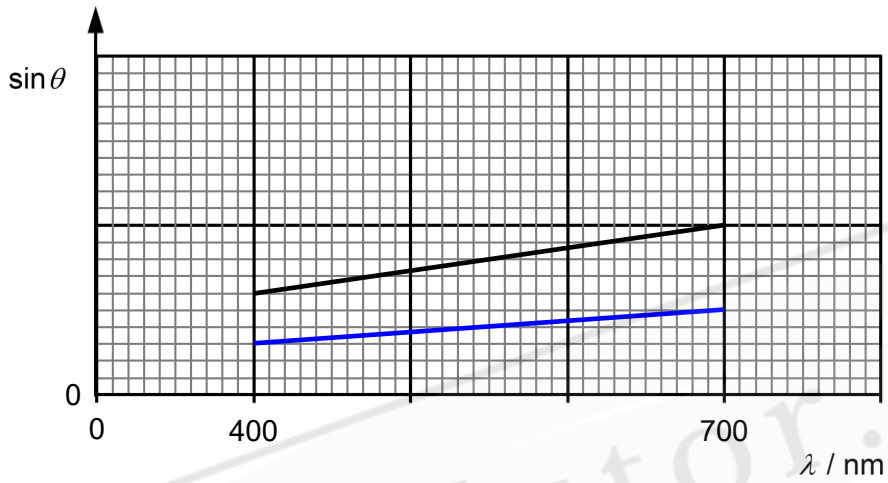
No.	Solution	Remarks
8(c)(i)	Using $d\sin\theta = n\lambda \quad (n = 4)$, $d\sin\theta = 4\lambda$ $\sin\theta = \frac{4}{d}\lambda$ So, $G = \frac{4}{d}$ $\therefore \quad d = \frac{4}{G}$	[1] for correct answer
8(c)(ii)	 [1] straight line from 400 nm to 700 nm that is always below printed line and has a smaller gradient than printed line [1] straight line is 3 small squares high at wavelength of 400 nm and 5 small squares high at wavelength of 700 nm	
9(a)	The half-life of a radioactive nuclide is the <u>time taken for the radioactive nuclei to reduce to half its initial value</u>.	[1]
9(b)(i)	For α-decay: $^{214}_{83}\text{Bi} \rightarrow {}^{210}_{81}Tl + {}^{4}_{2}\text{He}$ For β^--decay: $^{214}_{83}\text{Bi} \rightarrow {}^{214}_{84}\text{Po} + {}^{0}_{-1}\text{e}$	[1] [1]
9(b)(ii)	mass difference $= 213.9987u - (209.9901u + 4.0015u)$ $= 0.0071u$ energy released $= \Delta mc^2$ $= 0.0071(1.66\times10^{-27})(3.00\times10^{8})^2$ $= 1.06074\times10^{-12}$ $\approx 1.06\times10^{-12}$ J	[1] [1] for correct substitution [1] for correct answer

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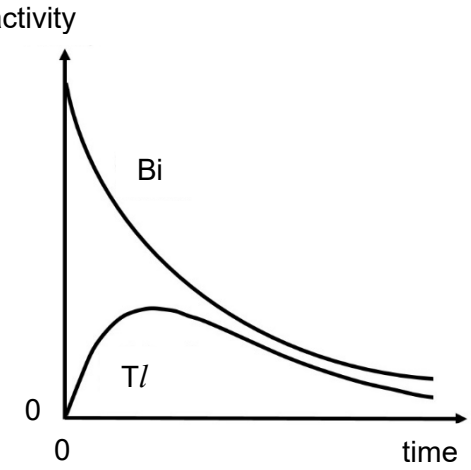
No.	Solution	Remarks
9(b)(iii)	The mass difference of reactant and products in both decay processes are different. So the total amount of energy released for each process will also be different. Hence the γ-ray photons emitted will have different energies.	[1] [1]
9(c)(i) and 9(c)(ii)		[1] for correct Bi graph [1] for correct Tl graph
9(d)(i)	214 g of Bi contains 1 mol of atoms, which is 6.02×10^{23} atoms. number of atoms in sample $=\frac{2.0\times10^{-6}}{214}\left(6.02\times10^{23}\right)$ $=5.626\times10^{15}$ $\approx5.6\times10^{15}$ (shown)	[1] correct substitution
9(d)(ii)	activity $A=\lambda N$ $\lambda=\frac{A}{N}$ $=\frac{3.3\times10^{12}}{5.626\times10^{15}}$ $=5.866\times10^{-4}$ $\approx5.9\times10^{-4}\ \text{s}^{-1}$	[1] correct substitution [1] correct answer
9(d)(iii)	$t_{1/2}=\frac{\ln2}{\lambda}$ $=\frac{\ln2}{5.866\times10^{-4}}$ $=1182$ $\approx1.2\times10^{3}\ \text{s}$	[1] for correct answer

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No.	Solution	Remarks
9(d)(iv)	$A = A_o e^{-\lambda t}$ $3.3\times10^{6} = 3.3\times10^{12} e^{-5.866\times10^{-4} t}$ $\frac{3.3\times10^{6}}{3.3\times10^{12}} = e^{-5.866\times10^{-4} t}$ $t = 2.355\times10^{4}$ $\approx 2.4\times10^{4}$ s	[1] correct substitution [1] correct answer
9(e)	<u>β - particles are fast moving electrons</u> and the β - particles are emitted collide with the atoms of the lead container. These collisions result in the β - particles undergoing <u>deceleration</u>, either being slowed down <u>by collision or by deflection</u>. The electrons will then <u>release energy</u> in the form of the continuous <u>spectrum of the X-ray produced</u>, also called Bremsstrahlung radiation.	[1] [1] [1] [1]

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TEST QUESTIONS AND ANSWER KEYS

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Name: _____ Class: _____

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JC2 Preliminary Examination 2023

PHYSICS **9749/03**
Higher 2 **18 September 2023**

Paper 3 Longer Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

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

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

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

For Examiner's Use	
1	/ 10
2	/ 8
3	/ 8
4	/ 9
5	/ 6
6	/ 11
7	/ 8
8	/ 20
9	/ 20
Total	/ 80

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Data

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

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{GM}{r}$
temperature	$T / \mathrm{K} = T / {}^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{{x_0}^2 - x^2}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + ...$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** questions in the spaces provided

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1 A golf ball is hit from point A on the ground and moves through the air to point B. The path is illustrated in Fig. 1.1.

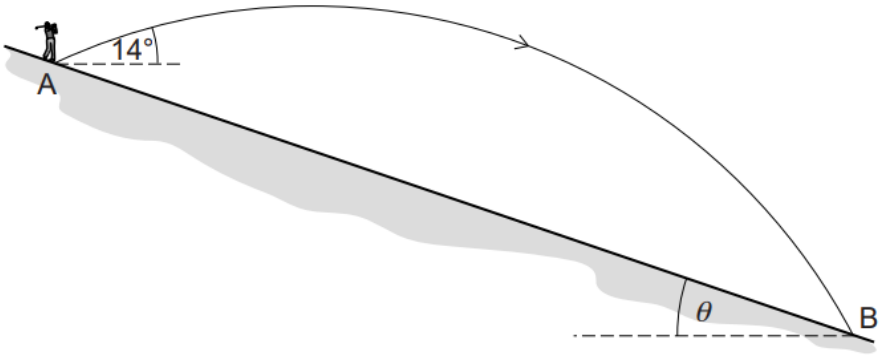

Fig. 1.1

The ground slopes downhill with a constant gradient. The ball has an initial speed of 67 m s^{-1} at an angle of 14° to the horizontal. The ball hits the ground at B after 4.9 s.

(a) Ignoring air resistance, calculate

(i) the horizontal and vertical components of the ball's velocity at A,

horizontal component at A = ……..... m s^{-1} [1]

vertical component at A = ……..... m s^{-1} [1]

(ii) the horizontal displacement from A to B,

horizontal displacement = ……..... m [1]

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(iii) the vertical displacement from A to B,

vertical displacement = ……..... m [2]

(iv) the angle of the slope to the horizontal, θ.

angle θ = ……..... ° [2]

(b) In a real situation, air resistance provides a force on the ball in the opposite direction to its motion.

(i) On Fig. 1.1, sketch a likely path of the ball hit from A when air resistance is taken into account. [1]

(ii) Give reasons for the shape you have drawn in **(b)(i)** for

1. the path of the ball at the start,

……

……

…… [1]

2. the angle at which the ball hits the ground.

……

……

…… [1]

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2 **(a)** A satellite of mass 500 kg moves in a circular orbit at constant speed around the Earth, at a radius r of 9.0×10^6 m, with a period T. The satellite is then moved such that it proceeds to orbit around the Earth at a new radius of 1.0×10^7 m.

The mass of the Earth is 5.97×10^{24} kg and may be assumed to be a point mass at the centre of the Earth.

(i) Determine T.

T = ... s [2]

(ii) Determine the work done required in moving the satellite to its new orbit.

work done = ... J [2]

(b) **(i)** Explain why a geostationary satellite must orbit in the equatorial plane.

.....

.....

.....

.....

..... [3]

(ii) Explain why geostationary satellites are often used for telecommunication.

.....

.....

..... [1]

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3 (a) (i) Explain what is meant by the *internal energy* of a system.

.....

.....

..... [1]

(ii) Write the equation representing the first law of thermodynamics, stating the meaning of each of the symbols clearly.

.....

.....

.....

..... [2]

(iii) Explain why the heat capacity of a fixed mass of gas at constant pressure is greater than its heat capacity at constant volume.

.....

.....

.....

.....

.....

..... [3]

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(b) A styrofoam cup of negligible heat capacity contains 500 g of water at 90 °C. 100 g of ice at 0 °C is then added to the water.

Data for the specific latent heat of fusion and specific heat capacity of water are shown in Fig. 3.1.

specific latent heat of fusion of water / J kg^{-1}	3.34×10^5
specific heat capacity of water / J kg^{-1} K^{-1}	4200

Fig. 3.1

Determine the equilibrium temperature of the mixture, assuming no heat loss to the surroundings.

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equilibrium temperature = ... °C [2]

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4 Fig. 4.1 shows a block of mass 0.400 kg attached to a light spring with spring constant of 18.5 N m^{-1} at its equilibrium position. By pulling the block to the lowest point and then releasing it, the block undergoes simple harmonic motion.

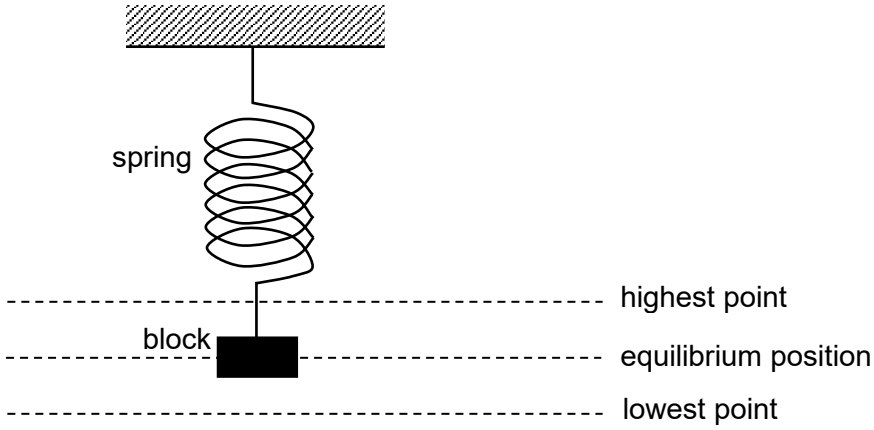

Fig. 4.1

(a) Explain what is meant by *simple harmonic motion*.

.....

.....

..... [1]

(b) The period T of the oscillations is given by the expression

$$T = 2\pi\sqrt{\frac{m}{k}},$$

where m is the mass of the block and k is the spring constant of the spring.

(i) Given that the block has a speed of 1.40 m s^{-1} when passing the equilibrium position, determine the amplitude of the oscillations.

amplitude = ... m [2]

[Turn over

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(ii) Calculate the maximum tension in the spring during the oscillations.

maximum tension = ... N [3]

(c) (i) On Fig. 4.2, sketch a graph to show the variation with displacement x of the velocity v of the block. Label the graph with appropriate numerical values.

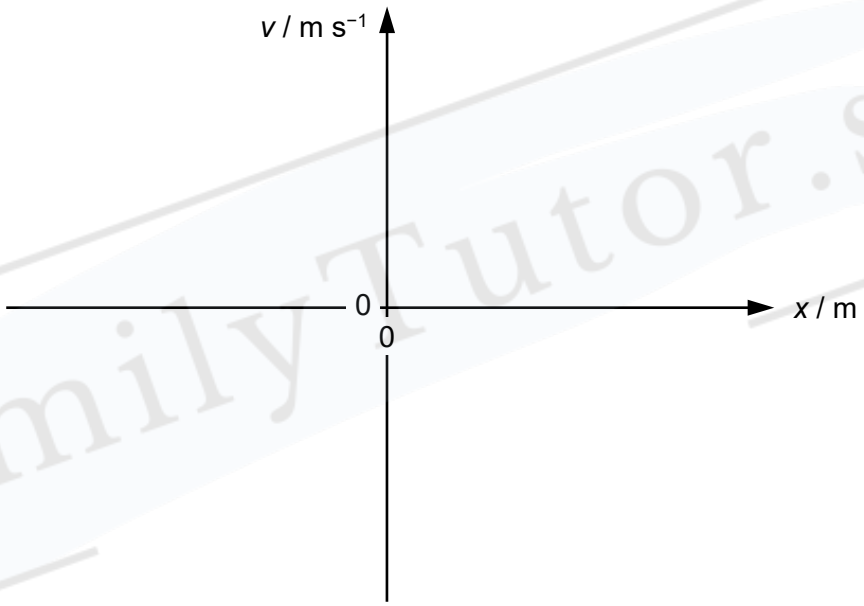

Fig. 4.2

[2]

(ii) The block is now replaced with one of mass larger than 0.400 kg and pulled down by the same amplitude calculated in **(b)(i)**.

On Fig. 4.2, sketch a second graph to show the variation with displacement x of the velocity v of the block with the larger mass.

Label the second graph **Z**. [1]

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5 **(a)** A copper wire of diameter 1.8 mm has a current of 17 mA flowing through it.

(i) The density of copper is 8.9×10^3 kg m^{-3} and its molar mass is 63.5 g mol^{-1}.

Assuming that copper has one conduction electron per atom, show that the number density of charge carriers in the copper wire is 8.4×10^{28} m^{-3}.

[2]

(i) Hence determine the drift velocity v of the charge carriers.

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

(b) One segment of the copper wire in **(a)** is found to be thinner compared to the rest of the wire.

State and explain how the drift velocity of charge carriers will change when they flow into the thinner segment.

.....

.....

..... [2]

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

.....

..... [1]

(b) A long solenoid of length 1.6 m is wound evenly with 400 turns of insulated wire. The solenoid has a circular cross-section of diameter 4.0 cm.

A coil Y having 80 turns of wire is wounded tightly around the centre of the solenoid, as illustrated in Fig. 6.1.

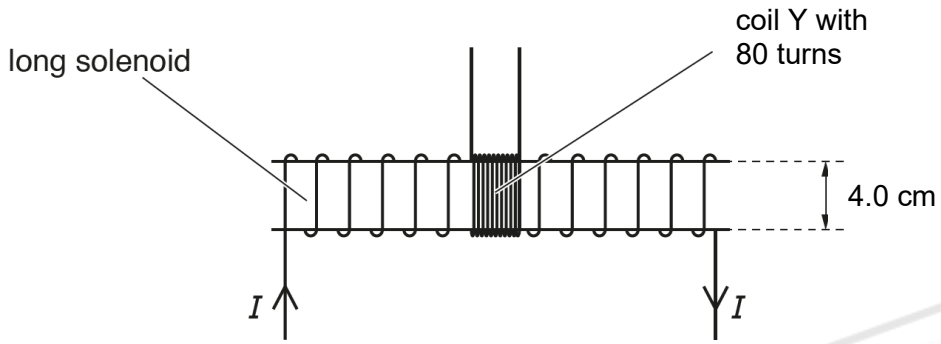

Fig. 6.1

(i) A current I of 3.8 A flows in the solenoid.

Calculate the magnetic flux linkage through coil Y.

magnetic flux linkage = ... Wb [3]

(ii) The current I in the solenoid in **(b)(i)** is reversed in 0.30 s.

Calculate the mean e.m.f. induced in coil Y.

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

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(iii) The current I in the solenoid in **(b)(ii)** varies with time t as shown in Fig. 6.2.

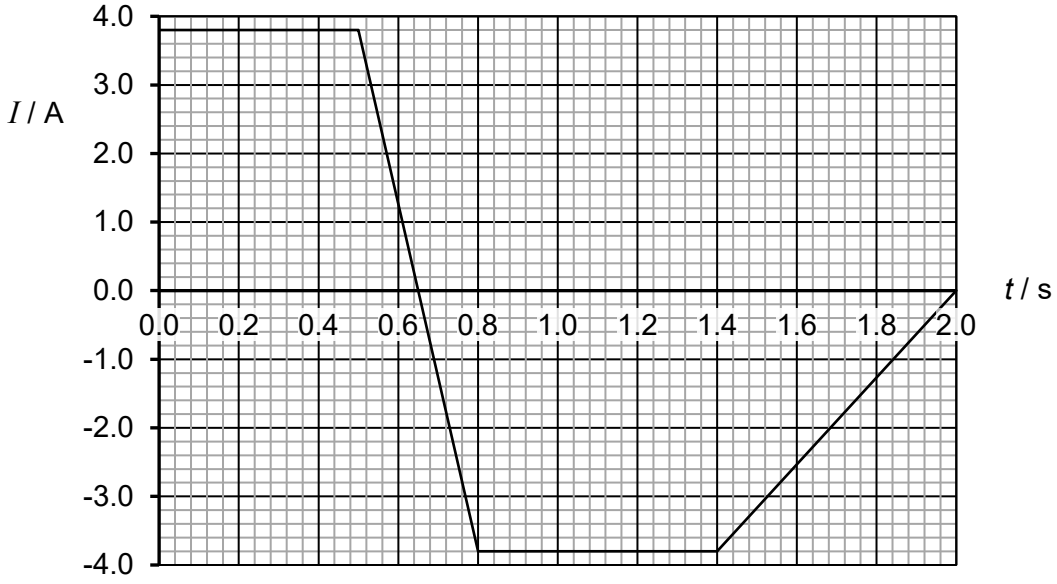

Fig. 6.2

Use your answer to **(b)(ii)** to sketch, on Fig. 6.3, the variation with time t of the e.m.f. E induced in coil Y.

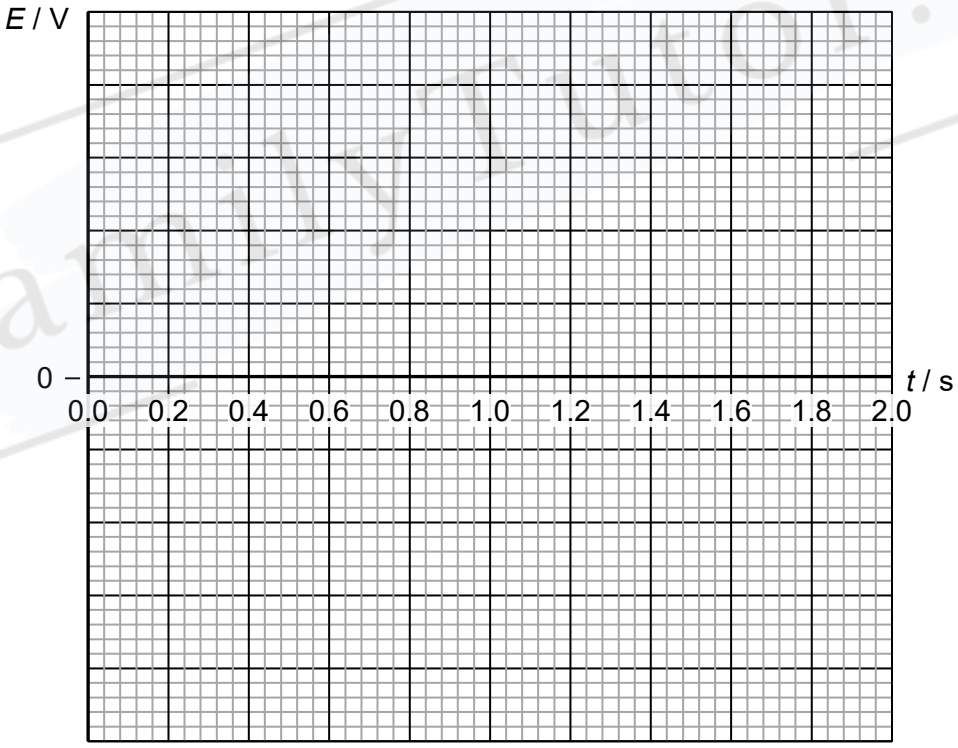

Fig. 6.3

[3]

[Turn over

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(iv) An iron core is inserted into the solenoid and then held stationary within the solenoid.

State and explain the effect, if any, on the change in Fig. 6.3.

……

……

……

..... [2]

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7 **(a)** The variation with time t of the current I for a sinusoidally alternating voltage supply of peak value of 240 V is shown in Fig. 7.1.

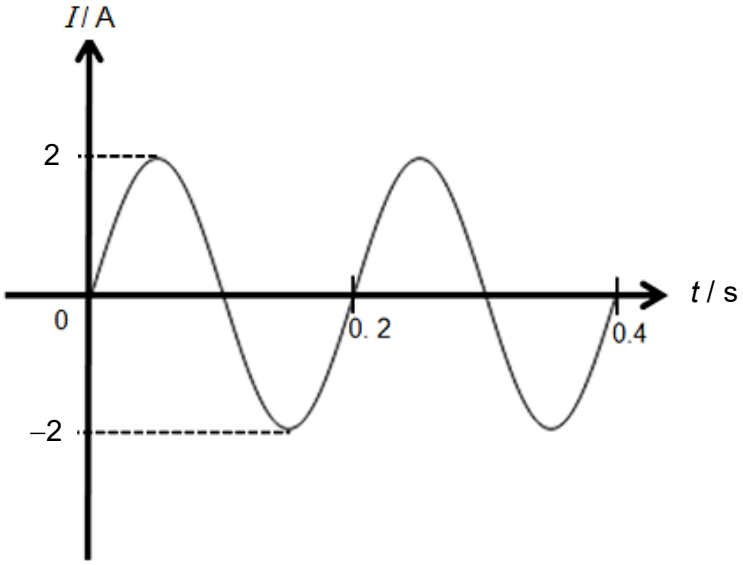

Fig. 7.1

(i) Determine the root-mean-square value of the current.

current = ... A [2]

(ii) Determine the mean power supplied.

mean power = ... W [2]

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(b) A transformer has 500 turns in the primary coil and 10 turns in the secondary coil. The alternating voltage supply in **(a)** is connected to the primary coil.

(i) Determine the peak values of the voltage and current in the secondary coil.

State an assumption made.

voltage in secondary coil = ... V

current in secondary coil = ... A [2]

Assumption: ……..……..……..

..... [1]

(ii) Suggest one use for such a current from the secondary coil of the transformer.

……..……..……..

..... [1]

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Section B

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

8 **(a)** A horizontal string is stretched between two fixed points A and B. A vibrator is used to oscillate the string and produce an observable stationary wave.

At one instant, the moving string is straight, as shown in Fig. 8.1.

Fig. 8.1

The dots in Fig. 8.1 represent the positions of the nodes on the string. Point P on the string is moving downwards.

The wave on the string has a speed of 35 m s^{-1} and a period of 0.040 s.

(i) Explain how the stationary wave is formed on the string.

.....

.....

.....

..... [2]

(ii) On Fig. 8.1, sketch a line to show a possible position of the string a quarter of a cycle later than the position shown in Fig. 8.1. [1]

(iii) Determine the horizontal distance from A to B.

distance = ... m [2]

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(iv) A particle on the string has zero displacement at time $t = 0$. From time $t = 0$ to time $t = 0.060$ s, the particle moves through a total distance of 72 mm.

Calculate the amplitude of oscillation of the particle.

amplitude = ... mm [2]

(b) Light from a laser is used to produce an interference pattern on a screen as shown in Fig. 8.2.

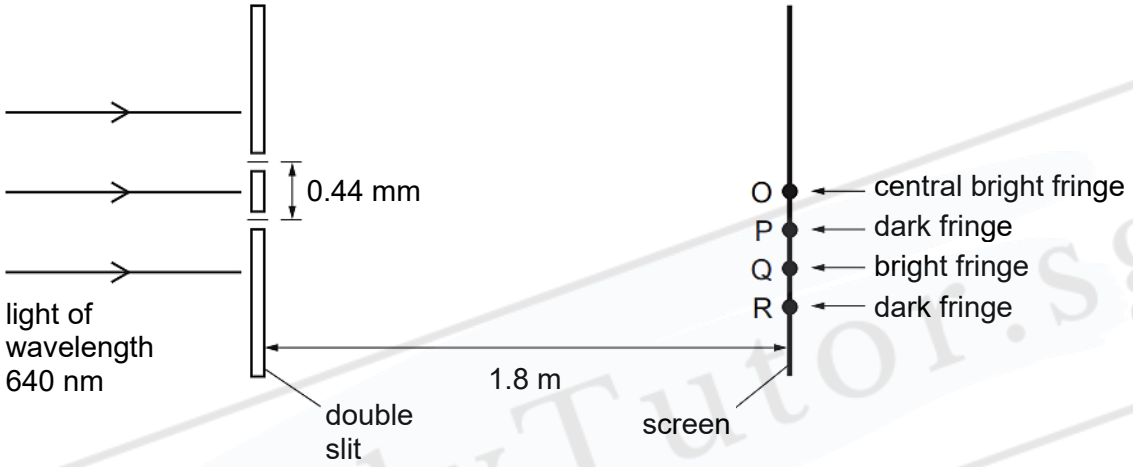

Fig. 8.2 (not to scale)

The light of wavelength 640 nm is incident normally on two slits that have a separation of 0.44 mm. The double slit is parallel to the screen. The perpendicular distance between the double slit and the screen is 1.8 m.

The central bright fringe on the screen is formed at point O. The next dark fringe below point O is formed at point P. The next bright fringe and the next dark fringe below point P are formed at points Q and R respectively.

(i) The light waves from the two slits are coherent.

State what is meant by coherent.

..... [1]

(ii) For the two light waves superposing at R, calculate

1. the difference in their path lengths from the slits,

path difference = ... nm [1]

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2. their phase difference.

phase difference = ... ° [1]

(iii) Determine the distance OR.

distance OR = ... m [2]

(iv) The intensity of the light incident on the double slit is increased without changing the frequency.

Describe how the appearance of the fringes after this change is different from, and similar to, their appearance before the change.

.....

.....

.....

.....

..... [3]

(v) The light of wavelength 640 nm is now replaced by blue light from a laser.

State and explain the change, if any, that must be made to the separation of the two slits so that the fringe separation on the screen is the same as it was for light of wavelength 640 nm.

.....

.....

.....

..... [2]

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(c) A diffraction grating is used with different wavelengths of visible light. The angle θ of the fourth-order maximum from the zero-order (central) maximum is measured for each wavelength.

The variation with wavelength λ of $\sin\theta$ is shown in Fig. 8.3.

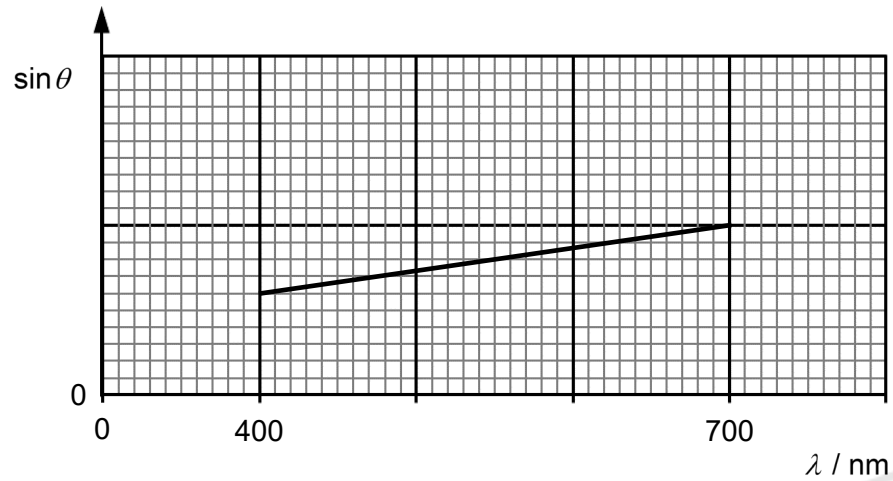

Fig. 8.3

(i) The gradient of the graph is *G*.

Determine an expression, in terms of *G*, for the distance *d* between the centres of two adjacent slits in the diffraction grating.

d = ... [1]

(ii) On Fig. 8.3, sketch a graph to show the results that would be obtained for the second-order maxima. [2]

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9 (a) Explain what is meant by the *half-life* of a nuclide.

.....

..... [1]

(b) Bismuth-214 ($^{214}_{83}Bi$) has an unusual decay pattern. Sometimes it decays by emission of an α-particle into thallium (T*l*) and sometimes by emission of a β^--particle into polonium (Po).

(i) Complete the nuclear equations for these two decays of $^{214}_{83}Bi$.

α-decay:

$^{214}_{83}Bi \rightarrow Tl +$

β^--decay:

$^{214}_{83}Bi \rightarrow Po +$

[2]

(ii) Data for the α-decay of $^{214}_{83}Bi$ to form T*l* are given in Fig. 9.1.

nucleus	mass of nucleus / *u*
Bi	213.9987
T*l*	209.9901
α	4.0015

Fig. 9.1

Use the data in Fig. 9.1 to calculate the energy released during the decay.

energy released = ... J [3]

[Turn over

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(iii) The two decay patterns of $^{214}_{83}Bi$ each give rise to γ-ray photons.

Suggest why photons from these two decays have different energies.

.....

.....

.....

..... [2]

(c) (i) On Fig. 9.2, sketch a labelled graph (without numerical values) to show how starting with only $^{214}_{83}Bi$ nuclei, the activity of the $^{214}_{83}Bi$ changes with time. Label the graph Bi. [1]

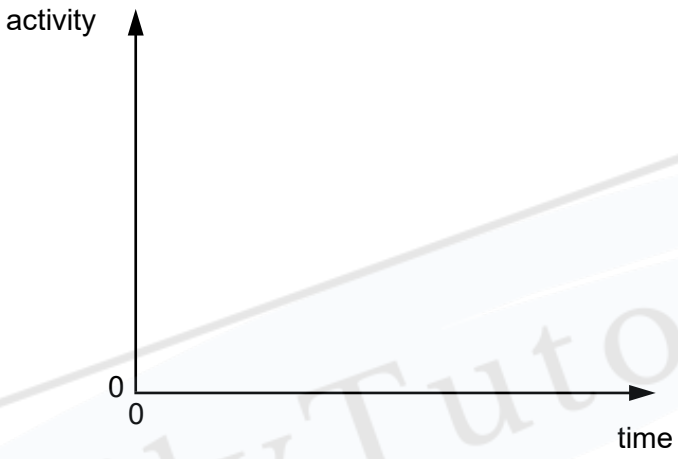

Fig. 9.2

(ii) The thalium (T*l*) produced is also radioactive and has a shorter half-life than that of $^{214}_{83}Bi$.

On the same axes in Fig. 9.2, sketch another graph to show how the activity of the T*l* changes with time. Label the graph T*l*. [1]

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(d) A sample of $^{214}_{83}Bi$ has mass 2.0 μg at time t = 0 s.

(i) Show that the sample contains approximately 5.6×10^{15} atoms.

[1]

(ii) The activity at t = 0 s is 3.3×10^{12} Bq.

Calculate the decay constant.

decay constant = ... s^{-1} [2]

(iii) Calculate the half-life.

half-life = ... s [1]

(iv) Calculate the time taken for the activity to fall to 3.3×10^{6} Bq.

time = ... s [2]

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(e) The $^{214}_{83}Bi$ sample is stored in a non-radioactive lead container with thin walls of thickness 1 mm. Background radiation is negligible.

Suggest why, although the lead container provides adequate shielding for the α and β^--emissions, some X-ray radiation may be detected outside the lead container.

……..

……..

……..

……..

……..

…… [4]

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End of paper

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Suggested Solutions

<table>
<tr><th>No.</th><th>Solution</th><th>Remark</th></tr>
<tr><td>1(a)</td><td>$x = \frac{15.0 + 15.0}{2} = 15.0$ cm

Period $T = \frac{20.8 + 20.7}{2 \times 20} = 1.04$ s</td><td>[1]
- for correct measurements with units
- 1 d.p in cm
- repeat
[1]
- 1 or 2 d.p in timing
- repeat
- T in 3 s.f. or 4 s.f. depending on the d.p. of t_1 and t_2
$t \geq 20.0$ s</td></tr>
<tr><td>1(b)</td><td>
<table>
<tr><th rowspan="2">x/cm</th><th rowspan="2">N</th><th colspan="2">Time for N oscillation</th><th rowspan="2">Period T/s</th><th rowspan="2">T^4/s^4</th></tr>
<tr><th>t_1/s</th><th>t_2/s</th></tr>
<tr><td>11.0</td><td>25</td><td>24.2</td><td>24.1</td><td>0.966</td><td>0.871</td></tr>
<tr><td>13.0</td><td>25</td><td>25.1</td><td>25.2</td><td>1.01</td><td>1.04</td></tr>
<tr><td>15.0</td><td>20</td><td>20.8</td><td>20.7</td><td>1.04</td><td>1.17</td></tr>
<tr><td>17.0</td><td>20</td><td>21.4</td><td>21.6</td><td>1.08</td><td>1.36</td></tr>
<tr><td>19.0</td><td>20</td><td>22.1</td><td>22.2</td><td>1.11</td><td>1.52</td></tr>
<tr><td>21.0</td><td>20</td><td>22.9</td><td>22.8</td><td>1.14</td><td>1.69</td></tr>
</table>
</td><td>[1]
- headings and units
- 6 sets of data

[1]
- d.p. of raw data
- $t \geq 20.0$ s

[1] s.f. of processed data

[1] correct calculation, allow 1 slip

Don't accept x = 0 cm. This <u>will not</u> be considered one set of data.</td></tr>
<tr><td>1(c)</td><td>Refer to attached graph.</td><td>[1] axes: units, scale

[1] plotted points accurate to half of smallest division

[1] best fit line</td></tr>
<tr><td>1(c)</td><td>Given $T^4 = Px + Q$
Graph of T^4 vs x is plotted, where P is the gradient and Q is the y-intercept.</td><td>[1]
- Big triangle
- substitution of gradient coordinates
- linearisation</td></tr>
</table>

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	Gradient$=\frac{1.67-0.89}{20.8-11.4}=0.0830$ P = 0.0830 s^4 cm^{-1} Substitute $(20.8,1.67)$ into the equation, $1.67=(0.0830)(20.8)+Q$ $Q=-0.0564$ s^4	[1] P calculated correctly with units [1] Q calculated correctly with units

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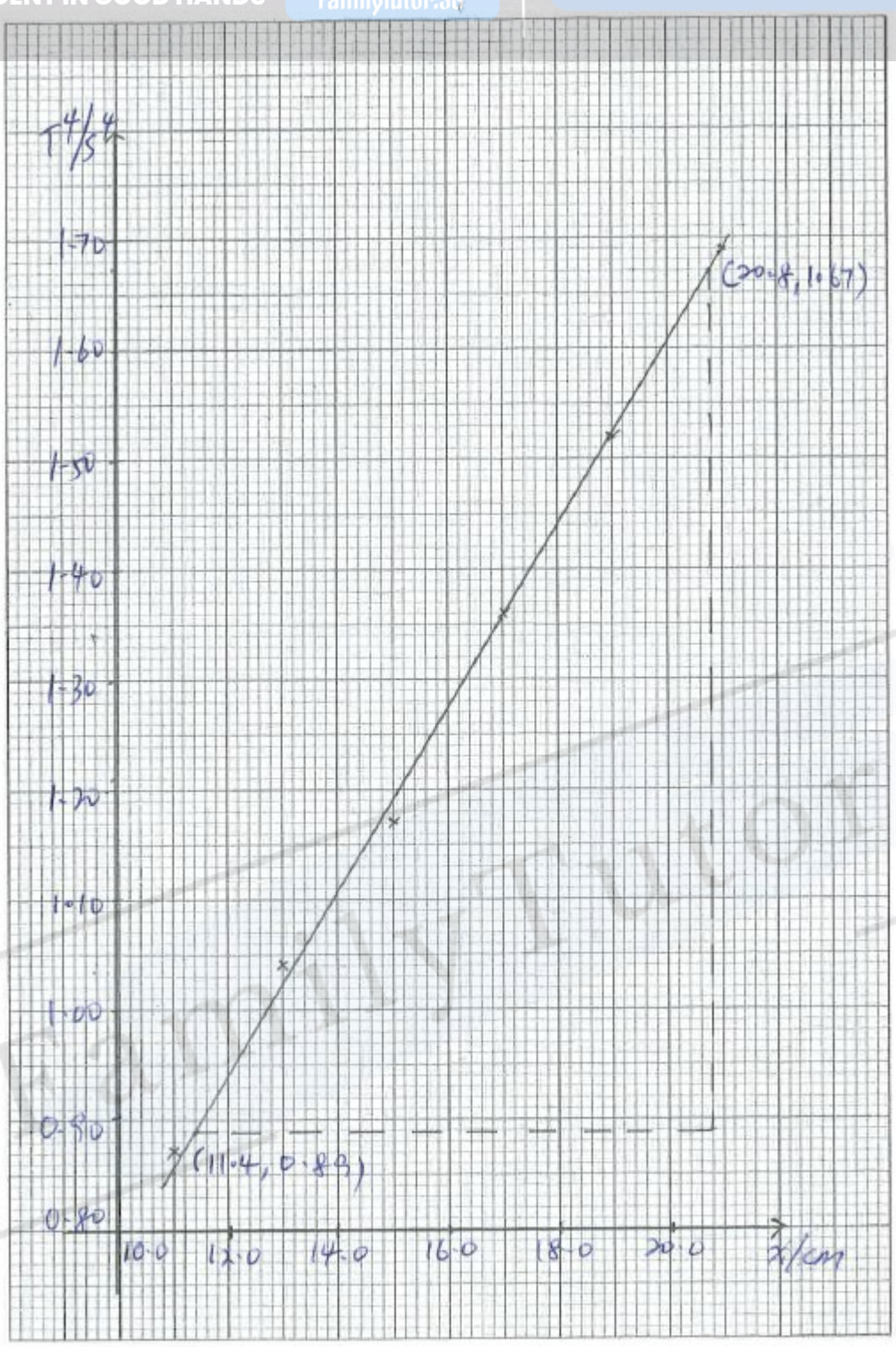

[Total: 12]

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No.	Solution	Remarks
2(a)(i)	$L_0 = \frac{7.5 + 7.5}{2} = 7.5$ cm	[1] correct measurements with unit and d.p
2(a)(ii)	Volume $V = (1.9\times10^{-3})(1.9\times10^{-3})(2\times7.5\times10^{-2})$ $= 5.42\times10^{-7}$ m^3	[1] ans
2(b)(i)	$L = \frac{8.8 + 8.8}{2} = 8.8$ cm Extension e = 8.8 – 7.5 = 1.3 cm = 0.013 m Force $F = 100\times10^{-3} \times 9.81 = 0.981$ N	[1] - both e and F calculated correctly - repeat measurement for L - answer for F in 2 or 3 sig. fig
2(b)(ii)	<table><tr><th>m/kg</th><th>L/m</th><th>e/m</th><th>F/N</th></tr><tr><td>0.000</td><td>0.075</td><td>0.000</td><td>0.000</td></tr><tr><td>0.100</td><td>0.088</td><td>0.013</td><td>0.981</td></tr><tr><td>0.200</td><td>0.116</td><td>0.041</td><td>1.96</td></tr><tr><td>0.300</td><td>0.165</td><td>0.090</td><td>2.94</td></tr><tr><td>0.400</td><td>0.212</td><td>0.137</td><td>3.92</td></tr><tr><td>0.500</td><td>0.261</td><td>0.186</td><td>4.91</td></tr></table>	[1] - headings and units - 6 sets of data (award full credit if m = 0.000 kg not included in the table) [1] - d.p. of raw data - m in 3 d.p - s.f of processed data [1] correct calculation, allow 1 slip
2(b)(iii)	Refer to attached graph.	[1] - plotted points accurate to half of smallest division - best fit curve / line
2(b)(iv)	When the extended length is $2L_0$, the extension e is L_0 = 0.075 m and force F is 2.7 N. Energy stored = area under the graph $= \frac{1}{2}(0.013)(0.981) + \frac{(0.981+1.96)(0.028)}{2} + \frac{(1.96+2.7)(0.034)}{2}$ = 0.127 J	[1] correct calculation No marks awarded if best fit curve / line does not pass through origin
2(b)(v)	Energy stored per unit volume $= \frac{0.127}{5.41\times10^{-7}}$ $= 2.35\times10^{5}$ J m^{-3}	[1] correct calculation

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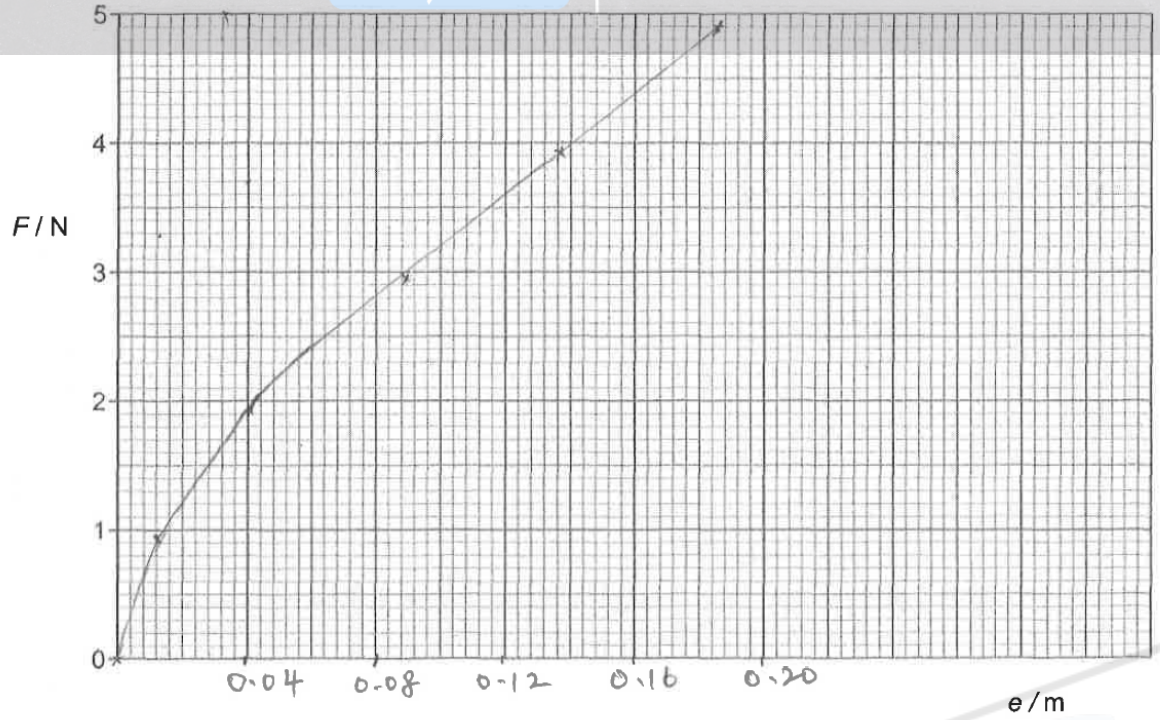

[1]

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No.	Solution	Remarks
3(a)	$D_Y = \frac{4.5 + 4.5}{2} = 4.5$ cm Diameter $d_Y = \frac{0.30 + 0.30}{2} = 0.30$ mm	[1] - correct measurement for D_Y. Accept 4.0 cm to 5.0 cm - repeat [1] - correct measurement for d_Y. Accept 0.25 mm to 0.35 mm - repeat
3(b)(i)	There are 13 turns on cardboard tube Y. $L_Y = 13 \times 2 \times \pi \times r$ $= 13 \times D_Y \times \pi$ $= 13 \times 4.5 \times \pi$ $= 184$ cm	[1] sub [1] ans
3(b)(ii)	$L_Y = 13\pi D_Y$ $\frac{\Delta L_Y}{L_Y} = \frac{\Delta D_Y}{D_Y}$ $\frac{\Delta L_Y}{L_Y} \times 100\% = \frac{\Delta D_Y}{D_Y} \times 100\%$ Hence percentage uncertainty in $L_Y = \frac{0.2}{4.5} \times 100\% = 4.4\%$	[1] for correct percentage uncertainty (1 or 2 s.f.)
3(c)	$R = 15\ \Omega$ $I = 140.6 \times 10^{-3}$ A	[1] - correct R - correct I with d.p
3(d)	R/Ω | I/A | IR/V 15 | 0.1406 | 2.1 18 | 0.1329 | 2.4 22 | 0.1227 | 2.7 27 | 0.1148 | 3.1 33 | 0.1128 | 3.7	[1] - headings and units - 5 sets of data [1] - d.p, units of raw data - s.f of processed data [1] correct calculation

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3(e)	Gradient$=\frac{3.4-2.2}{30-16}=0.0857$ $G=0.0857$ A Substitute $(30,3.4)$ into the equation, $3.4=(0.0857)(30)+H$ $H=0.829$ V $X_Y=\frac{H}{G}=\frac{0.829}{0.0857}=9.67\ \Omega$	[1] - points plotted correctly - best fit line drawn [1] - value of G calculated correctly (with or without unit) [1] value of X_Y calculated correctly in 2 or 3 sig. fig
3(f)(i)	$D_Z=\frac{4.5+4.5}{2}=4.5$ cm Diameter $d_Z=\frac{0.20+0.20}{2}=0.20$ mm (0.15 to 0.25 mm) $L_Z=\frac{3L_Y}{4}=\frac{3(184)}{4}=138$ cm	[1] - correct measurement for D_Z - Accept 4.0 cm to 5.0 cm - (repeat) - correct measurement for d_Z - Accept 0.15 mm to 0.25 mm - (repeat) - correct calculation
3(f)(ii)		[1] - headings and units - 5 sets of data - d.p, units of raw data - s.f of processed data

R/Ω	I/A	IR/V
15	0.1258	1.9
18	0.1165	2.1
22	0.1079	2.4
27	0.1001	2.7
33	0.0972	3.2

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	Gradient= $\frac{3.05-2.0}{31.5-16.5}=0.0700$ $G=0.0700$ A Substitute $(31.5,3.05)$ into the equation, $3.05=(0.0700)(31.5)+H$ $H=0.845$ V $X_Z=\frac{H}{G}=\frac{0.845}{0.0700}=12.1\,\Omega$	[1] value for X_Z calculated correctly

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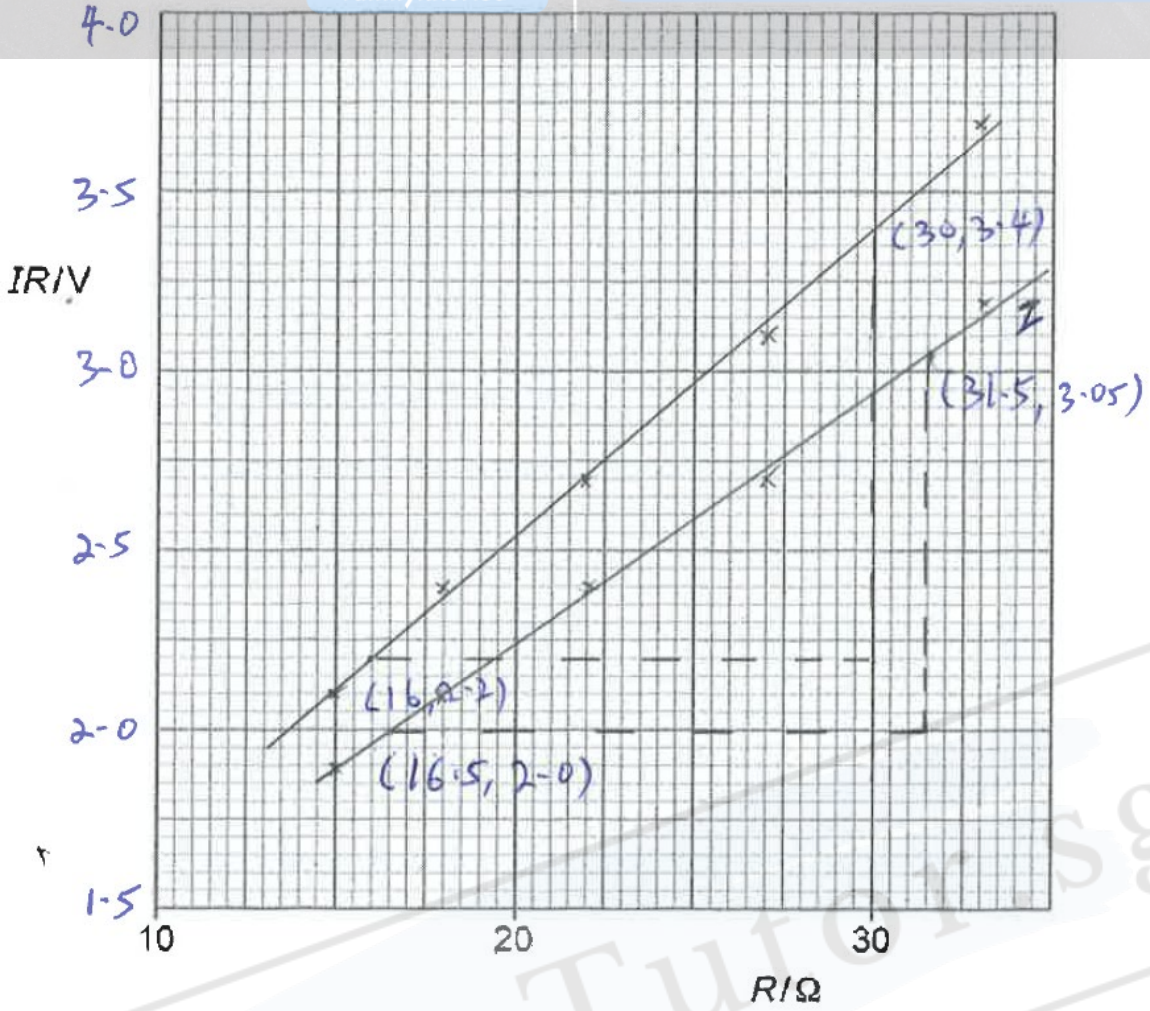

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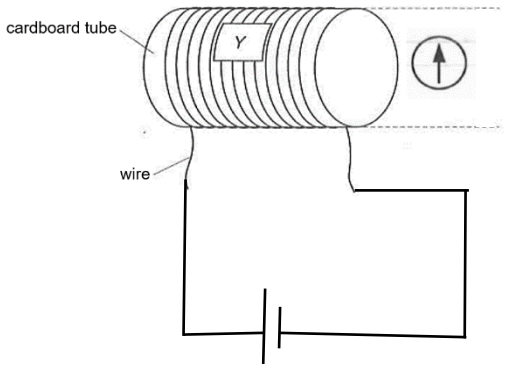
3(f)(iii)	Difference: The calculated value is 12.1 Ω and the measured value is 21.6 Ω. Measured value is higher than the calculated value. Reason: Due to the contact resistance of crocodile clip.	[1] for difference and reason
3(g)(i)	Given $X = \frac{kL}{d^2} \Rightarrow k = \frac{Xd^2}{L}$ First value of k (for wire Y) $k_Y = \frac{9.67(0.30\times10^{-3})^2}{1.84} = 4.73\times10^{-7}\ \Omega\ \text{m}$ Second value of k (for wire Z) $k_Z = \frac{12.1(0.20\times10^{-3})^2}{1.38} = 3.51\times10^{-7}\ \Omega\ \text{m}$	[1] correct calculation of value of both k.
3(g)(ii)	Percentage difference $= \frac{(4.73-3.51)\times10^{-7}}{3.51\times10^{-7}}\times100\% = 35\%$ The percentage difference of 35% between the two k values are higher than the percentage uncertainties of L_Y at 4.4%. As such, the result of my experiment does not support the suggested relationship.	[1] valid evaluation based on comparing percentage difference with percentage uncertainties of L_Y
3(h)(i)	From the equation $B = CnI$, magnetic flux density B at each end of the tube depends on n, number of turns of wire per unit length. Since tube Y has greater number of turns of wire per unit length than tube Z, tube Y has greater magnetic flux density at its ends.	[1] explanation
3(h)(ii)	 **Fig. 1**	[1] Diagram to show - battery connected directly across the coil - compass placed beside on end of the tube

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Fig. 2

1. Set up the circuit as shown in Fig. 1 for both tube Y and Z.

2. The needle of the compass points due north when there is no current flowing in the coil.

3. Count the number of turns of wires, N and measure the length of the tube l and determine $n = \frac{N}{l}$.

4. The deflection of the needle of the compass as shown in Fig. 2 gives the direction of the resultant magnetic flux density due to the Earth magnetic flux density and the magnetic flux density at the end of the tube.

5. Measure the angle of deflection using a protractor. The angle of deflection of the compass needle is used to determine the relative field strength.

6. By comparing the angle of deflection of compass needle for both tube Y and Z will conclude whether tube Y or tube Z has a greater magnetic flux density at its end.

[1]
- Distance between compass and coil Y and Z must be constant

- Tube Y and Z arranged in East-West direction

[1] compare angle of deflection to determine the relative field strength

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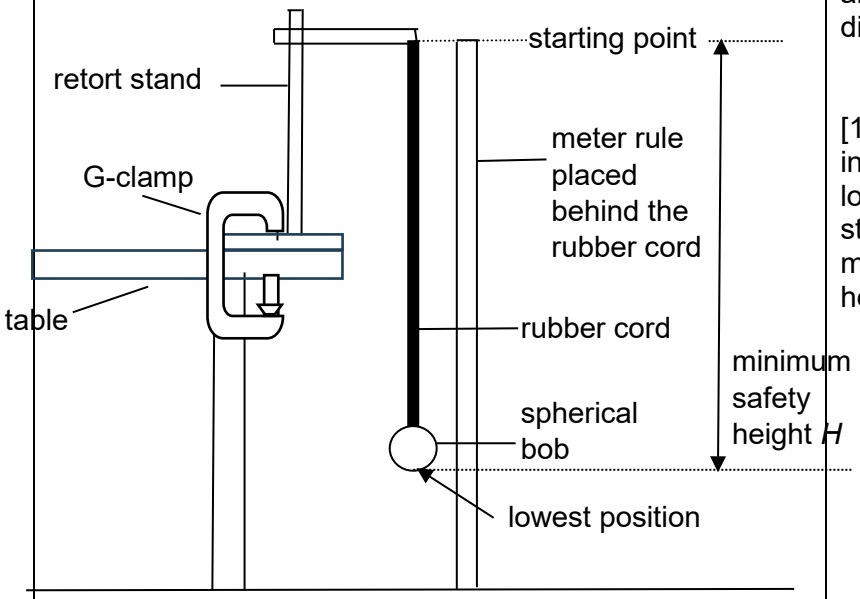
4	**Aim:** To investigate how the minimum safety height *H* depends on the mass *M* of the object and the length *L* of the rubber cord.	[1] feasible set up and labelled diagram
		[1] clear information on lowest position, starting point and minimum safety height
	Experiment 1 – to determine *p* **Independent variable**: mass of the spherical bob, *M* measured using the electronic balance. **Dependable variable**: minimum safety height *H*, measured using the metre rule. **Controlled variable**: - length of the rubber cord. - release the sphere at rest from starting point.	[1] correct variables for Experiment 1
	Procedure: **a)** Set up the apparatus as shown in the diagram above. **b)** The retort stand is placed at the edge of the table. **c)** One end of the rubber cord is tied securely to the end of the clamp. **d)** Measure the length of the rubber cord *L* using a metre rule. **e)** Weigh the mass of the spherical bob *M* using the electronic balance. **f)** Suspend the spherical bob from the starting point and release. Note the position of the lowest point reached and record the minimum safety height *H* by using the metre rule behind the rubber cord. Minimum safety height is measured from the starting point to the lowest position reached by the spherical bob.	[2] for correct and detailed procedure [1] mention of apparatus for different measurement – length of rubber cord, - mass of spherical bob, - minimum safety height

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	g) Repeat **(f)** at least two times to get an average value of the minimum safety height *H*.	
	h) Repeat **(e)** to **(g)** using spherical bobs of different mass and same length of the rubber cord to get five additional readings of *M* and *H*.	
	i) Based on the equation $H = k M^p L^q$, we get $\lg H = p \lg M + \lg(kL^q)$. Plot a graph of lg *H* against lg *M*, where *p* is the gradient.	[1] correct graph plotted
	Experiment 2 – to determine *q*	
	Independent variable: length of the rubber cord *L*, measured using metre rule.	
	Dependable variable: minimum safety height *H*, measured using the metre rule behind the rubber cord.	[1] correct variable for Experiment 2
	Controlled variable: - mass of the spherical bob. - release the sphere at rest from starting point.	
	j) Repeat **(e)** to **(g)** using rubber cord of different length and same mass of spherical bob to get six readings of *L* and *H.*	
	k) Based on the equation $H = k M^p L^q$, we get $\lg H = q \lg L + \lg(kM^p)$. Plot a graph of lg *H* agains lg *L*, where *q* is the gradient.	[1] correct graph plotted
	Precautions for accuracy:	
	1. Conduct preliminary experiments by using the longest rubber cord and heaviest spherical bob so as to obtain a workable range for *H*.	[2] any 2
	2. Release the spherical bob with no downward velocity. Do not exert any force vertically or horizontally on the sphere upon release of the spherical bob.	
	3. The retort stand is placed at the edge of the table because the extension of the rubber cord can be longer than the height of the retort stand.	
	4. Measure the unstretched length of the rubber cord before releasing the spherical bob of different mass to ensure that the same length of the rubber cord is used for all spherical bobs.	

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	Precautions for safety: **1.** Use the G-clamp to clamp the base of the retort stand to stabilize it and prevent the retort stand from toppling. **2.** Place the retort stand at a higher level e.g. on a table so that the spherical bob will not hit the ground (this may cause hazard to others) after the rubber cord has fully extended.	[1] any 1

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Apparatus List

Odd Number Bench

Question 1

- Retort stand
- Boss
- Clamp
- Split cork
- Pendulum made from strings and two slotted masses
- Stopwatch
- 30 cm ruler

Question 2

- Retort stand
- Boss head
- Clamp
- 3 x 100 g slotted masses
- Rubber band with dimensions of its cross section written on a card
- 100 g mass hanger
- Four 100 g slotted masses
- 30 cm rule

Even Number bench

Question 3

- Cardboard tube Y, with wire wrapped around it
- Cardboard tube Z, with wire wrapped around it
- Switch
- 1.5 V dry cell in holder
- 0 – 400 mA multimeter
- 0 – 400 Ω multimeter
- One each of the following labelled resistors:
  15 Ω, 18 Ω, 22 Ω, 27 Ω, 33 Ω
- Six connecting wires
- 30 cm ruler
- Micrometer screwgauge (one per 2 candidates)

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Name	Class	Index Number

JURONG PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9749/04**
Higher 2

Paper 4 Practical

17 August 2023

2 hours 30 minutes

READ THESE INSTRUCTIONS FIRST

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

Answer **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

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

Shift
Laboratory

For Examiner's Use	
1	/ 12
2	/ 9
3	/ 22
4	/ 12
Total	/ 55

This document consists of **18** printed pages and **2** blank pages.

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1 In this experiment, you will investigate the motion of a system of masses.

(a) Set up the apparatus as shown in Fig. 1.1.

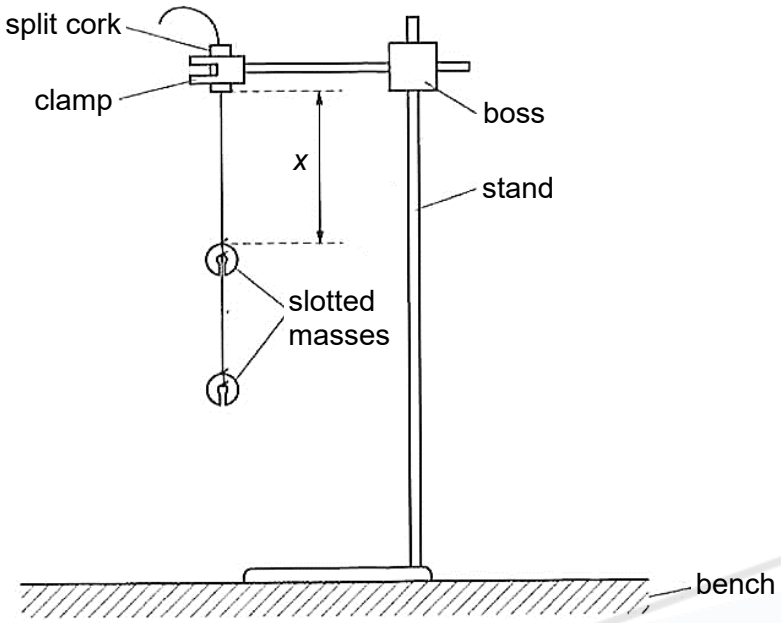

Fig. 1.1

The distance between the bottom of the split cork and the top of the upper string loop is *x*.

Adjust the apparatus until *x* is approximately 15 cm.

Measure and record *x*.

x = …….....

Move the bottom mass a short distance to the left and release it. The masses will oscillate with a period *T*.

Determine and record *T*.

T = …….....
[2]

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(b) Vary x and repeat **(a)**.

Present your results clearly.

[4]

(c) T and x are related by the expression:

$$T^4 = Px + Q$$

where P and Q are constants.

Plot a suitable graph to determine P and Q.

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P = ...

Q = ...

[6]

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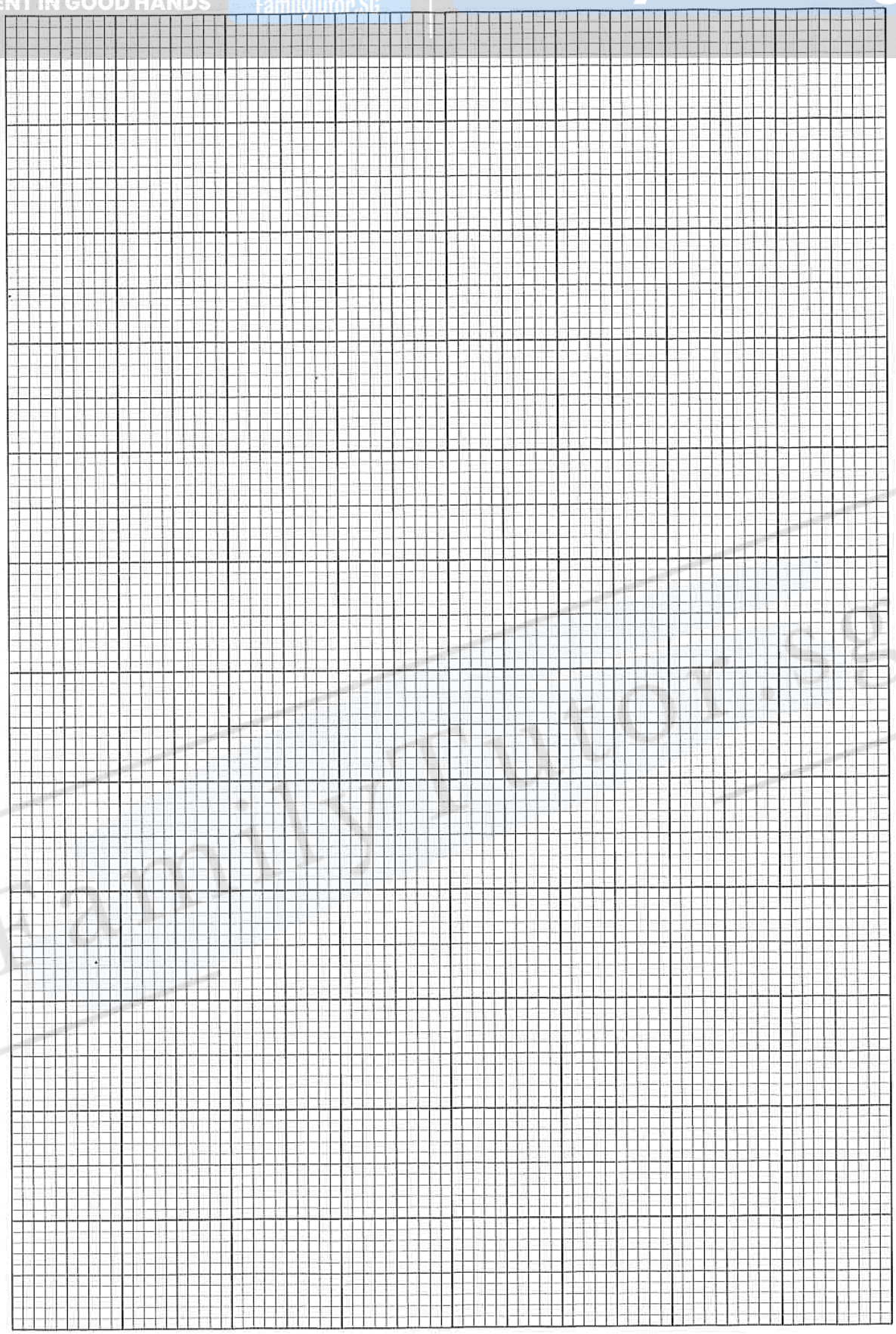

[Total: 12]

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2 In this experiment, you will investigate the energy stored in a stretched rubber band.

(a) (i) Place the rubber band on the bench so that it is taut without being stretched, as shown in Fig. 2.1.

The length of the rubber band is L_0.

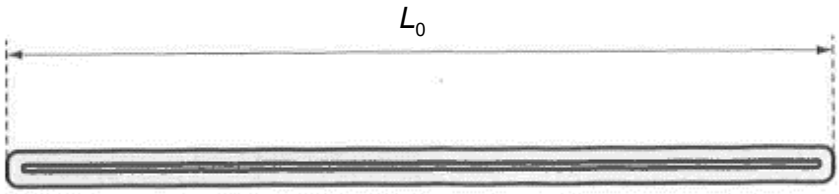

Fig 2.1

Measure and record L_0 for your rubber band.

L_0 = ... [1]

(ii) Use the dimensions given on the card to calculate the volume V of the rubber band.

V = ... [1]

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(b) (i) Set up the apparatus as shown in Fig. 2.2 with the mass hanger suspended from the rubber band.

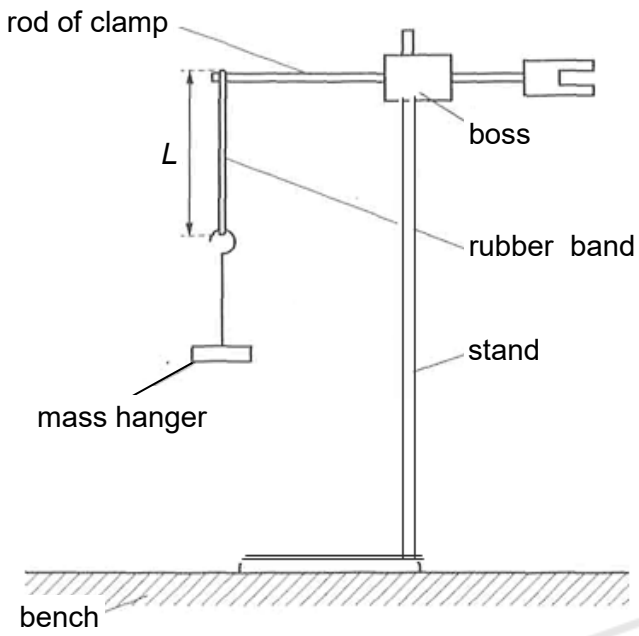

Fig 2.2

The extended length of the rubber band is *L*.

Calculate the extension *e* of the rubber band where:

$$e = L - L_0.$$

Record your answer in metres.

e = ... m

The force *F* acting on the rubber band is given by:

$$F = mg$$

where *m* is the mass, in kg, suspended from the rubber band and $g = 9.81\ \text{N kg}^{-1}$.

Calculate and record *F*.

F = ... N
[1]

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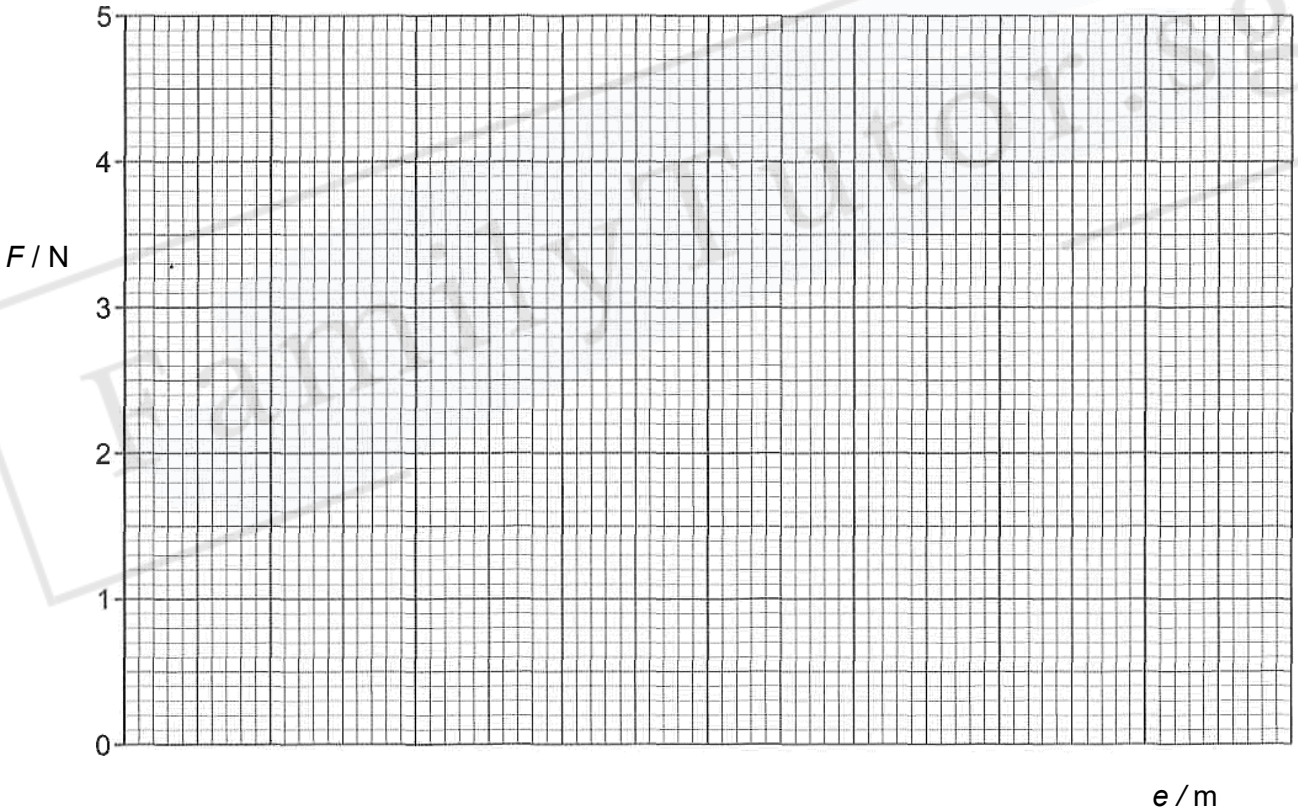
(ii) Vary m and repeat **(b)(i)**.

Present your results clearly.

[3]

(iii) Plot your results on the grid below.



[1]

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(iv) The area under the graph represents the approximate energy stored by the rubber band.

Estimate this energy when its extended length $L = 2L_0$.

energy stored = ... J [1]

(v) Calculate the energy stored per unit volume, in J m^{-3}, in the rubber band when its extended length $L = 2L_0$.

energy stored per unit volume = ... J m^{-3} [1]

[Total: 9]

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3 This experiment investigates the properties of a coil of wire.

(a) You have been provided with two cardboard tubes with wire wrapped around them.

The diameter of the tube labelled Y is D_Y, as shown in Fig. 3.1.

The diameter of the wire is d_Y.

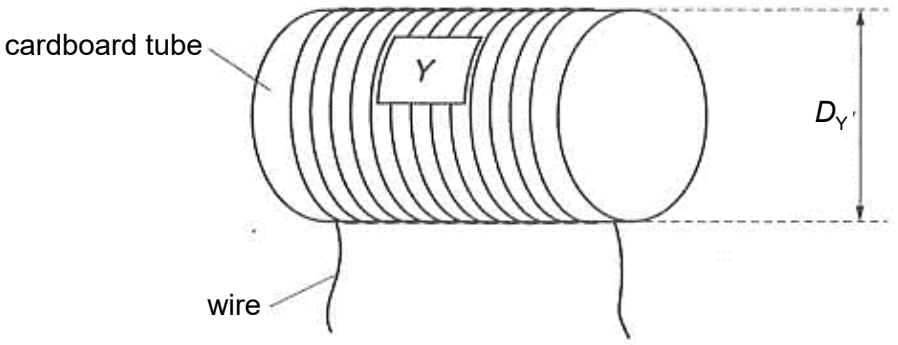

Fig. 3.1

Measure and record D_Y and d_Y.

D_Y = ... cm

d_Y = ... mm
[2]

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(b) (i) The total length of wire is L_Y.

Estimate and record your value for L_Y.

Show your working.

L_Y = ... cm [2]

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

percentage uncertainty in L_Y = ... [1]

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(c) Connect the circuit shown in Fig. 3.2 where resistor R has a resistance R of 15 Ω.

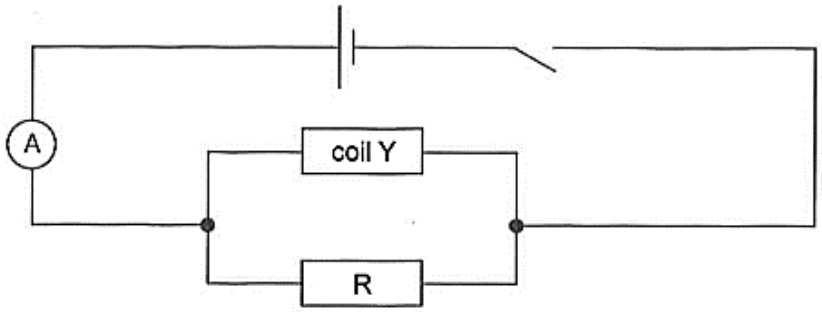

Fig. 3.2

Close the switch.

Note and record R and the ammeter reading I.

R = ... Ω

I = ... A

[1]

Open the switch.

(d) Vary R and repeat **(c)**.

Present your results clearly.

[3]

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(e) Plot your results on Fig. 3.3 and label this line Y.

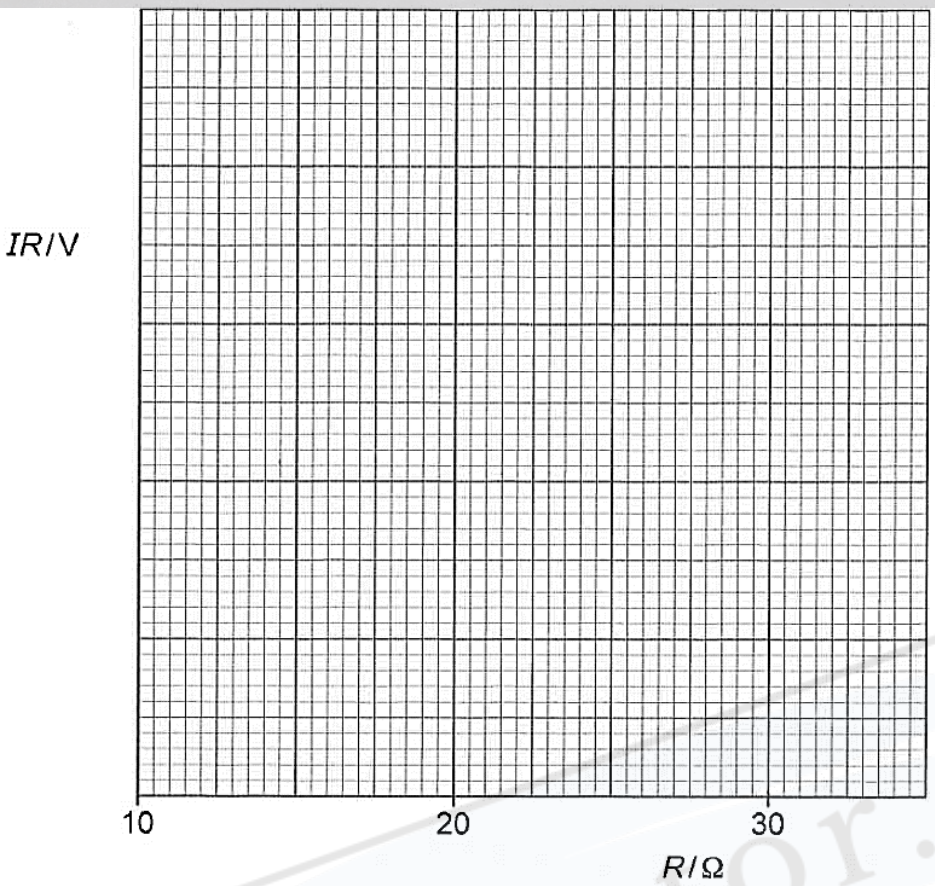

Fig. 3.3

I and R are related by the expression:

$$IR = GR + H$$

where G and H are constants.

The resistance X_Y of coil Y is given by:

$$X_Y = \frac{H}{G}$$

Use your graph to determine X_Y.

X_Y = ... Ω
[3]

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(f) The diameter of the tube labelled Z is D_Z. The diameter of the wire is d_Z.

(i) Measure and record D_Z and d_Z.

D_Z = ... cm

d_Z = ... mm

The length of wire wrapped around tube Z is L_Z, where:

$$L_Z = \frac{3L_Y}{4}.$$

Calculate L_Z.

L_Z = ... cm
[1]

(ii) The resistance of coil Z is X_Z.

Repeat **(c)**, **(d)** and **(e)** to find X_Z.

Plot your results on Fig. 3.3 and label this line Z.

X_Z = ... Ω
[2]

(iii) Use a digital multimeter to measure X_Z.

Describe any difference between your two values for X_Z and suggest a reason for this difference.

difference .....

reason .....

.....
[1]

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(g) It is suggested that the resistance of a wire, X, is given by the relationship:

$$X = \frac{kL}{d^2}$$

Where L is the length of the wire, d is the diameter of the wire and k is a constant.

(i) Use your values from **(a), (b)(i), (e), (f)(i)** and **(f)(ii)** to determine two values of k.

first value of k = ...

second value of k = ...

[1]

(ii) State whether or not the results of your experiment support the suggested relationship.

Justify your conclusion by referring to your value in **(b)(ii)**.

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..... [1]

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(h) (i) When there is a current I in one of the coils, the magnetic flux density B at each end of the tube along its axis is given by:

$$B = CnI$$

where C is a constant and n is the number of turns of wire per unit length on the tube.

Without taking further readings, explain whether tube Y or tube Z has a greater magnetic flux density at its ends when the voltage supply is connected directly across the coil.

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..... [1]

(ii) Describe, using a diagram, how you would check your conclusion in **(h)(i)** using a small compass.

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..... [3]

[Total: 22]

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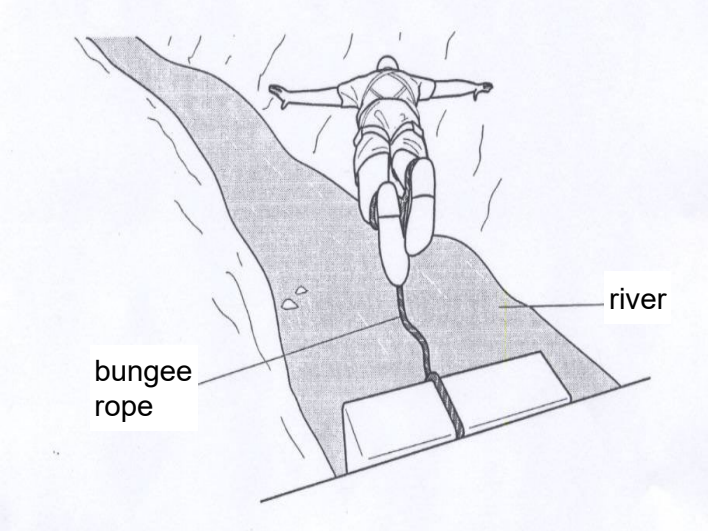
4 The origin of bungee-jumping is quite recent but the activity is related to the centuries-old ritualistic practices of "land divers" of the Pentecost Island in the Pacific Archipelago of Vanuatu. The men would demonstrate their courage and offer their injuries to the gods for a plentiful harvest of yams. Nowadays, the sport uses cranes, towers, bridges or hot-air balloons to serve as jump platforms.



A group of bungee jumping enthusiasts proposed to set up a Bungee Jumping Extreme Club in the college. There are many safety considerations to consider. One of the most important safety considerations would be the minimum safety height from which the jumper jumps. If this safety consideration is not enforced, the jumper might hit the ground and suffer serious injury before the rubber cord that is tied to his ankles is fully extended. It is suggested that the minimum safety height depends on the mass of the jumper and the original length of the rubber cord.

For the safety of the bungee jumping enthusiasts, design a scaled down experiment in the laboratory to investigate how the minimum safety height H (from the point of release) depends on the mass of the object M and the length of the rubber cord, L.

The minimum safety height is given by the equation

$$H = k M^p L^q$$

where k, p and q are constants.

Design an experiment to determine the values of p and q.

The apparatus available includes the following:
rubber cords, metre ruler, spherical bobs, G-clamp, retort stand with clamp and boss head

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

(a) the equipment you would use,
(b) the procedure to be followed,
(c) how the minimum safety height is measured,
(d) the control of variables,
(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

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Diagram

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TEST QUESTIONS AND ANSWER KEYS

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2023 Preliminary Examination

PHYSICS
Higher 2
Paper 1 Multiple Choice

9749/01
September 2023
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

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

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

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

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This document consists of **16** printed pages.

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Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi\times10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi))\times10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut+\frac{1}{2}at^2$
	v^2	=	u^2+2as
work done on / by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T / K	=	T / °C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0\sin\omega t$
velocity of particle in s.h.m.	v	=	$v_0\cos\omega t=\pm\omega\sqrt{x_0^2-x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1+R_2+\ \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots.$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0\sin\omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0\exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

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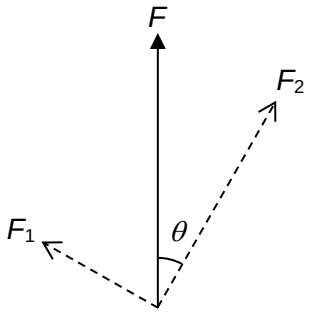
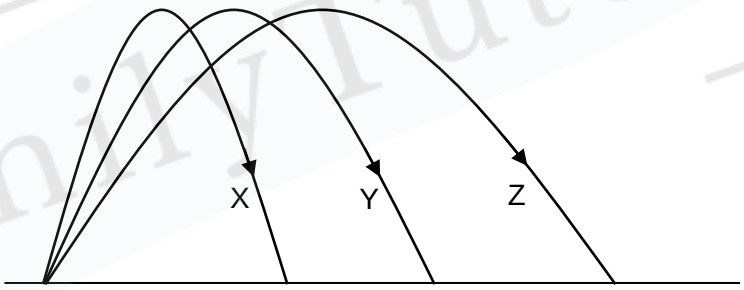
1 A vector F can be resolved into two perpendicular components F_1 and F_2. The angle between F and F_2 is θ.



How do the magnitudes of F_1 and F_2 change as θ is increased from 0° to 90°?

	F_1	F_2
A	increase	increase
B	increase	decrease
C	decrease	increase
D	decrease	decrease

2 Three paths of a kicked football are shown.



Ignoring the effects of air resistance, which of the following statements is **not** correct?

A The initial speed for path Z is the largest.

B The three paths have the same time of flight.

C The vertical component of the initial velocity for path X is the largest.

D The horizontal component of the initial velocity for path X is the smallest.

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3 Two forces F_1 and F_2 are applied to an object initially at rest. F_1 is constant while F_2 acts in the opposite direction of F_1 with a magnitude that is proportional to the square of the speed of the object.

Which statement best describes the motion of the object?

A Its speed will increase from zero to a maximum.

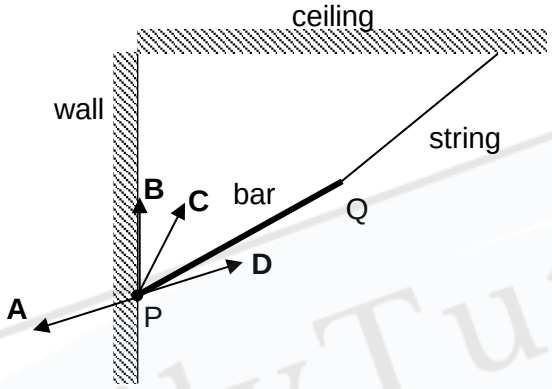
B Its speed will increase from zero to a maximum and then decrease.

C Its acceleration will increase from zero to a maximum.

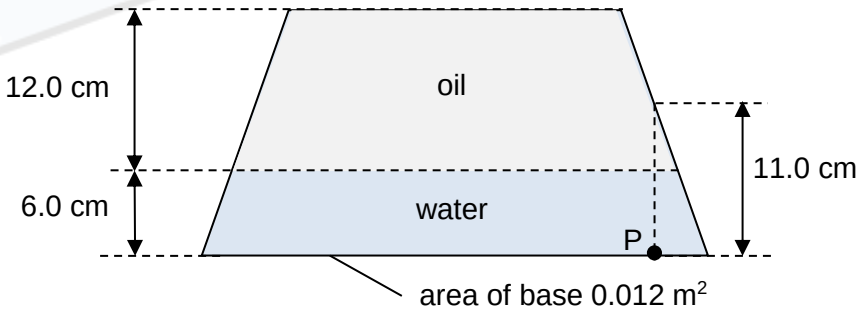
D Its acceleration will increase from zero to a maximum and then decrease.

4 A uniform bar PQ is hinged at a vertical wall at end P and tied to a string at end Q.

Which arrow best represents the direction of the force exerted by the wall on the bar?



5 A container is filled with oil and water. The oil has a mass of 0.40 kg and density 750 kg m^{-3}. The water has a mass of 0.30 kg and density 1000 kg m^{-3}.



What is the pressure exerted by the oil and water at point P on the base of the container?

A 5.7×10^2 Pa **B** 9.6×10^2 Pa **C** 1.5×10^3 Pa **D** 1.0×10^5 Pa

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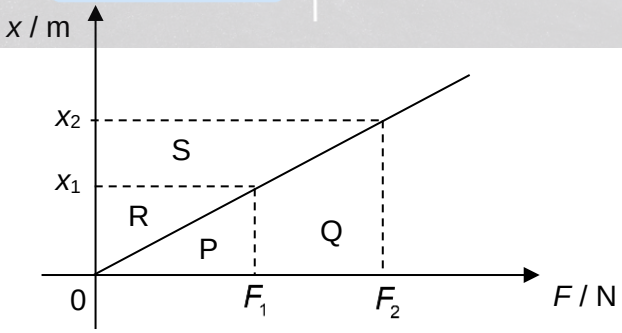
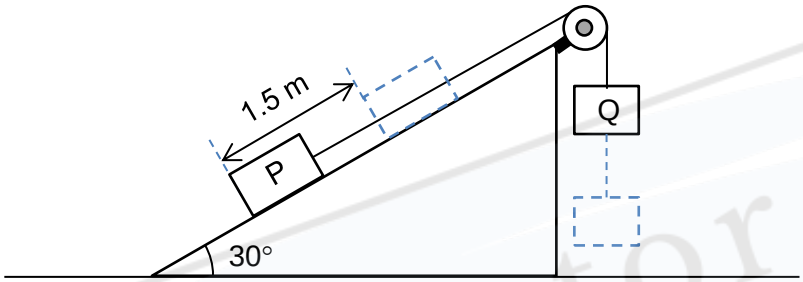
6 The variation with force F of the extension x of a spring is shown in the figure below.



Which area represents the work done in stretching the spring from x_1 to x_2?

A P + Q **B** Q **C** R + S **D** S

7 Two bodies, P and Q, of masses 3.0 kg and 4.0 kg respectively, are connected by a light cord passing over a light, frictionless pulley. P is held at rest on a rough slope inclined at 30° to the horizontal as shown.

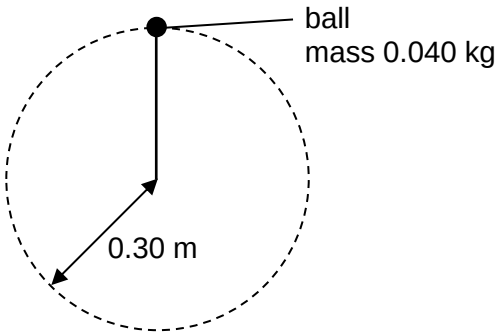


When P and Q are released, P experiences a constant frictional force of 2.5 N.

What is the total kinetic energy of P and Q when P has travelled 1.5 m up the slope?

A 11 J **B** 18 J **C** 33 J **D** 41 J

8 A small ball of mass 0.040 kg is attached to a light string and rotates in a vertical circle of radius 0.30 m. When the ball is vertically above the centre of the circle, the tension in the string is 1.2 N.



What is the centripetal acceleration of the ball when it is vertically below the centre of the circle?

A 40 m s^{-2} **B** 59 m s^{-2} **C** 69 m s^{-2} **D** 79 m s^{-2}

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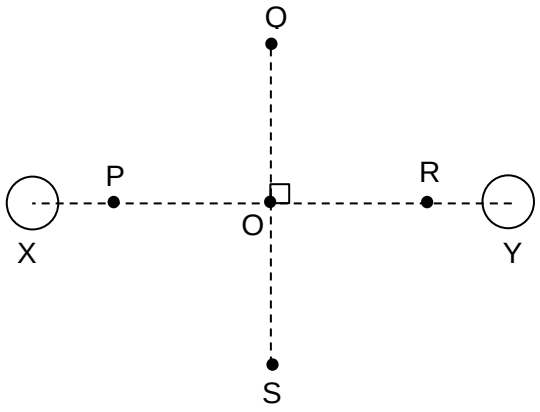
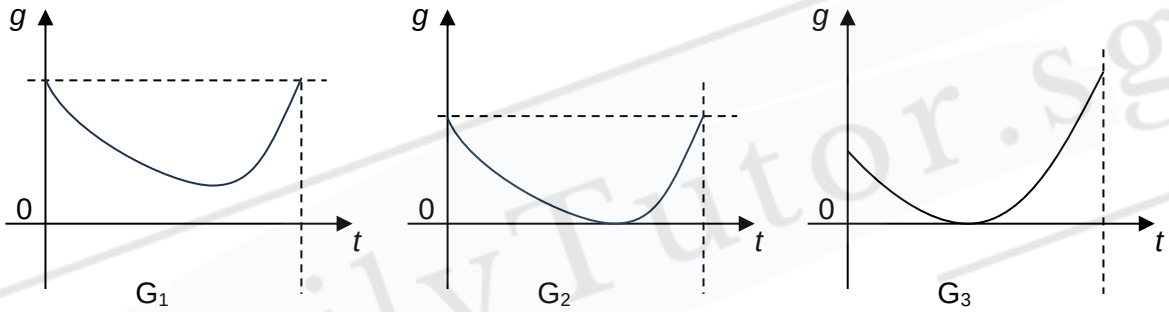
9 The diagram shows two stars, X and Y and 5 points, O, P, Q, R and S.
O is the midpoint of the line joining the centres of X and Y.
P and R are on the line joining the centres of X and Y and are at the same distance from the centres of X and Y respectively.
Q and S are on the perpendicular bisector of the line joining P and R and are at the same distance from O.



A spacecraft travels with constant acceleration in its direction of travel between 2 points.

Graphs G_1, G_2 and G_3 show the possible variations in the magnitude of the resultant gravitational field strength g due to the stars at the position of the spacecraft with time t.



Which graphs correspond to the motions of the spacecraft from S to Q and P to R?

	S to Q	P to R
A	G_1	G_2
B	G_1	G_3
C	G_2	G_1
D	G_2	G_3

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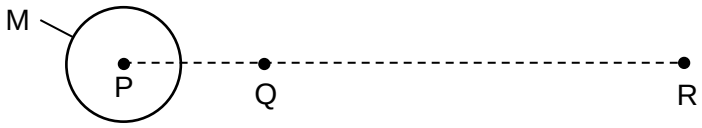
10 Point P is at the centre of a uniform sphere M. The work done by an external force in bringing a mass of 1.0 kg from infinity to point Q is –2.0 J.

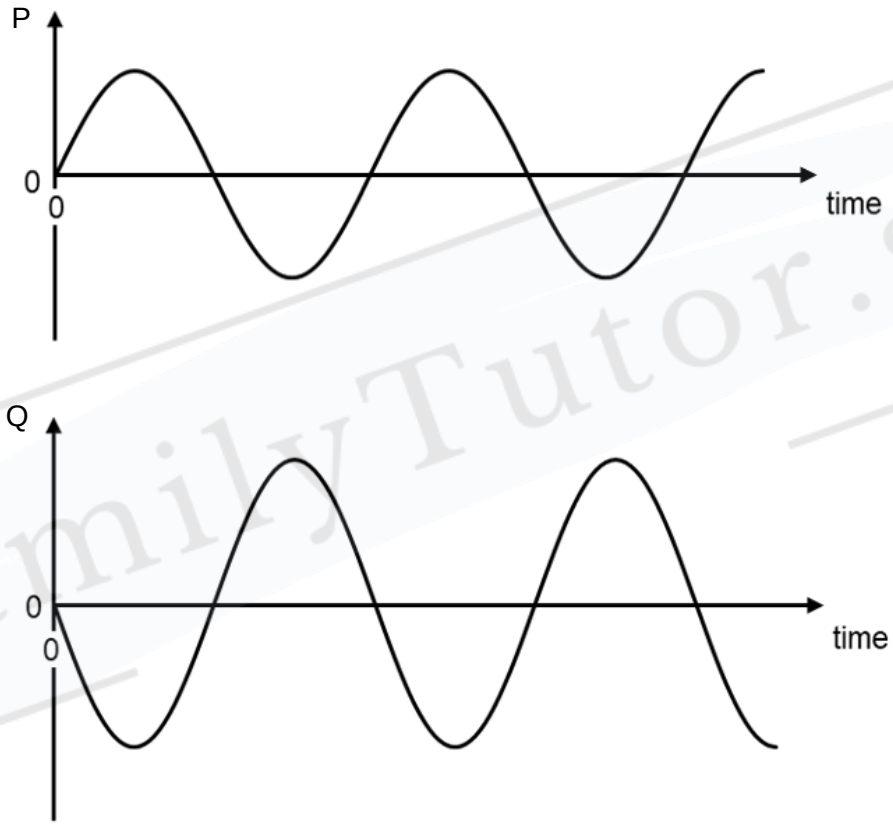


The ratio $\frac{PQ}{QR}$ is $\frac{1}{3}$.

What is the work done by an external force to bring a mass of 3.0 kg from Q to R?

A –18 J **B** –4.5 J **C** 4.5 J **D** 18 J

11 The two graphs below are for the motion of a body undergoing simple harmonic motion.



What could be represented by the quantities P and Q?

	P	Q
A	acceleration	displacement
B	acceleration	velocity
C	displacement	velocity
D	potential energy	velocity

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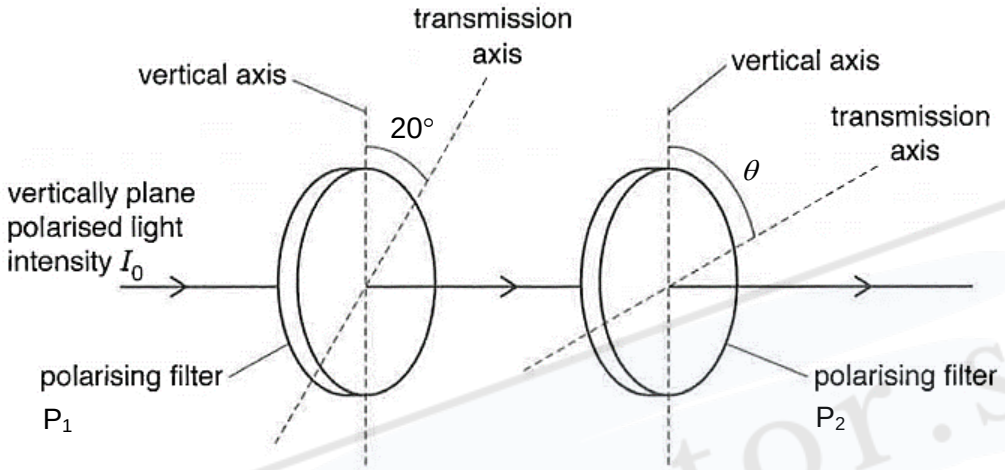
12 The total energy of a mass which undergoes simple harmonic motion on a vibrating platform is 18 mJ.

The amplitude of the oscillation is now doubled and the period of oscillation is tripled.

What is the new total energy of the mass?

A 0.89 mJ **B** 8.0 mJ **C** 72 mJ **D** 650 mJ

13 A beam of vertically polarised light of intensity I_0 is transmitted through two polarising filters P_1 and P_2 as shown. The axes of polarisation of P_1 and P_2 are at 20° and θ relative to the direction of polarisation of the incident light. The intensity of the light after passing through P_2 is 0.25 I_0.



What is the value of θ?

A 38° **B** 58° **C** 78° **D** 95°

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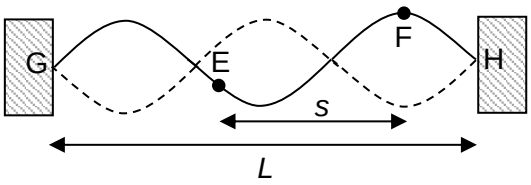
14 A string of length L is stretched between two fixed points G and H and made to vibrate transversely as shown below.

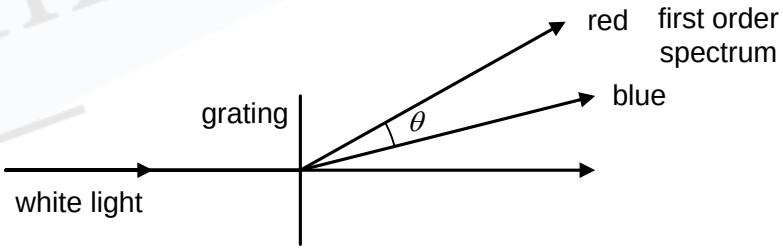


Two particles E and F on the string are separated by a distance s. The maximum kinetic energies of particles E and F are K_E and K_F respectively.

Which of the following gives the correct phase difference and relationship between maximum kinetic energies of the particles?

	phase difference / rad	maximum kinetic energy
A	$\frac{3s}{2L} \times 2\pi$	same
B	$\frac{3s}{2L} \times 2\pi$	$K_E < K_F$
C	π	same
D	π	$K_E < K_F$

15 White light covers the range of wavelength from 400 nm to 700 nm. A diffraction grating with 5.0×10^5 lines per metre is placed perpendicular to a ray of white light and produces the first order spectrum as shown.



What is the angle θ between the red and blue ends of the spectrum?

A 9.0 ° **B** 12 ° **C** 20 ° **D** 32 °

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[Turn over

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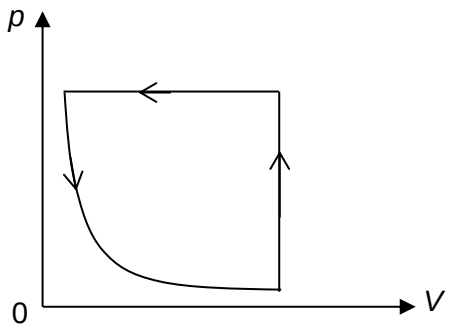
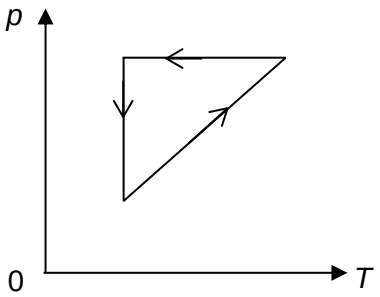
16 A fixed mass of ideal gas undergoes a thermodynamic cycle that comprises a constant pressure process, a constant temperature process and a constant volume process. The variation with volume V of pressure p of the ideal gas is shown.

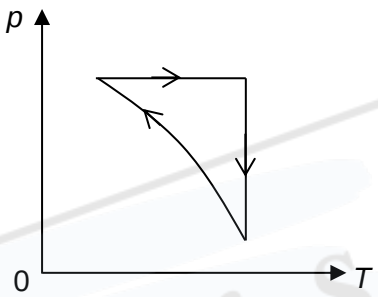


Which of the following shows the same cycle on a graph of pressure p against the thermodynamic temperature T?

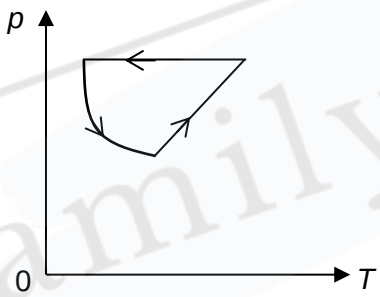
A



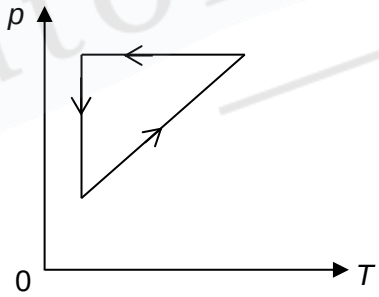
B



C



D



17 A 500 W electric kettle is used to boil water and is left on even after the water begins to boil. After 5 minutes, the temperature of its heating coil reaches a constant value.

When the first law of thermodynamics is used to quantitatively describe the heating coil after this time, which row correctly describes the application of the first law?

	rate of increase of internal energy / W	rate of heat supplied to the coil / W	rate of work done on the coil / W
A	+500	+500	0
B	+500	0	+500
C	0	+500	−500
D	0	−500	+500

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18 A point charge of $+Q$ is placed at X and a point charge of $-Q$ is placed at Y.

What happens to the electric force acting on an electron as it moves in a straight line from X to Y?

	magnitude of force	direction of force
A	decreases to a minimum at midpoint of XY and increases	always towards the left
B	decreases to a minimum at midpoint of XY and increases	always towards the right
C	increases to a maximum at midpoint of XY and decreases	always towards the left
D	increases to a maximum at midpoint of XY and decreases	always towards the right

19 An oil drop, carrying a charge of -3.2×10^{-19} C, is stationary in the region between two horizontal plates when the potential difference between the two plates is 5.0×10^{3} V. The separation of the plates is 16 mm.

What is the initial acceleration of the oil drop when the potential difference is decreased to 4.0×10^{3} V?

A 0.20 m s^{-2} **B** 2.0 m s^{-2} **C** 7.8 m s^{-2} **D** 18 m s^{-2}

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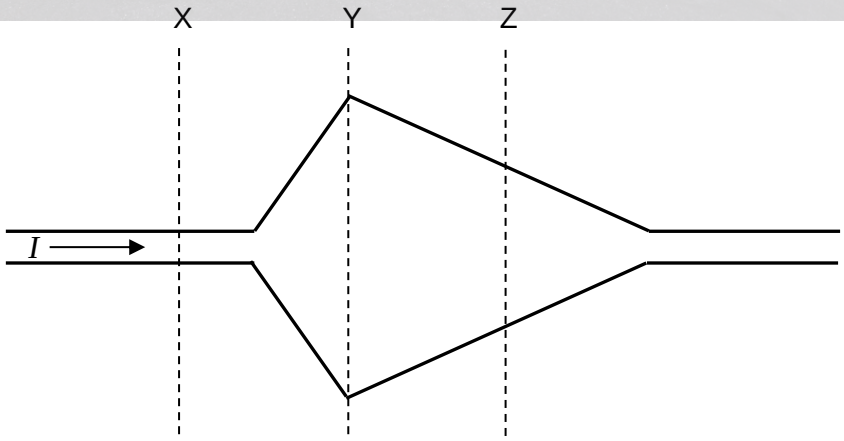
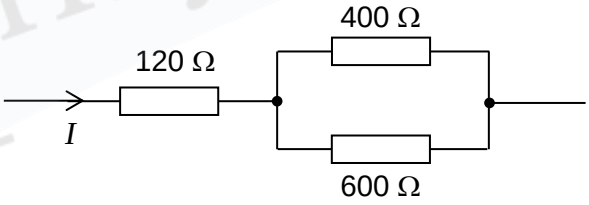
20 An electric current I in a flat metal specimen of uniform thickness and of the shape shown.



Which of the following correctly describes the magnitude of the current I and drift velocity v at sections X, Y and Z?

	I	v
A	$I_X = I_Y = I_Z$	$v_X = v_Y = v_Z$
B	$I_X = I_Y = I_Z$	$v_X > v_Z > v_Y$
C	$I_X > I_Z > I_Y$	$v_X = v_Y = v_Z$
D	$I_X > I_Z = I_Y$	$v_X > v_Z > v_Y$

21 Three resistors are arranged in a part of a circuit, and the resistance of each resistor is labelled as shown.



The current through the 120 Ω resistor is I.

What is the value of $\frac{\text{power dissipated in the 120 Ω resistor}}{\text{power dissipated in the 600 Ω resistor}}$?

A 0.20 **B** 0.50 **C** 1.3 **D** 5.0

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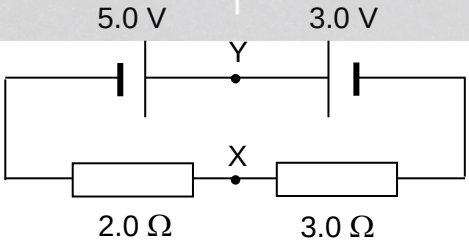
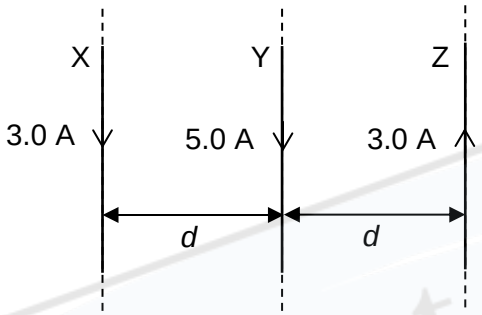
22 A circuit is connected as shown below. The internal resistance of each cell is negligible.



What is the potential difference between point X and point Y?

A 0.80 V **B** 1.2 V **C** 3.0 V **D** 4.2 V

23 Three long, parallel wires X, Y and Z carry currents of 3.0 A, 5.0 A and 3.0 A respectively in the directions shown. X and Z are at distance *d* from Y. Wire Y exerts a force per unit length of 8.0×10^{-6} N m^{-1} on wire Z.



What is the resultant force per unit length acting on wire X?

A 5.6×10^{-6} N m^{-1} to the right

B 5.6×10^{-6} N m^{-1} to the left

C 8.0×10^{-6} N m^{-1} to the right

D 8.0×10^{-6} N m^{-1} to the left

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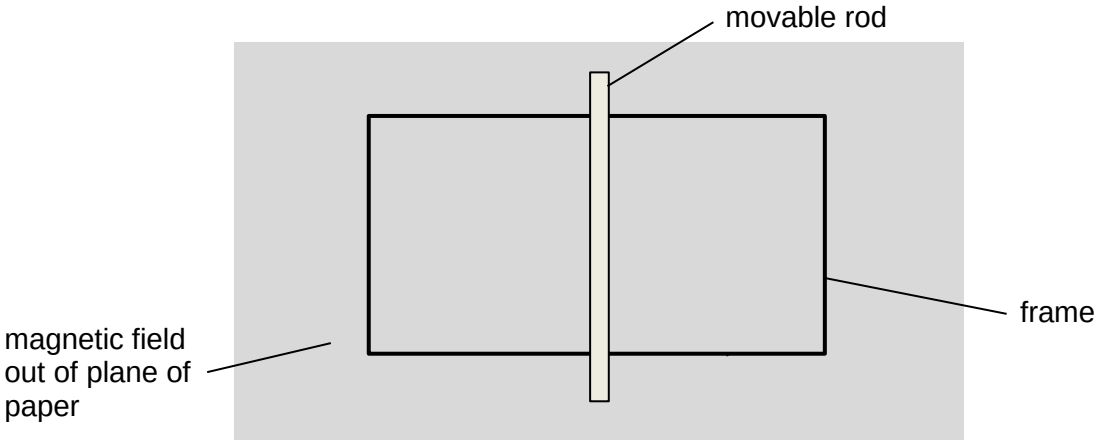
24 A movable metal rod is placed in the middle of a rectangular metal frame. A uniform magnetic field directed out of the plane of the paper acts perpendicular to the frame.



Which of the following actions will induce a clockwise current in the frame?

A Sliding the rod to the left while maintaining contact with the frame.

B Sliding the rod to the right while maintaining contact with the frame.

C Decreasing the magnitude of the magnetic flux density of the field.

D Increasing the magnitude of the magnetic flux density of the field.

25 In a region where the magnetic flux density of the Earth is 5.6×10^{-5} T, and directed at 72° to the horizontal, a ceiling fan with four horizontal blades rotates about a vertical axis at a frequency of 1.6 Hz. The length of each blade is 0.55 m.

What is the e.m.f. induced between the axle of the fan and the tips of the blades?

A 26 μV **B** 81 μV **C** 85 μV **D** 150 μV

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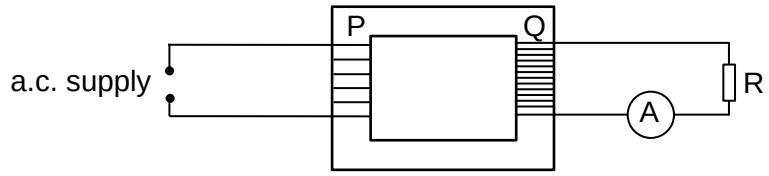
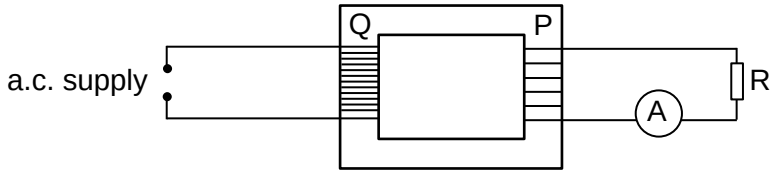
26 The diagram shows an ideal iron-cored transformer. The ratio of the number of turns of P to the number of turns of Q is 1:20.

P is connected to an a.c. supply and Q is connected to a resistor R. The reading on the ammeter is 2.0 A.



The transformer is turned around such that Q is now connected to the same a.c. supply and P is connected to R as shown below.



What is the new reading on the ammeter?

A 0.0050 A **B** 0.10 A **C** 2.0 A **D** 40 A

27 In an evacuated chamber, particles are accelerated from rest through a potential difference of the same magnitude.

Which of the following has the shortest de Broglie wavelength after the acceleration?

A proton ${}^{1}_{1}\mathrm{p}$

B electron ${}^{0}_{-1}\mathrm{e}$

C deuterium nucleus ${}^{2}_{1}\mathrm{H}$

D helium nucleus ${}^{4}_{2}\mathrm{He}$

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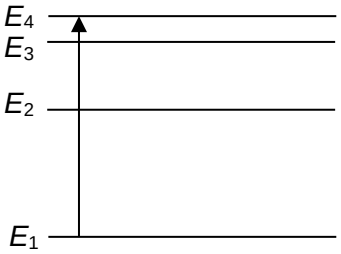
28 A beam of electrons of energy E excite atoms of element X from ground state E_1 to an excited state E_4 as shown.



element X

Photons emitted from element X interact with atoms of another element Y at their ground state. Three emission spectral lines are obtained from element Y.

The process is then repeated with atoms of element Y at ground state being excited by the same beam of electrons of energy E. Photons emitted from element Y now interact with atoms of element X at their ground state.

Which of the following is **not** a possible number of emission spectral lines obtained from element X following this interaction?

A 0 **B** 3 **C** 4 **D** 6

29 The rest mass of the deuteron, ${}^{2}_{1}\mathrm{H}$, is equivalent to an energy of 1876 MeV. The rest masses of a proton and a neutron are equivalent to 939 MeV and 940 MeV respectively.

Which of the following occurs when a deuteron disintegrates into a proton and neutron?

A The deuteron emits a γ-ray photon of energy 2 MeV.

B The deuteron captures a γ-ray photon of energy 2 MeV.

C The deuteron emits a γ-ray photon of energy 3 MeV.

D The deuteron captures a γ-ray photon of energy 3 MeV.

30 Which of the following illustrates the random nature of radioactive decay?

A Activity of a radioactive sample decreases with time.

B Fluctuations in the count rate from a radioactive sample.

C Activity of a radioactive sample does not change upon heating.

D Some isotopes of an element are radioactive while others are not.

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Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2023 Preliminary Examination

PHYSICS
Higher 2
Paper 2 Structured Questions

9749/02
September 2023
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen 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	/ 9
	2	/ 10
	3	/ 8
	4	/ 7
	5	/ 10
	6	/ 10
	7	/ 6
	8	/ 20
Deduction		
Total		/ 80

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

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Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi\times10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi))\times10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut+\frac{1}{2}at^2$
	v^2	=	u^2+2as
work done on / by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T / K	=	T / °C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0\sin\omega t$
velocity of particle in s.h.m.	v	=	$v_0\cos\omega t=\pm\omega\sqrt{x_0^2-x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1+R_2+\ \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots.$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0\sin\omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0\exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

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

1 Tarzan wants to get a coconut from a coconut tree by throwing a stone at the coconut to knock it down. The coconut is 18.0 m above the ground as shown in Fig. 1.1.

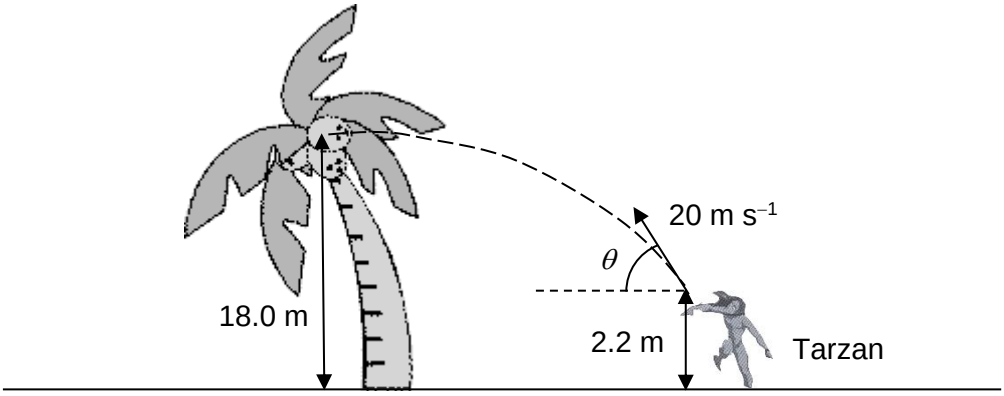

Fig. 1.1

Tarzan throws a stone such that it hits the coconut horizontally. The stone is projected with an initial speed of 20 m s^{-1} at 2.2 m above the ground. Air resistance is negligible.

(a) Determine the angle θ to the horizontal at which the stone has to be projected so that it will hit the coconut horizontally.

θ = ... ° [3]

(b) Determine the time taken for the stone to reach the coconut at this angle of projection.

time taken = ... s [2]

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(c) Hence, calculate the horizontal displacement from the coconut at which Tarzan should project the stone so that it hits the coconut horizontally.

horizontal displacement = ... m [2]

(d) If air resistance is not negligible, state and explain how the angle θ calculated in **(a)** and the horizontal displacement calculated in **(c)** should change so that the stone is still able to hit the coconut horizontally when the stone is projected with the same initial speed.

.....

.....

.....

..... [2]

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2 **(a)** Define *linear momentum*.

.....

.....

[1]

(b) Two particles A and B with masses $2m$ and m respectively, move at the same speed u towards each other along a horizontal line and collide elastically. Particle B moves vertically down after the collision and particle A is deflected through an angle θ as illustrated in Fig. 2.1.

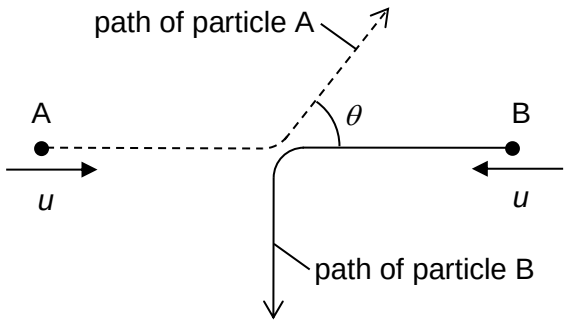

Fig. 2.1

(i) By considering the kinetic energies of both particles, show that:

$$3u^2 = 2v_A^2 + v_B^2$$

where v_A and v_B are the speeds after collision of particles A and B respectively.

[1]

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(ii) The value of m is 1.7×10^{-27} kg and the value of u is 3.5×10^{5} m s^{-1}.

1. By considering the momenta of both particles in the vertical and horizontal directions and using the equation in **(b)(i)**, determine v_B.

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

2. Hence, calculate the change in momentum of particle B due to the collision.

magnitude of change = ... kg m s^{-1}

direction of change = ... [3]

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(iii) The two particles are in contact for a time of 1.2 μs during collision.

Determine the average force exerted by particle B on particle A.

magnitude of average force = ... N

direction of average force = ... [2]

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

.....

.....

.....

..... [2]

(b) A uniform metre rule is pivoted at its centre as shown in Fig. 3.1.

The left end of the rule is suspended from a fixed point using a spring of force constant 21 N m^{-1}. A mass of 0.25 kg is hung from the same end of the rule using a string.

A block M is hung from the rule using a string at a distance of 30 cm from the pivot.

The rule is horizontal and the extension of the spring is 1.5 cm.

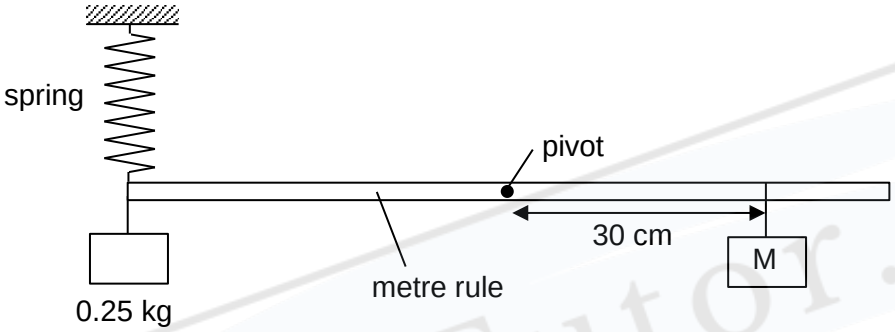

Fig. 3.1

(i) Show that the mass of block M is 0.36 kg.

[2]

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(ii) Block M is now shifted to the end of the rule as shown in Fig. 3.2.

To keep the rule horizontal, half of block M is submerged in a liquid of unknown density.

The density of block M is 8.9×10^3 kg m^{-3}.

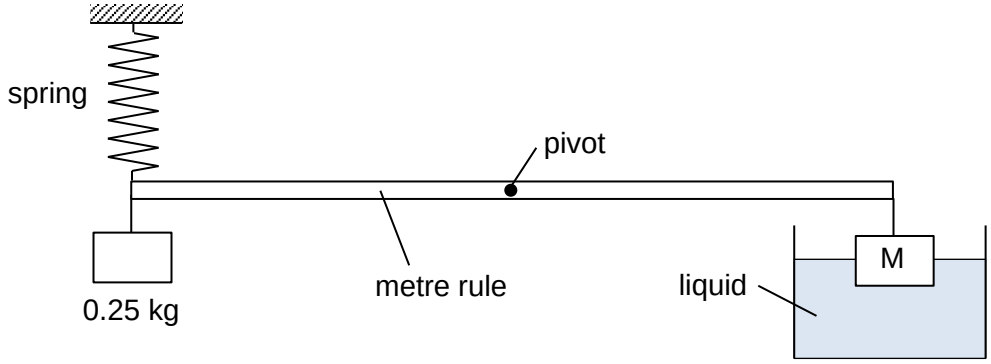

Fig. 3.2

Determine the density of the liquid.

density of liquid = ... kg m^{-3} [3]

(iii) Without further calculation, describe the equilibrium positions of the metre rule and block M when the spring in Fig. 3.2 is removed.

.....

..... [1]

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4 **(a)** State what is meant by a *longitudinal* wave.

.....

.....

.....

[1]

(b) Fig. 4.1 shows the equilibrium positions of 14 equally spaced air molecules, labelled 1 to 14, along a line AB. The separation between two adjacent equilibrium positions is 0.020 m.

When a point source of sound located on the left of A is switched on, a sinusoidal sound wave travels through the air at a speed of 343 m s^{-1}.

At time t = 0 s, air molecule 4 is at its maximum displacement towards the right from its equilibrium position, while air molecule 8 is the closest molecule that is at its maximum displacement towards the left.

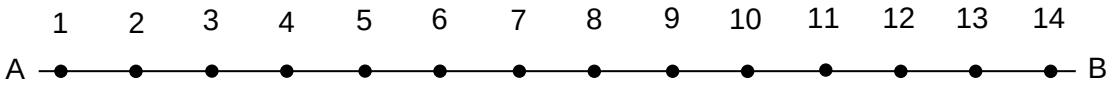

Fig. 4.1

(i) Determine, for the sound wave,

1. its wavelength

wavelength = ... m [1]

2. its frequency

frequency = ... Hz [1]

(ii) Label, on Fig. 4.1, with the letter C a point of compression, and the letter R a point of rarefaction.

[1]

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(iii) On the axes in Fig. 4.2, sketch the variation with time *t* of the displacement *y* of air molecule 9 for one period of the wave.

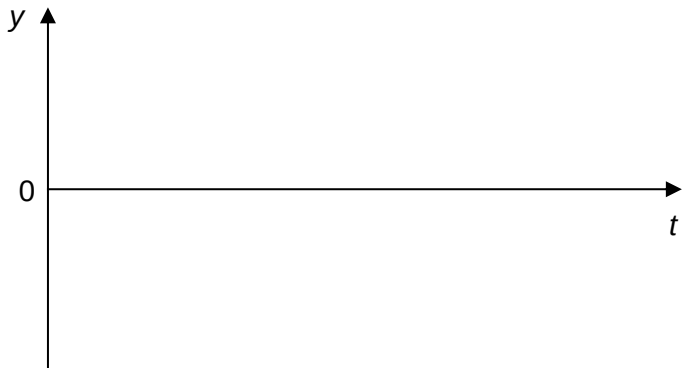

Fig. 4.2

[1]

(iv) The power of the source is *P*. The intensity of sound recorded by a small detector placed 0.25 m away from the source along AB is I. The detector is then shifted further away along AB until it records an intensity of ½ I.

Determine the distance moved by the detector.

distance = ... m [2]

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5 A cell of e.m.f. 6.0 V and internal resistance *r* is connected in series with a fixed resistor S and a variable resistor as shown in Fig. 5.1. Voltmeter X is connected across the cell while voltmeter Y is connected across the variable resistor.

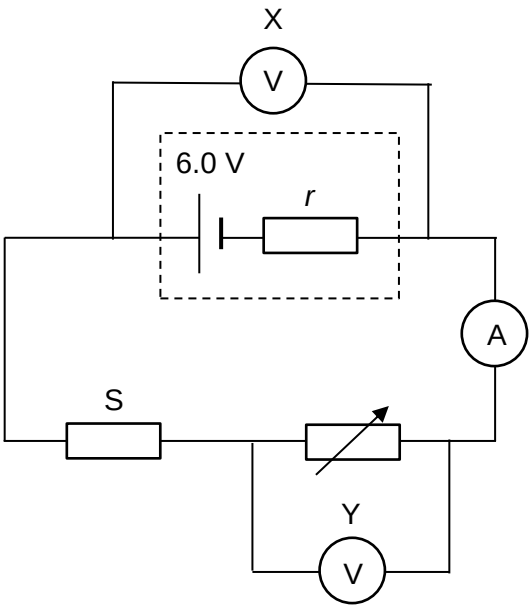

Fig. 5.1

(a) State what is meant by *resistance* of a resistor.

.....

..... [1]

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(b) The resistance of the variable resistor is varied and the variations of the readings V on voltmeters X and Y with the reading I on the ammeter are shown in Fig. 5.2.

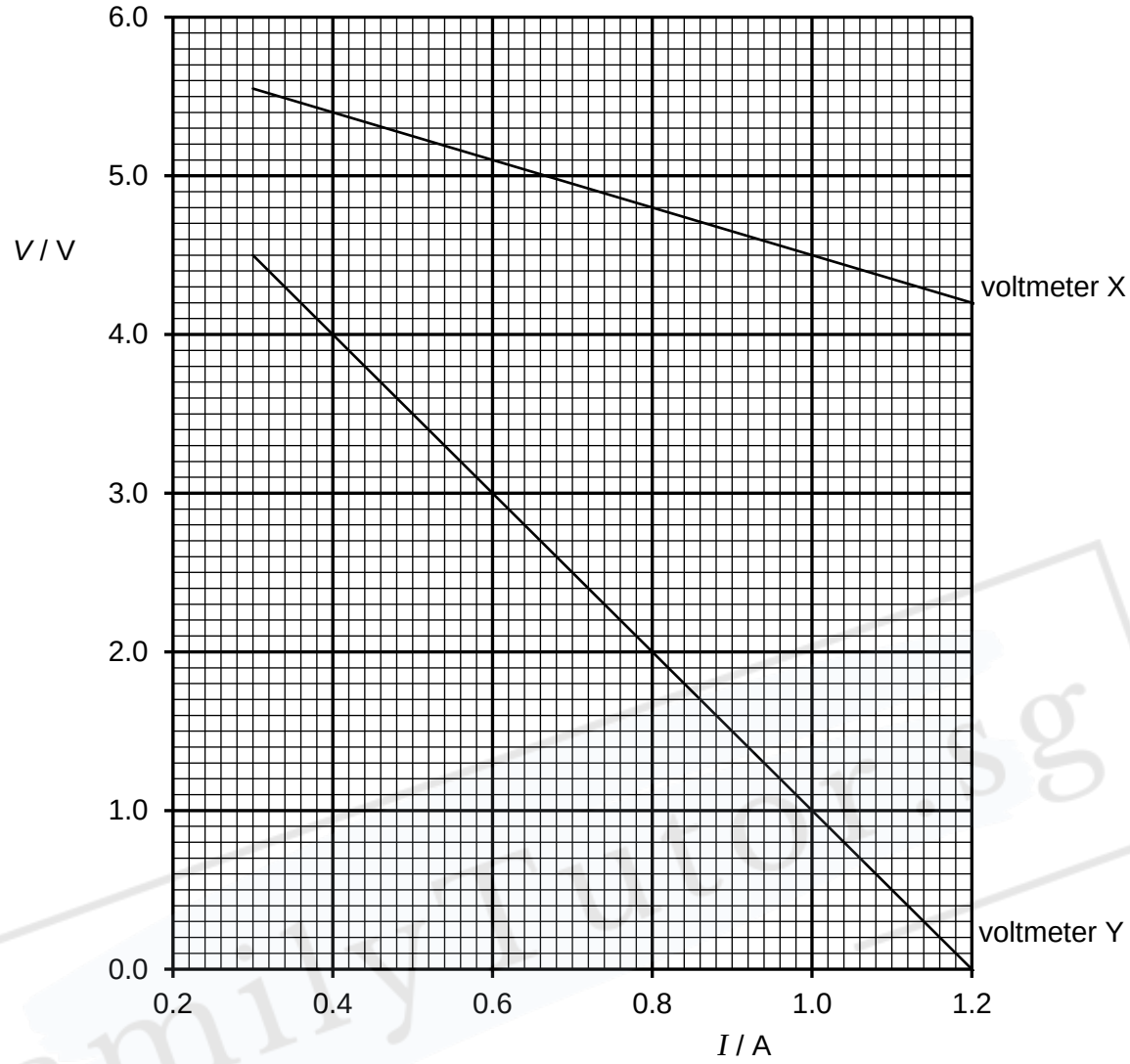

Fig. 5.2

(i) Determine the internal resistance r of the cell.

r = ... Ω [2]

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(ii) Show that the resistance of resistor S is 3.5 Ω.

[2]

(c) Explain why the current in the circuit cannot fall below 0.30 A.

.....

..... [1]

(d) The variable resistor is adjusted such that the reading on voltmeter X is 5.25 V.

Calculate the power dissipated in the variable resistor.

power = ... W [2]

(e) **(i)** On Fig. 5.2, draw a graph of the variation of the potential difference across resistor S with I.

Label this graph Z.

[1]

(ii) Hence or otherwise, state the value of I when the potential difference across resistor S and the potential difference across the variable resistor are equal.

I = ... A [1]

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6 **(a)** There are two situations in which a charged particle in a magnetic field does not experience a magnetic force.

State these two situations.

1. .....

.....

2. .....

..... [2]

(b) A beam of particles of charge $+3.2 \times 10^{-19}$ C travels in a vacuum at 4.7×10^{5} m s^{-1}. The particles enter a region of uniform magnetic field of flux density 0.12 T at an angle of 20° to the direction of magnetic field as shown in Fig. 6.1.

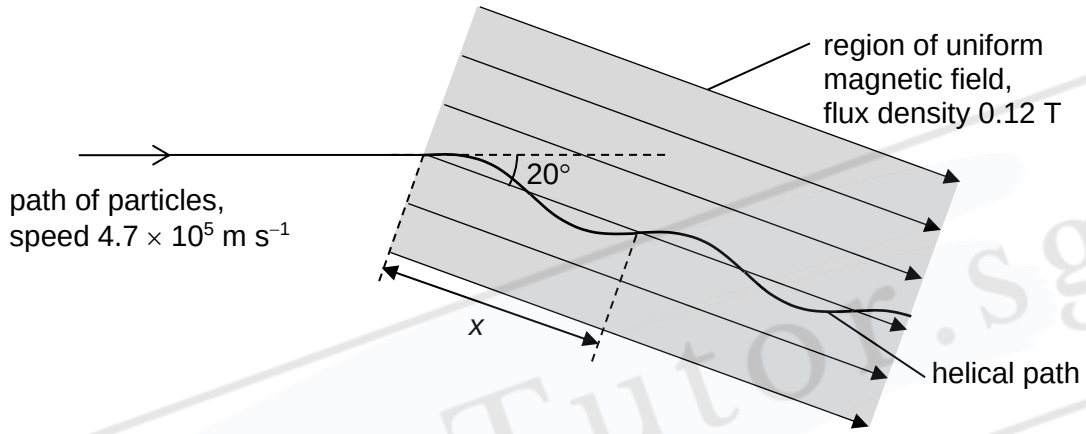

Fig. 6.1

The path of the particles in the magnetic field is a helix with a diameter of 5.6 cm.

In the time taken for the particles to complete one revolution in the helix, the particles travel a displacement *x* along the direction of the magnetic field.

(i) Calculate the component of the velocity of the particles in the direction normal to the magnetic field.

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

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(ii) Determine the mass of each particle.

mass = ... kg [2]

(iii) Determine the displacement *x*.

x = ... m [3]

(iv) Electrons with the same speed of 4.7×10^5 m s^{-1} enter the magnetic field at the same angle of 20°.

Without further calculation, state **two** differences between the path of the electrons and the path of the particles in the magnetic field.

1. .....

2. ..... [2]

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7 **(a)** The variation of the voltage V with time t of a periodic voltage source is shown in Fig. 7.1.

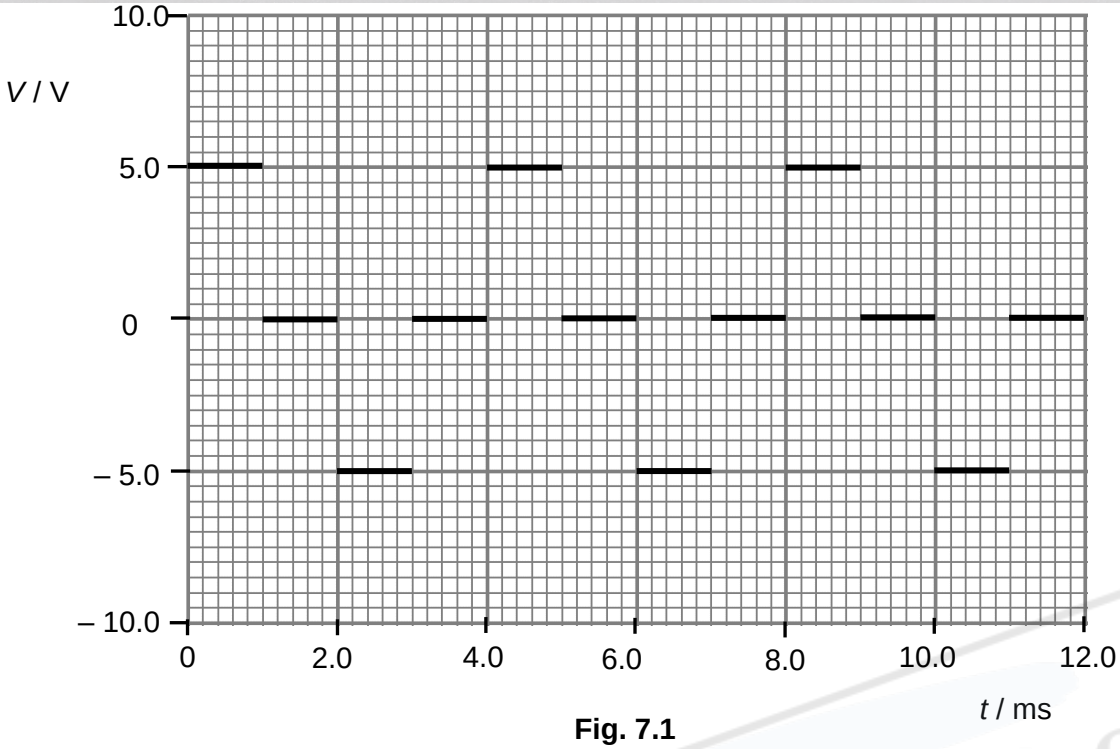

Fig. 7.1

The source is connected to an 8.0 Ω resistor and a diode as shown in Fig. 7.2.

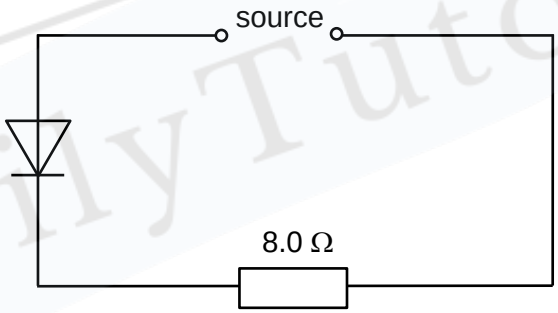

Fig. 7.2

(i) Determine the root-mean-square voltage across the resistor.

root-mean-square voltage = ... V [2]

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(ii) Determine the average power dissipated in the resistor.

average power = ... W [1]

(b) The voltage source in **(a)** is replaced by another voltage source represented by the equation:

$$V = V_0 \sin(\omega t)$$

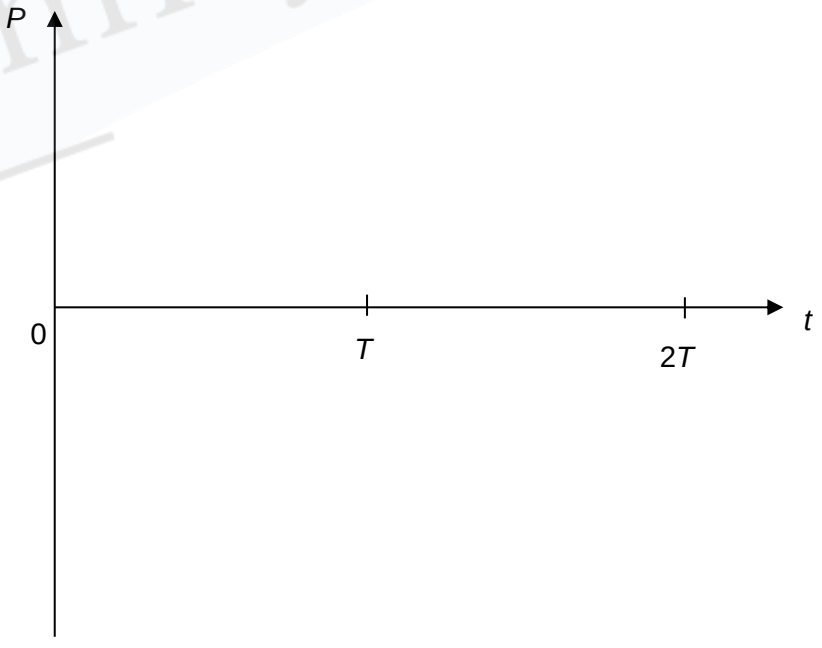
where ω and V_0 are constants, V is in volts and t is in seconds.

(i) The average power dissipated in the resistor using this source has the same value as **(a)(ii)**.

Determine the value of V_0.

V_0 = ... V [2]

(ii) The new voltage source has period T. Sketch the variation of the instantaneous power P dissipated in the resistor with time t for two periods of this new voltage source.



[1]

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

Modern train system

With the advancement in technology, the train system has greatly evolved over the years to meet the need for speed, ride comfort and lower maintenance cost.

One main consideration when designing the train system is for train vehicles to navigate curves at high speeds without derailing or toppling over. To achieve this, the outer side of the track of a railway may be raised. This is similar to the banking of roads for cars to turn around a bend at high speed without skidding.

Fig. 8.1 shows the cross section of a railway track that is tilted by an angle θ. The quantity cant E is used to indicate the amount of banking of the railway track. Cant is the difference in vertical height between the two rails of the track. Another important quantity is the rail gauge w which is the distance between the two rails.

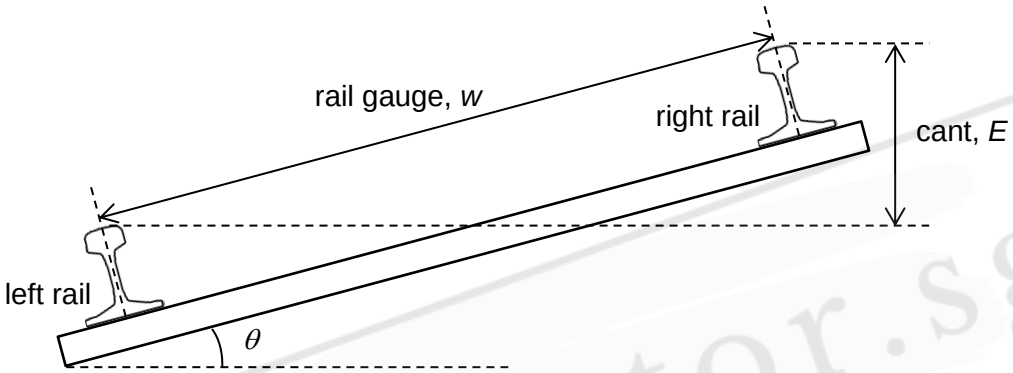

Fig. 8.1

When the train is on the track, the rails exert an effective contact force on the train.

For any banked track with cant E_0, the balance speed v_0 is the speed of the train such that this contact force is perpendicular to the bank.

However, trains do not always travel at the same speed. For example, compared to freight trains, passenger trains move at a higher speed and is usually higher than the balance speed.

At speeds above v_0, a larger cant E_v would be required to ensure that the contact force is perpendicular to the bank. The difference between the required cant E_v and actual cant E_0 is known as the cant deficiency, CD, where

$$CD = E_v - E_0$$

For example, a train moving on a track of cant E_0 = 120 mm has v_0 = 125 km h^{-1}.
When it moves at v = 140 km h^{-1} on the same track, the cant E_v required = 150 mm.
Hence,

$$CD = 150 \text{ mm} - 120 \text{ mm} = 30 \text{ mm}$$

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In every railway design, there is a maximum allowable cant deficiency CD_{max} to ensure that trains do not derail and skid outwards.

The CD_{max} for common railway systems in the world are shown in Fig. 8.2.

type of railway	rail gauge, w / mm	maximum allowable cant deficiency, CD_{max} / mm
A	1435	110
B	1524	125
C	1668	135

Fig. 8.2

(a) A train is turning on a banked track at balance speed v_0.

(i) Explain why the train has an acceleration despite moving at a constant speed.

.....

.....

[1]

(ii) With reference to Fig. 8.1, show that the angle θ is related to the cant E and rail gauge w by the expression

$$\tan\theta = \frac{E}{\sqrt{\left(w^2 - E^2\right)}}$$

[1]

(iii) Show that the balance speed v_0 for the train is

$$v_0 = \left(\frac{Erg}{\sqrt{w^2 - E^2}}\right)^{\frac{1}{2}}$$

where r is the radius of curvature of the track and g is the acceleration due to gravity.

[2]

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(b) A passenger train that runs on a type A railway system travels around a bend with a cant of 95 mm and a radius of curvature of 1500 m.

(i) Suggest why passenger trains travel at a higher speed compared to freight trains.

.....

.....

[1]

(ii) Using Fig. 8.2 and the equation in **(a)(iii)**, determine the maximum speed that the passenger train can travel.

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

(iii) A luggage bag of mass 19.6 kg sits on the train carriage when it is turning at 150 km h^{-1}. Fig. 8.3 shows the frictional force between the luggage bag and the carriage floor.

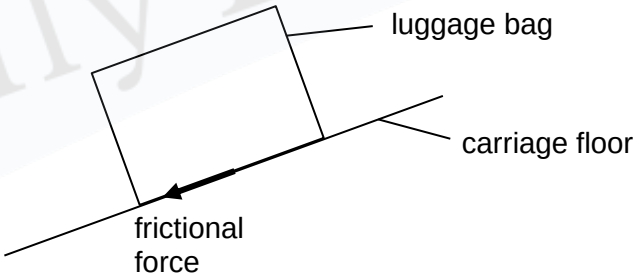

Fig. 8.3

1. On Fig. 8.3, draw and label arrows to show the other forces acting on the luggage bag.

[1]

2. Show that the centripetal force acting on the luggage bag is 23 N.

[1]

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3. Show that the carriage floor is tilted at an angle of 3.8° with the horizontal.

[1]

4. The maximum friction between the bag and the carriage floor is 20 N.

Determine whether the luggage will slide when the train is turning.

[4]

(c) Another safety consideration for a train going around a bend is to ensure that both train wheels are constantly in contact with the rails. Otherwise, the train might derail.

As the wheels on each side of the train are connected by an axle, they always rotate at the same angular speed when the train is moving. When the train goes around a bend, the outer rail traces a slightly longer arc length than the inner rail, as shown in Fig. 8.4.

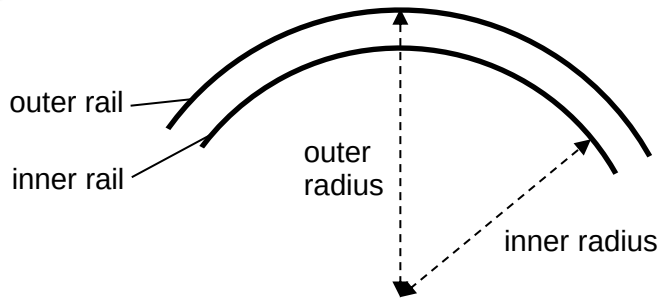

Fig. 8.4

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This creates a problem as the outer wheel needs to cover more distance than the inner wheel. To overcome this problem, train wheels are designed to be slightly conical. When the train turns, it will move outward such that the effective diameter of the outer wheel becomes D_o and the effective diameter of the inner wheel becomes D_i where $D_o > D_i$ as shown in Fig. 8.5.

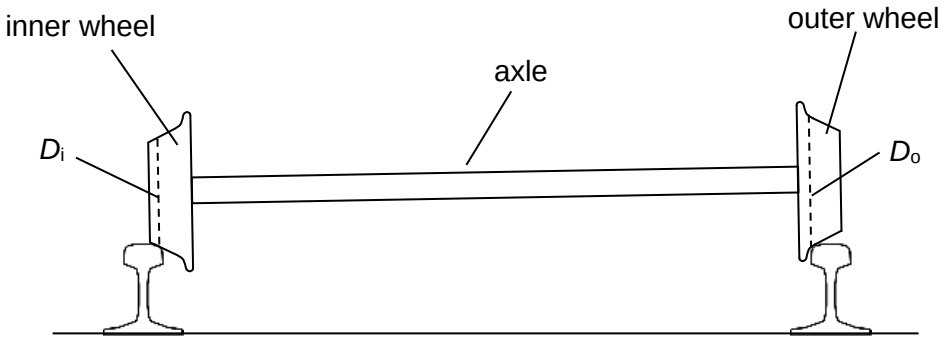

Fig. 8.5

(i) Explain how the conical shape of the wheels allows trains to stay in contact with the rails when going around a bend.

.....

..... [1]

(ii) On a particular bend along a type B railway on level ground, the inner rail has a radius of 200 m and D_i is 1150 mm.

Determine D_o for the train to stay on track while turning.

D_o = ... m [2]

(d) Generally, train systems can run on ground level, elevated or underground.

Suggest one advantage of a train system that runs

(i) on ground level

.....

..... [1]

(ii) underground.

.....

..... [1]

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Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2023 Preliminary Examination

PHYSICS
Higher 2
Paper 3 Longer Structured Questions

9749/03
September 2023
2 hours

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

READ THESE INSTRUCTIONS FIRST

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

You are advised to spend one and a half hours on Section A and half an hour on Section B.
The number of marks is given in brackets [ ] at the end of each question or part question.

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

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

This document consists of **16** printed pages.

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

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T / K	=	T / °C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots.$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

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Section A

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

1 **(a)** The angular velocity ω of a satellite in a circular orbit of radius r about the Earth is given by:

$$\omega = A r^{k}$$

where A and k are constants.

(i) Use Newton's law of gravitation to write an equation that relates the centripetal force on the satellite to the gravitational force acting on the satellite and determine the value of k.

k = ... [2]

(ii) A geostationary orbit has a radius of 42 000 km.

Determine the angular velocity of a satellite with an orbital radius of 6700 km.

angular velocity = ... rad s^{-1} [2]

(b) **(i)** By considering the potential energy and kinetic energy of the satellite, show that the total energy E_T of the satellite in a circular orbit of radius r about the Earth is given by:

$$E_T = -\frac{GMm}{2r}$$

where M and m are the masses of the Earth and the satellite respectively.

[2]

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[Turn over

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(ii) When a geostationary satellite is near the end of its useful life, it will be decommissioned and moved to a graveyard orbit. A graveyard orbit is an orbit that lies far away from common orbits used by satellites in service and its radius is at least 300 km more than that of the geostationary orbit.

The mass of the Earth is 6.0×10^{24} kg.

Determine the minimum energy needed to bring a geostationary satellite of mass 700 kg to a graveyard orbit from a geostationary orbit.

minimum energy = ... J [2]

(c) The Moon is the Earth's only natural satellite. Its orbital path is actually elliptical and not circular. Fig. 1.1 shows the orbit of the Moon about the Earth when viewed normal to the plane of the orbit of the Moon. There are points where the Moon is closer to the Earth and points when it is further from the Earth.

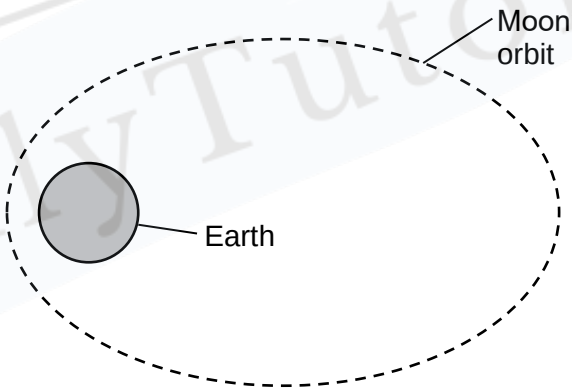

Fig. 1.1 (not to scale)

On Fig. 1.1, mark with a cross on the Moon's orbit where the Moon has the largest speed. Explain your answer.

.....

..... [1]

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2 In a particular combustion engine, a fixed amount of ideal gas undergoes a cycle of four stages as shown in Fig. 2.1.

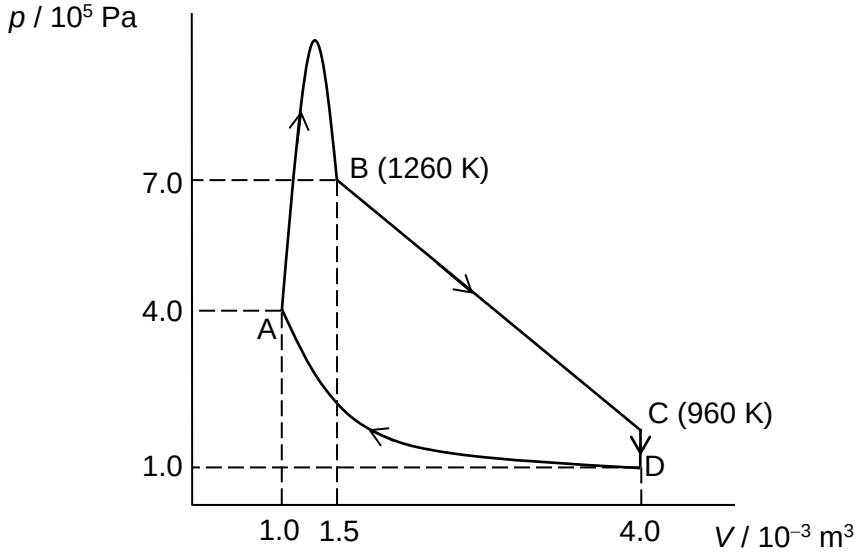

Fig. 2.1

Some values for the pressure p and volume V of the gas at the various states are labelled in the figure.

The four stages of the cycle are:

A → B: the gas gains 2625 J of heat through an explosion and the pressure rises rapidly before decreasing to 7.0×10^5 Pa at state B

B → C: the gas expands to state C

C → D: the gas cools to state D at constant volume

D → A: the gas is compressed at constant temperature to state A.

(a) The temperatures of the gas at states B and C are 1260 K and 960 K respectively.

(i) Determine the pressure of the gas at state C.

pressure = ... Pa [2]

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(ii) Hence, determine the magnitude of the work done by the gas in the stage B → C.

work done = ... J [2]

(b) The stage D → A is compression at constant temperature.

State **two** conditions under which the process in the engine is carried out such that it may be considered to be a constant temperature process.

1. .....

.....

2. .....

..... [2]

(c) Some energy changes during one cycle of the engine are shown in Fig. 2.2.

Complete Fig. 2.2.

stage	work done on gas / J	heat supplied to gas / J	increase in internal energy / J
A → B	–1000	2625	
B → C		500	
C → D			
D → A		–555	

Fig. 2.2

[3]

(d) In Fig. 2.1, the stage A → B is represented by a curve.

Explain why it may not be appropriate to represent the process with a curve on the graph.

.....

..... [1]

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3 Fig. 3.1 shows two slits S_1 and S_2, separated by distance a, illuminated by a point source of light producing coherent light of wavelength 750 nm. The light source is equidistant from both slits.

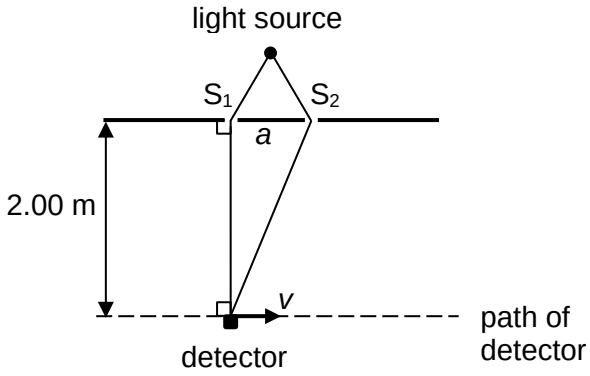

Fig. 3.1 (not to scale)

A light detector, 2.00 m below the slits, is moving to the right at a uniform speed v, in the direction shown.

(a) When the detector is directly below S_1, the detector records a minimum intensity reading.

Show that the minimum value for a is 1.22 mm.

[2]

(b) The slits are now fixed at 1.22 mm apart, with the light source still equidistant from both slits.

(i) The detector detects three maxima per second while moving to the right.

Determine the speed v at which the detector is moving.

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

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(ii) The light detector now moves with the same speed v along a diagonal path as shown in Fig. 3.2.

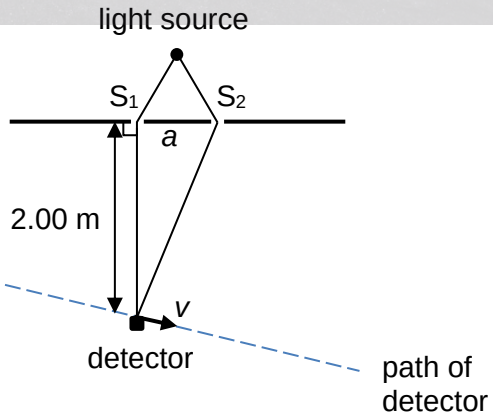

Fig. 3.2 (not to scale)

Describe and explain what happens to the frequency at which the detector detects maxima.

.....

.....

.....

..... [2]

(c) The detector is now replaced with a camera. The camera lens is at a distance R below the two slits and is equidistant from both slits.

The camera lens has an aperture diameter of 4.0 mm.

Determine the value of R where the images of both slits are just resolved.

R = ... m [2]

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4 **(a)** Define *electric potential* at a point.

.....

.....

.....

..... [2]

(b) A solid metal sphere A of radius 27 cm is fixed in a vacuum and carries a charge of +0.060 μC. The charge on the metal sphere may be considered as a point charge at its centre.

(i) Determine the electric potential V_R at the surface of the sphere.

V_R = ... V [1]

(ii) On the axes of Fig. 4.1, draw a graph to show the variation with distance x from the centre of sphere A of the electric potential V for x = 0 to x = 120 cm.

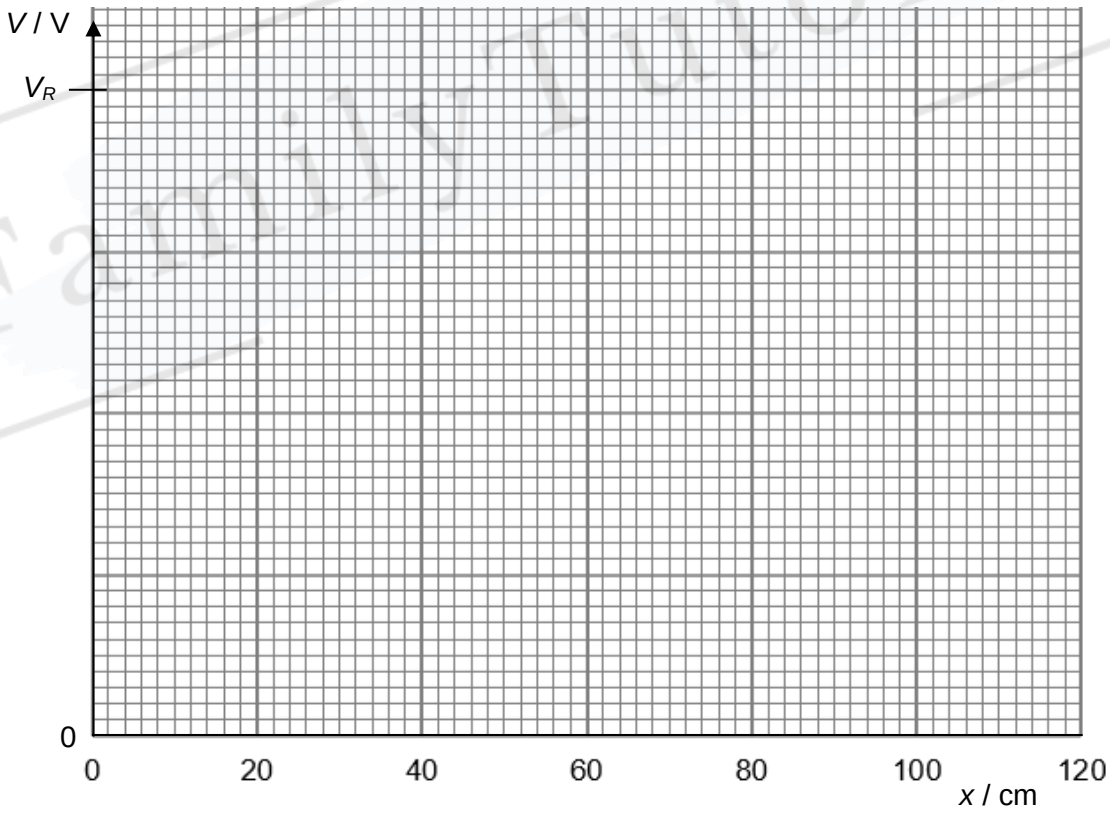

Fig. 4.1

[3]

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(iii) A charged particle B is placed at a distance 1.4 m from the centre of sphere A as shown in Fig. 4.2.

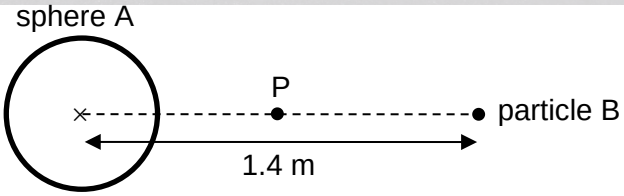

Fig. 4.2

Particle B carries a charge of −0.035 μC. Sphere A and particle B are fixed in position. Point P is the midpoint of the line joining the centre of the sphere and particle B.

Determine the magnitude of electric field strength at point P.

magnitude of electric field strength = ... N C^{-1} [2]

(iv) State and explain, in practice, whether the magnitude of the electric field strength at point P is greater than, smaller than or the same as your answer to **(b)(iii)**.

.....

.....

.....

..... [2]

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5 A cell of electromotive force (e.m.f.) 6.0 V and negligible internal resistance is connected to a resistor of 12 Ω, a resistor of 33 Ω, a resistor R and an ammeter as shown in Fig. 5.1.

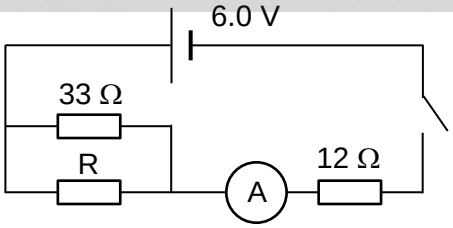

Fig. 5.1

When the switch is closed, the reading on the ammeter is 150 mA.

(a) Determine the charge *Q* that passes through the 12 Ω resistor in a time of 20 minutes.

Q = ... C [1]

(b) Calculate the potential difference across the 12 Ω resistor.

potential difference = ... V [1]

(c) Hence, determine the resistance of the resistor R.

resistance = ... Ω [3]

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(d) Resistor R is replaced by an NTC thermistor. Initially the resistance of the thermistor is 200 Ω. The switch is closed.

State and explain the change, if any, to the ammeter reading when the temperature of the thermistor increases.

.....

.....

.....

..... [2]

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6 A plane circular coil of radius 0.17 m has 30 turns and is placed with its plane horizontal in a vertical magnetic field of flux density *B* as shown in Fig. 6.1.

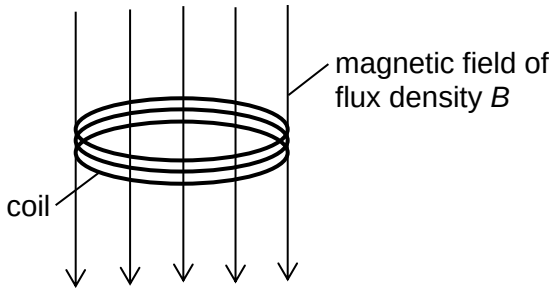

Fig. 6.1

Fig. 6.2 shows the variation with time *t* of the magnetic flux density *B*.

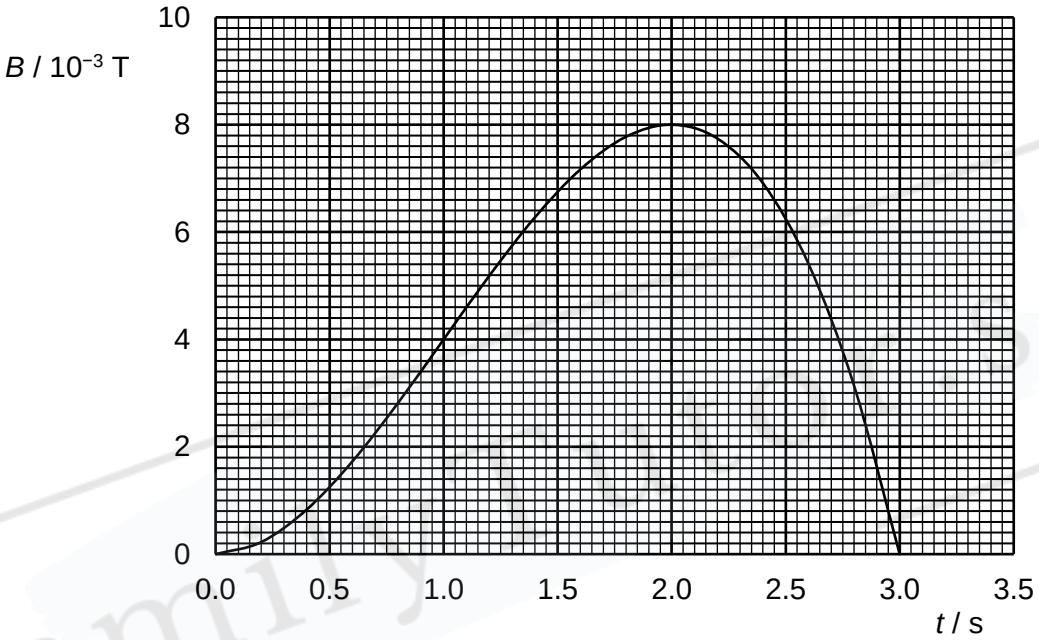

Fig. 6.2

(a) Calculate the maximum magnetic flux linkage of the coil.

maximum magnetic flux linkage = ... Wb [2]

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(b) Determine the maximum induced e.m.f. in the coil during the time interval t = 0 to t = 2.0 s.

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

(c) State and explain the direction of the induced current in the coil as viewed from the top for t = 0 to t = 2.0 s.

.....

.....

.....

..... [2]

(d) On the axes of Fig. 6.3, sketch the variation with time t of the induced e.m.f. in the coil from t = 0 to t = 3.0 s.

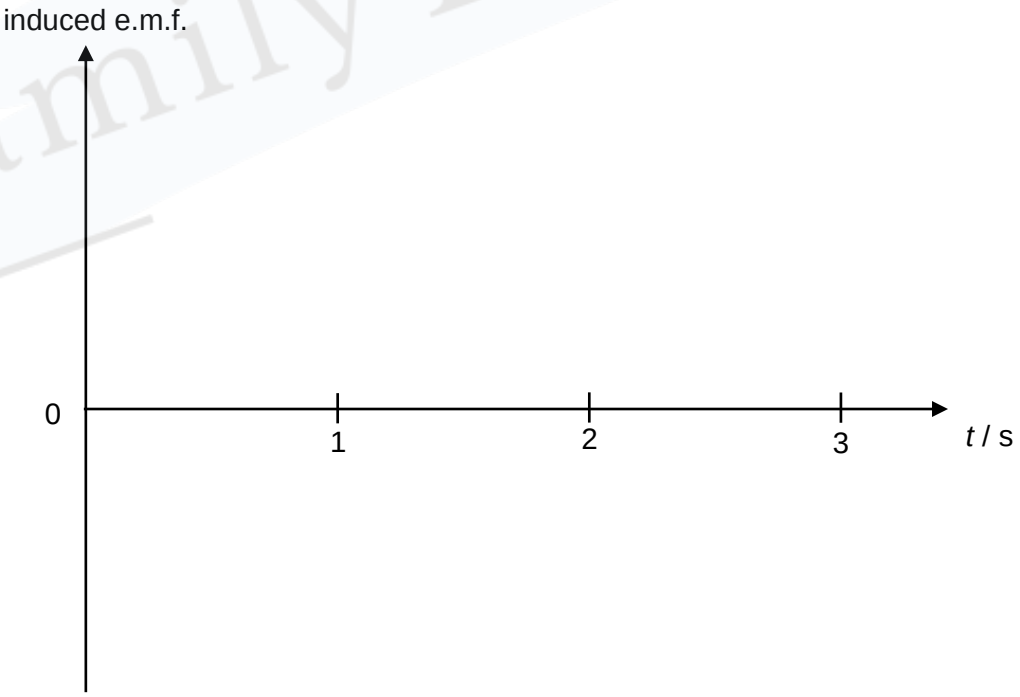

Fig. 6.3

[2]

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7 A circuit used to investigate the photoelectric effect is shown in Fig. 7.1.

Electromagnetic radiation of wavelength 450 nm is incident on metal plate A and the stopping potential is 1.1 V.

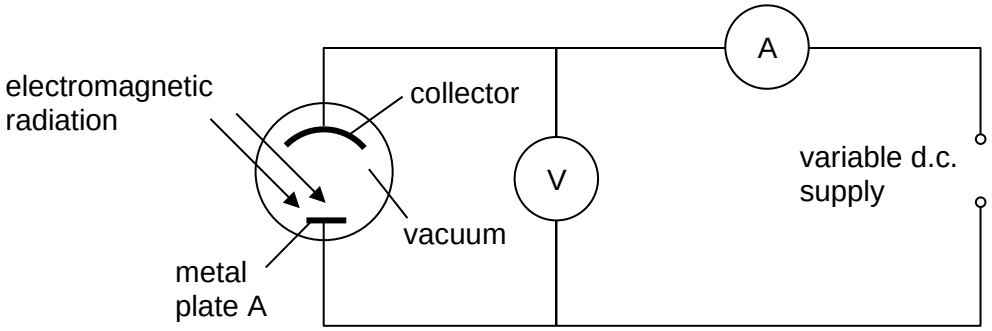

Fig. 7.1

(a) Calculate the maximum kinetic energy of the photoelectrons emitted from metal plate A.

maximum kinetic energy = ... J [2]

(b) Determine the threshold frequency of metal plate A.

threshold frequency = ... Hz [3]

(c) Explain whether maximum kinetic energy of the photoelectrons emitted from metal plate A is affected by the intensity of the electromagnetic radiation incident on the surface at constant frequency.

.....

..... [1]

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(d) The collector in Fig. 7.1 is replaced by metal plate B as shown in Fig. 7.2.

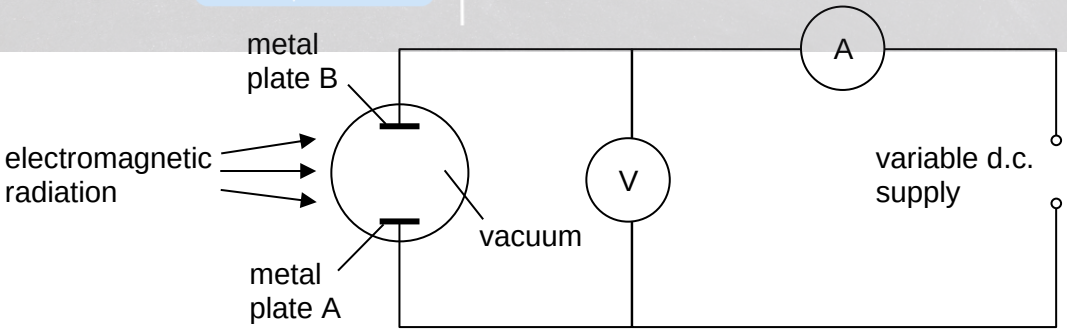

Fig. 7.2

Metal plate B has a higher threshold frequency than metal plate A.

The current-voltage (I – V) characteristic is obtained when both plates are illuminated with monochromatic electromagnetic radiation of frequency higher than the threshold frequencies of both plates.

On Fig. 7.3, sketch the I – V characteristic.

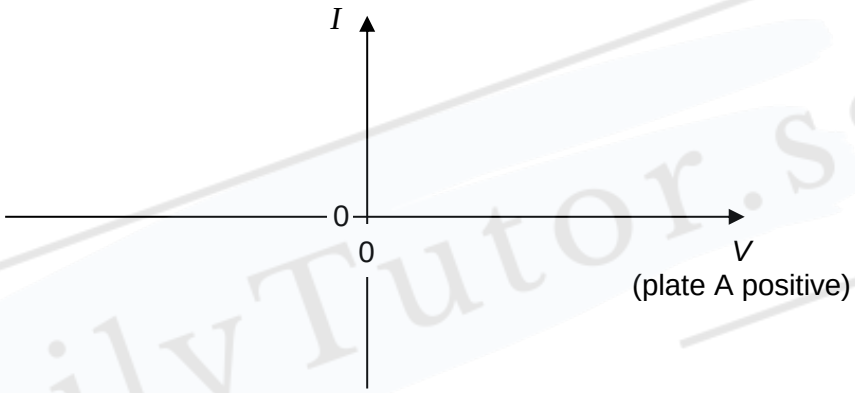

Fig. 7.3

[2]

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Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2023 Preliminary Examination

PHYSICS
Higher 2
Paper 3 Longer Structured Questions

9749/03
September 2023
2 hours

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

READ THESE INSTRUCTIONS FIRST

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

You are advised to spend one and a half hours on Section A and half an hour on Section B.
The number of marks is given in brackets [ ] at the end of each question or part question.

***This booklet only contains Section B.**

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

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This document consists of **9** printed pages.

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Section B

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

8 Fig. 8.1 shows block A of mass *m* at rest on a frictionless horizontal surface and connected to a mechanical oscillator through a horizontal light spring with spring constant *k*. The mechanical oscillator is fixed in position.

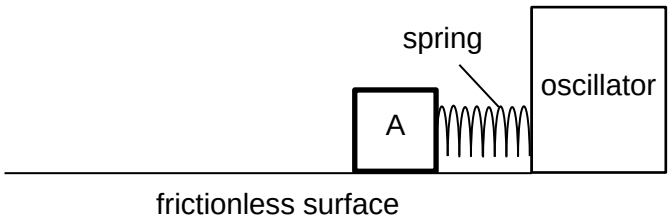

Fig. 8.1

(a) The mechanical oscillator is not switched on.
Block A is displaced from its original position along the axis of the spring and set into oscillation.

(i) For a displacement *x*, write down an expression for the force *F* exerted by the spring on block A.

.....

[1]

(ii) Use Newton's second law of motion to show that block A will oscillate with simple harmonic motion. Assume that air resistance on block A is negligible.

[2]

(iii) Show that the period *T* of the oscillations of block A is given by:

$$T = 2\pi\sqrt{\frac{m}{k}}.$$

[2]

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(b) Block A is now brought to rest at the equilibrium position. Block B of mass 18 g travels to the right with speed 5.3 m s^{-1} as shown in Fig. 8.2.

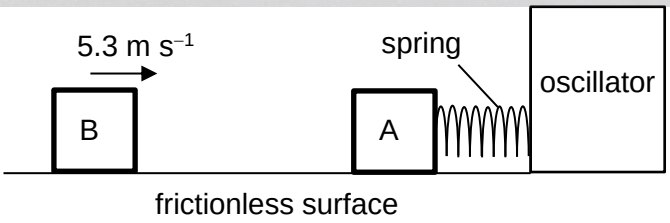

Fig. 8.2

The two blocks collide and stick together.
The mass of block A is 35 g and the force constant of the spring is 25 N m^{-1}.

(i) Determine:

1. the maximum compression of the spring

maximum compression = ... m [3]

2. the time it takes after the collision to reach this maximum compression.

time = ... s [2]

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(ii) On Fig. 8.3, sketch the variation with time t of the magnitude of the acceleration a of the blocks just after they collide to the time when the spring is at its maximum compression. Label the axes with appropriate values.

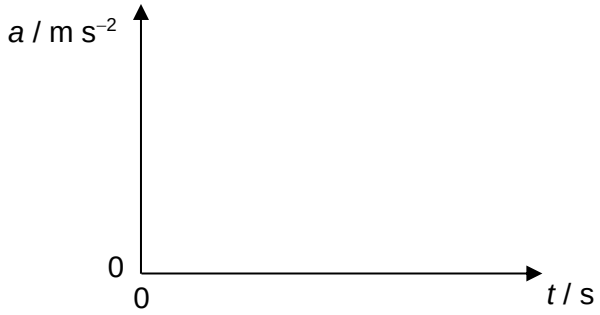

Fig. 8.3

[2]

(c) Block B is now placed on top of block A as shown in Fig. 8.4. Block A is again displaced from its original position and set into oscillation.

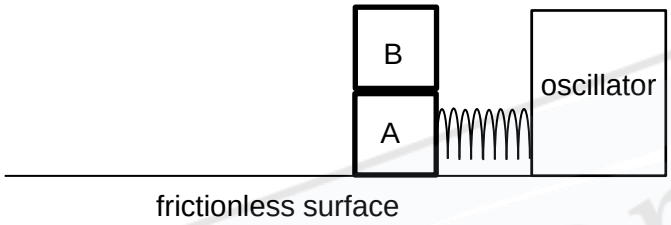

Fig. 8.4

(i) The maximum frictional force between the two blocks is 9.5×10^{-2} N.

Determine the maximum amplitude of oscillations x_0 such that block B remains stationary relative to block A.

x_0 = ... m [3]

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(ii) Block B is now attached to block A. The two blocks are set into oscillation by the mechanical oscillator such that both blocks move together. As the frequency *f* of the mechanical oscillator is varied, the amplitude is recorded.

1. It is observed that the amplitude becomes very large at a particular value of *f*.

Explain this phenomenon.

.....

.....

.....

..... [2]

2. On Fig. 8.5, sketch the variation of the amplitude with *f*.

Label the frequency axis with an appropriate value and label this line P.

Fig. 8.5

[2]

3. A sheet of cardboard of negligible mass is now fixed to the blocks to cause greater damping.

On Fig. 8.5, sketch the variation of the amplitude with *f* to show the effect of this change. Label this line Q.

[1]

[Total: 20]

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9 **(a)** The Rutherford alpha particle scattering experiment involved firing alpha particles at a thin gold foil. The experiment changed the existing model of the atom at that time.

State and explain the evidence from this experiment that changed the model of the atom in terms of its charge distribution and its mass distribution.

charge distribution .....

.....

.....

.....

mass distribution .....

.....

.....

..... [4]

(b) Plutonium-239 decays by α-emission spontaneously to form the isotope uranium-235. The half-life of plutonium-239 is significantly shorter than the half-life of uranium-235.

(i) Explain what is meant by *spontaneous* decay.

.....

..... [1]

(ii) Define the term *half-life*.

.....

..... [1]

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(iii) The nuclear decay is given by

$^{239}_{94}Pu \rightarrow {}^{235}_{92}U + {}^{4}_{2}He$.

Data for the nuclei in the decay are given in Fig. 9.1.

nucleus	mass / u
plutonium $^{239}_{94}Pu$	239.052163
uranium $^{235}_{92}U$	235.043930
helium $^{4}_{2}He$	4.003860

Fig. 9.1

1. Show that the energy released in this decay is 4.08 MeV.

[2]

2. The plutonium-239 nucleus was at rest before the decay.

Calculate the speed of the uranium-235 nucleus.

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

(iv) Explain why an alpha radiation source poses little danger to humans unless it is ingested or inhaled.

.....

..... [1]

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(c) A sample of pure plutonium-239 has N nuclei and an activity of A at time t. The variation with time t of ln A is shown in Fig. 9.2.

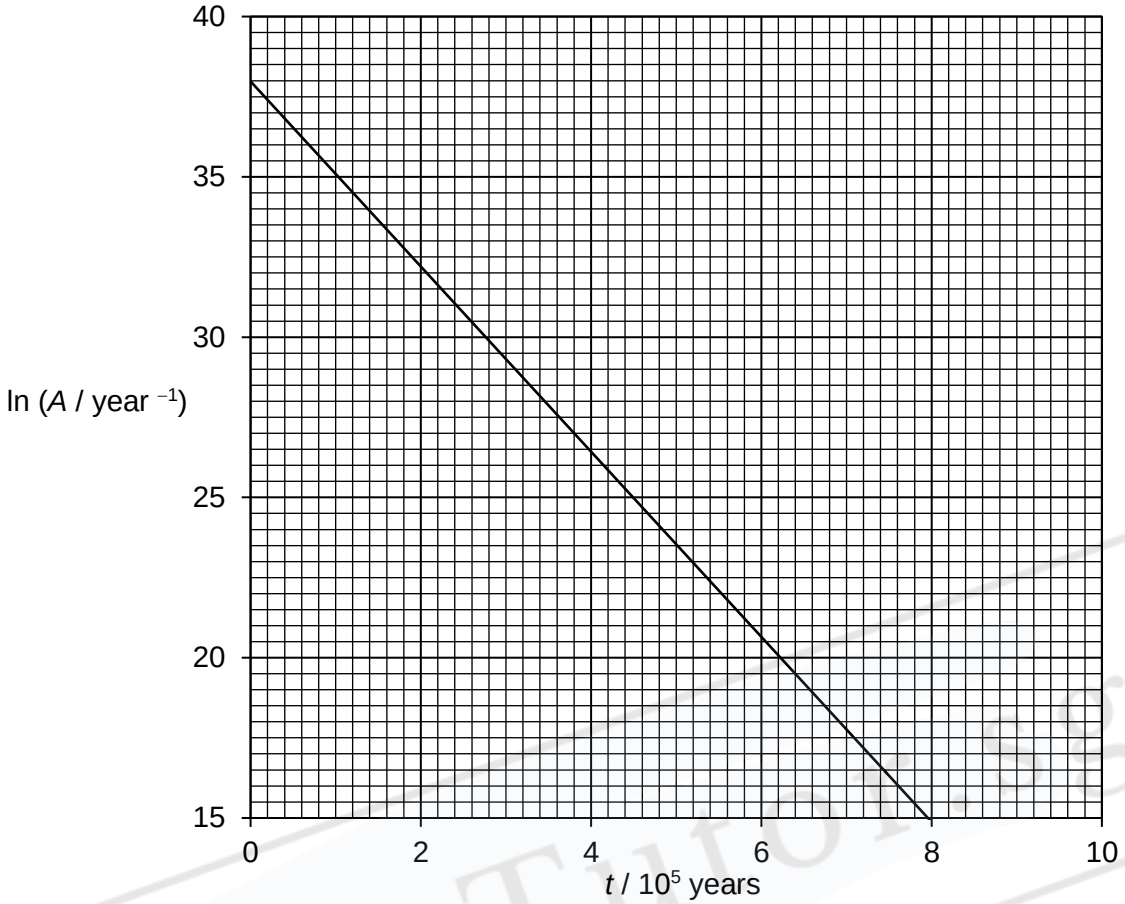

Fig. 9.2

(i) Explain why the activity decreases with time.

.....

..... [1]

(ii) Determine the half-life of plutonium-239.

half-life = ... years [3]

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(iii) Determine the initial number N_0 of plutonium-239 nuclei in the sample.

N_0 = ... [2]

(d) The activity of another pure sample of radioactive nuclei X is examined. The half-life of X is 0.5 times the half-life of plutonium-239.

At t = 0, the sample of X has the same number of nuclei N_0 as the sample of plutonium-239 in **(c)**.

On Fig. 9.2, draw the graph to show the variation with time t of ln A for this sample of X. [2]

[Total: 20]

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TEST QUESTIONS AND ANSWER KEYS

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Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

PHYSICS **9749/01**
Paper 1 Multiple Choice 15 September 2023
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 index number on the Answer Sheet provided.

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

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

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Data

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

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\,\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}<c^2>$
mean 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	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{½}}$

[Turn over

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1 The derived unit for which of the following quantities can be expressed in four different SI base units?

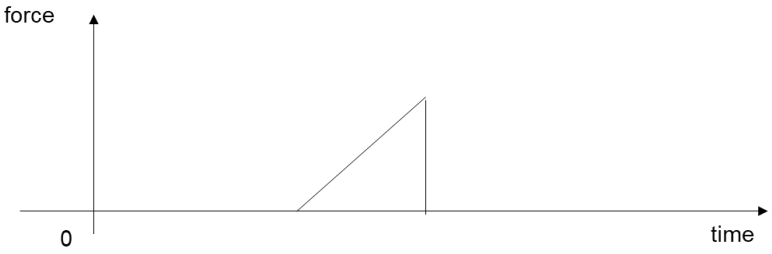
A electromotive force

B momentum

C magnetic flux density

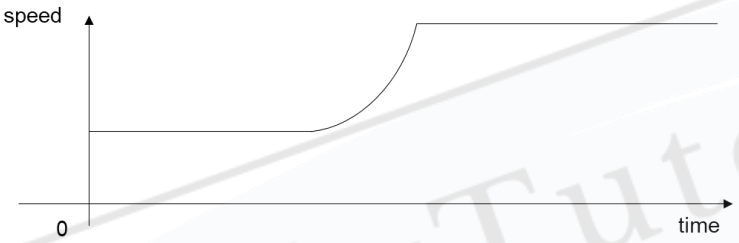
D power

2 A block initially moving on a smooth surface at constant speed, experiences a force that varies with time as shown.



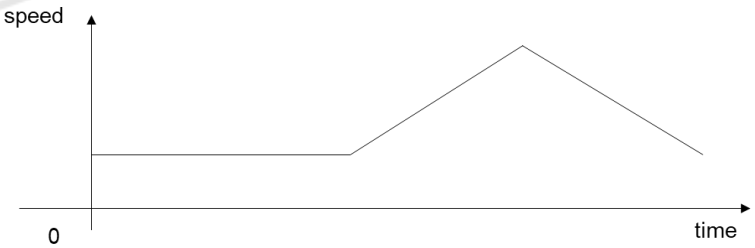
Which graph represents the variation with time of the speed of the block?

A

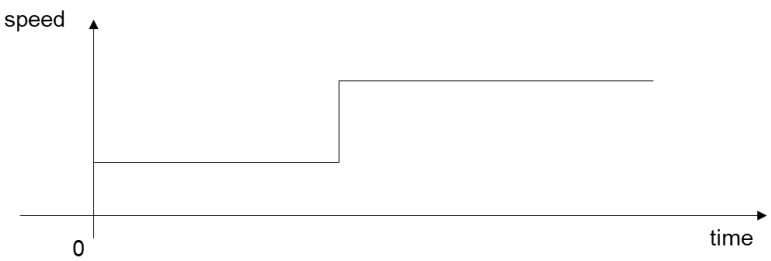


B

C



D



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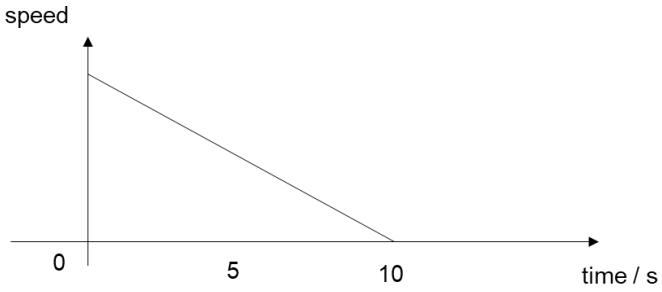
3 A drone descends from a height for 10 s. The variation with time of the vertical speed of the drone is shown.



What is the ratio $\frac{\text{distance travelled between 0 s to 10 s}}{\text{distance travelled between 0 s to 5 s}}$?

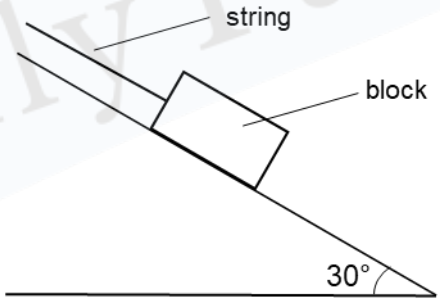
A 1.2 **B** 1.3 **C** 1.5 **D** 1.8

4 A 3.0 kg block is moving on a smooth surface with a speed of 2.0 m s^{-1}. A constant force of 1.5 N is exerted on the block over 2.0 s in a fixed direction.

Which of the following cannot be the magnitude of its final speed?

A 0.5 m s^{-1} **B** 1.0 m s^{-1} **C** 2.0 m s^{-1} **D** 3.0 m s^{-1}

5 A 5.0 kg block is placed on a rough slope inclined at an angle of 30° to the horizontal with a string attached to it as shown below.



The tension in the string is 2.0 N and the frictional force exerted by the slope is 3.0 N.

What is the magnitude of the acceleration of the block?

A 3.9 m s^{-2} **B** 5.1 m s^{-2} **C** 5.9 m s^{-2} **D** 7.5 m s^{-2}

[Turn over

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6 Diagram 1 shows two forces F acting on a circular disc of radius r. The disc is pivoted at a fixed point O which is the center of the disc. The forces give rise to a net moment M.

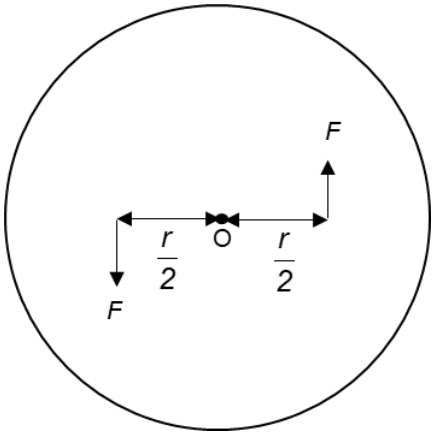

Diagram 1

In diagram 2, the lines of action of forces are moved to new points.

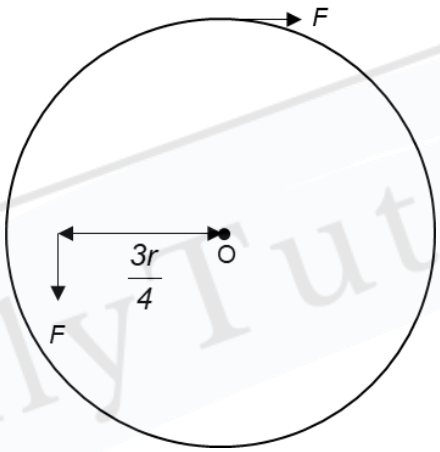

Diagram 2

What is the net moment now?

	magnitude	direction
A	$\frac{M}{4}$	anti-clockwise
B	$\frac{M}{4}$	clockwise
C	$\frac{4}{3}M$	anti-clockwise
D	$\frac{4}{3}M$	clockwise

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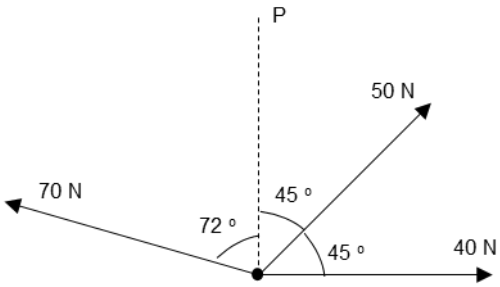
7 Three forces act on a body in various directions shown below.



An additional force will be required for the system to be at equilibrium.

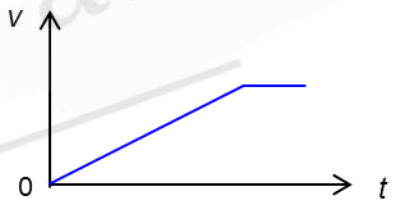
What is the magnitude and direction of the additional force measured from line P?

	force	direction
A	57.7 N	9 °
B	57.7 N	189 °
C	153 N	68 °
D	153 N	248 °

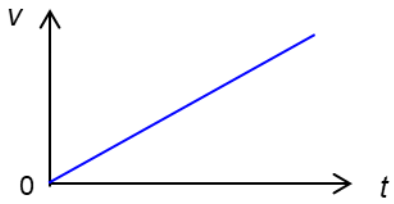
8 A motor with a constant output power pulls a wooden block vertically upwards from rest.

Which of the following graphs best represents the variation with time *t* of the speed *v* of the block?

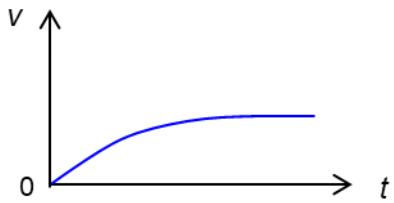
A



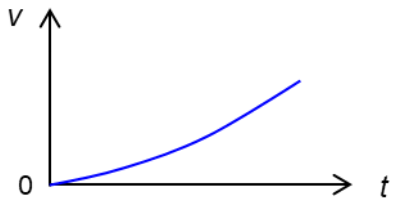
B



C



D



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9 Three identical slotted masses are placed at 2*R*, 4*R* and 6*R* respectively from the centre of a horizontal rough disc of radius 10*R*.

The disc rotates about its centre O.

Which statement is correct?

A All three slotted masses experience the same centripetal force.

B The slotted mass at 6*R* is most likely to move out of its circular path.

C The slotted mass at 2*R* completes the least number of revolutions per unit time.

D The slotted mass at 6*R* has three times the amount of kinetic energy as the slotted mass at 2*R*.

10 A binary star consists of two stars A and B. The two stars may be considered to be isolated in space. The centre of the two stars are separated by a constant distance *d*.

Star A, of mass M_A has a smaller mass than star B of mass M_B, such that $\frac{M_A}{M_B} = 0.2$.

The stars are in circular orbits about each other such that the centre of their orbits is at a fixed point with orbital period *T*.

Which row is correct?

	orbital radius of star A	magnitude of gravitational force on star B
A	$\frac{5}{6}d$	$\frac{10\pi^2 dM_A}{3T^2}$
B	$\frac{5}{6}d$	$\frac{10\pi^2 dM_B}{3T^2}$
C	d	$\frac{10\pi^2 dM_A}{3T^2}$
D	d	$\frac{10\pi^2 dM_B}{3T^2}$

11 The mean distance of the planet Saturn from the Sun is 9.5 times that of the mean distance of the Earth from the Sun.

How long does it take Saturn to orbit the Sun?

A 4.5 years

B 29 years

C 90 years

D 860 years

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12 A small ice cube of mass 30 g is heated. It changes from the solid state to the liquid state. During this change in state, the temperature of the substance does not change.

Which statement about this change in state is not correct?

A The internal energy of the molecules remains the same.

B The kinetic energy of the molecules remains the same.

C There is positive work done on the system as the ice melts.

D The amount of energy the ice absorbs is not equal to the specific latent heat of fusion.

13 Planet Z has a mass 6.4×10^{23} kg and a diameter of 6.8×10^{3} km.

Assuming helium-4 to be an ideal gas, what is the minimum temperature of the helium-4 gas for it to be able to escape from the surface of Planet Z?

A 2.0×10^{3} K

B 2.1×10^{3} K

C 4.0×10^{3} K

D 4.1×10^{3} K

14 An ideal gas is held in a constant volume container fitted with a valve through which gas can escape.

Starting at 150 K, the temperature of the gas is raised by 900 K while its pressure in the container is raised from P to $2P$. This results in a fraction of the original number of gas molecules escaping through the valve.

What is the pressure in the container after the gas is cooled back to its starting temperature?

A 0.29 P **B** 0.33 P **C** 0.50 P **D** P

15 A wooden block is floating on a body of highly viscous liquid. When the block is displaced vertically downwards by a small displacement and released, it is observed to oscillate a few complete cycles before coming to a complete rest.

What degree of damping does the block experienced when it is oscillating?

A Critical damping.

B Heavy damping.

C Light damping.

D No damping.

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16 An external oscillator is attached to the top of a vertical spring mass system.

Which statement about the forced oscillation is always true?

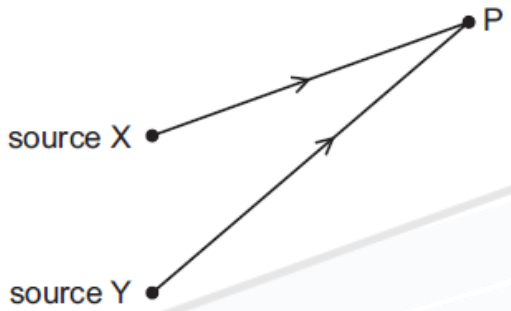
A The amplitude of the spring mass system will increase as the frequency of the oscillator increases.

B The amplitude of the spring mass system will not be affected by the amplitude of the oscillator.

C The spring mass system will always oscillate at its natural frequency.

D The spring mass system will always oscillate at the frequency of the oscillator.

17 Two identical water waves travel from two sources X and Y to meet at point P. The frequency of the waves is 0.40 Hz and the sources are in phase.



Waves from source X take 3.0 s to arrive at P, while waves from source Y take 3.5 s to arrive at P.

What is the phase difference, in radians, between the two waves at P?

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

18 A narrow beam of monochromatic light falls on a diffraction grating at normal incidence. The second order diffracted beam occurs at an angle of 31° to the normal.

What is the total number of intensity maxima from the grating that can be observed?

A 3 **B** 4 **C** 7 **D** 9

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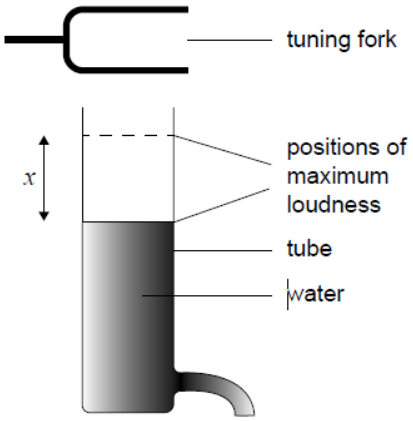
19 Water flows out from a vertical tube that was initially full. A vibrating tuning fork is held near the top of the tube.

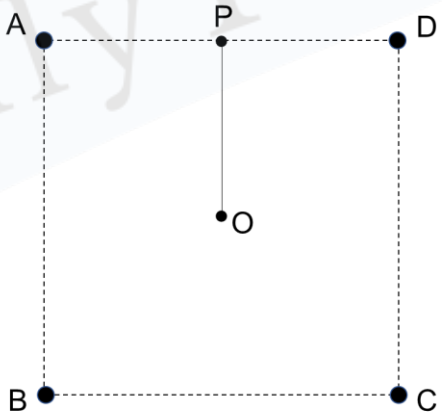


The distance between the two consecutive positions when the sound is at maximum loudness is x.

What is the wavelength of the sound emitted by the tuning fork?

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

20 Four point charges are at the corners of a square ABCD. The point charges A and B are negatively charged and the point charges C and D are positively charged. The magnitude of the charges are the same. A proton is brought from point P to point O in a straight line by an external force without any change in speed.



Which row about the change in electric potential energy of the system and the work done by the external force is correct?

	change in electric potential energy	work done by the external force
A	increase	positive
B	increase	negative
C	decrease	negative
D	no change	zero

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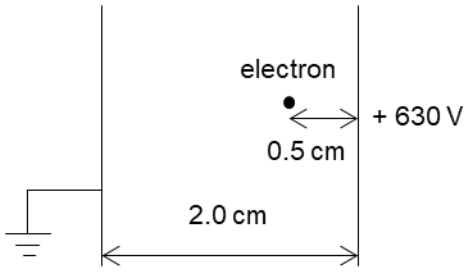
21 A pair of parallel plates placed 2.0 cm apart is shown below. One of the plates is charged positively and the other is earthed. An electron is placed at a distance 0.5 cm away from the positive plate as shown in the diagram.



What is the force on the electron by the electric field?

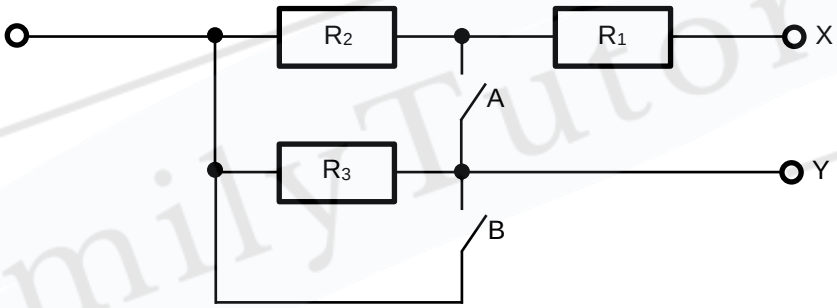
A 2.0×10^{-18} N

B 7.6×10^{-17} N

C 1.0×10^{-16} N

D 5.0×10^{-15} N

22 A circuit consists of three resistors R_1, R_2 and R_3, and two switches A and B, as shown in the figure.



The resistance between the terminals X and Y is measured for different settings of the switches A and B.

The results are shown in the table.

switch A	switch B	resistance between X and Y / kΩ
open	open	24
open	closed	20
closed	open	12
closed	closed	12

What is the ratio of the $\frac{\text{resistance of } R_1}{\text{resistance of } R_3}$?

A 0.33 **B** 0.50 **C** 1.0 **D** 3.0

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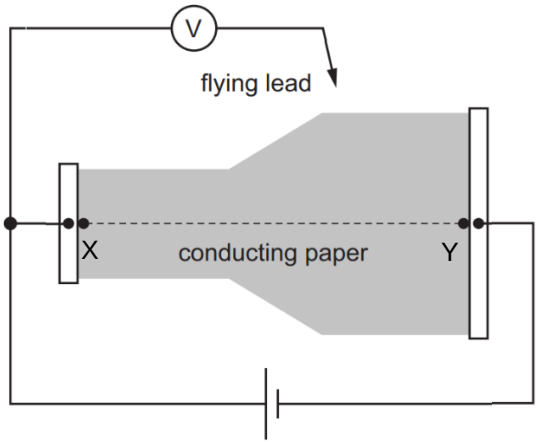
23 A sheet of conducting paper of uniform thickness is cut to the shape shown and a battery is connected to each end by aluminium strips. A high resistance voltmeter is also connected as shown.

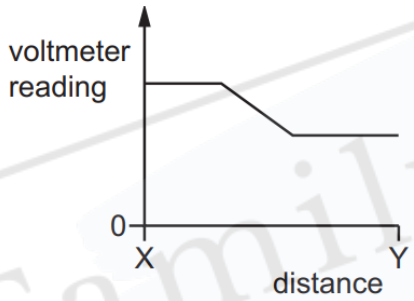


The flying lead of the voltmeter is placed in contact with the conducting surface at X and the reading is noted. This is repeated for a large number of points along the line XY, ending at point Y.

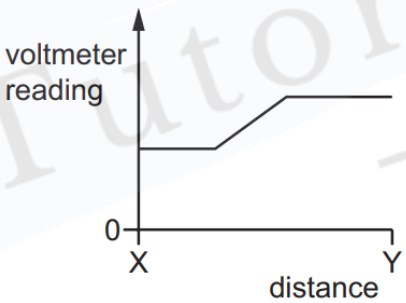
The readings are plotted on a graph of voltmeter reading against distance from X.

Which diagram shows the correct shape of the graph?

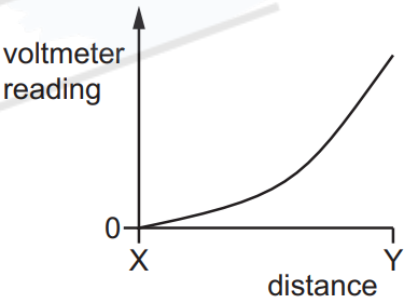
A



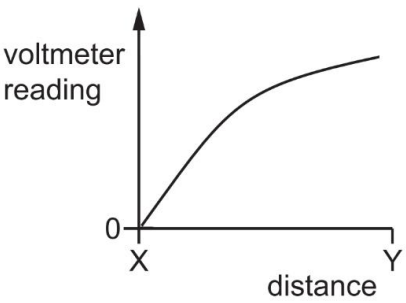
B



C



D



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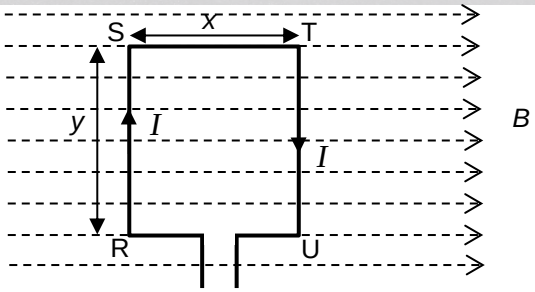
24 A rectangular wire loop RSTU with sides of length *x* and *y* carries a current I. A magnetic field of flux density *B* lies in the plane of the coil as shown.



Which statement is correct?

A The force on side ST is BIx.

B The moment on the loop is $BIxy$.

C There is a net force perpendicular to the magnetic field.

D There is no force acting on the wire loop.

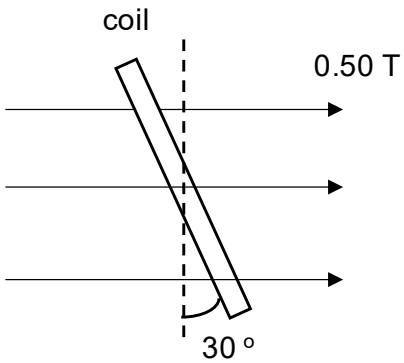
25 When an alternating current, $I = I_0 \cos \omega t$, passes through a resistor, the mean power dissipated in the resistor is *P*.

The peak value of the alternating current is then reduced by half and the current is passed through a diode.

What is the mean power dissipated in the resistor in terms of *P*?

A $\frac{P}{8}$ **B** $\frac{P}{4}$ **C** $\frac{P}{2}$ **D** P

26 A uniform magnetic field of flux density 0.50 T passes through a coil of area 20 cm^2. The coil has 15 turns and is tilted an at angle of 30 ^{o} as shown.



What is the magnetic flux linkage of the coil?

A 1.3×10^{-4} Wb **B** 7.5×10^{-3} Wb **C** 1.3×10^{-2} Wb **D** 1.3 Wb

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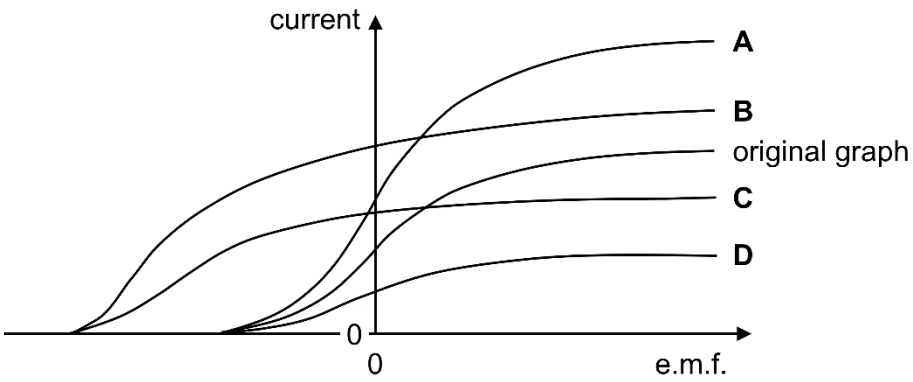
27 A photoelectric cell is connected to a variable d.c. power supply and a sensitive ammeter.

It is illuminated with ultraviolet radiation and photoelectrons are emitted. The variation with the electromotive force (e.m.f.) supplied of the current is obtained.

Which graph will be obtained if the experiment is repeated with a higher intensity of the ultraviolet radiation of the same frequency?



28 X-rays are produced when electrons are accelerated from rest by a potential difference and collide with a metal target.

The minimum wavelength of X-rays produced is λ_0.

What is the minimum wavelength of X-rays produced if the momentum of the electrons when they collide with the metal target is doubled?

A $\frac{\lambda_0}{4}$ **B** $\frac{\lambda_0}{2}$ **C** $2\lambda_0$ **D** $4\lambda_0$

29 In the Rutherford α - particle scattering experiment, α - particles are directed at a thin gold foil.

Which is a direct deduction from the results of the experiment?

A The α - particles are negatively charged.

B The α - particles are positively charged.

C The atom consists of a large amount of empty space.

D The proton number of the gold nucleus is 79.

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30 Consider the following nuclear fission reaction.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{92}_{36}Kr + {}^{141}_{56}Ba + 3\,{}^{1}_{0}n$$

The binding energy per nucleon for the particles are as shown.

Particle	Binding energy per nucleon / MeV
U	7.59
Kr	8.70
Ba	8.33

What is the amount of energy released by the reaction?

A 81.4 MeV **B** 110 MeV **C** 191 MeV **D** 199 MeV

End of Paper

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

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Physics Preliminary Examination
Higher 2

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CENTRE NUMBER	S 3 0 0 4	INDEX NUMBER	

PHYSICS **9749/02**
Paper 2 Structured Questions 23 August 2023
2 hours

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

READ THESE INSTRUCTIONS FIRST

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

At the end of the examination, fasten all your work securely together.

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

For Examiners' use only	
1	/ 8
2	/ 8
3	/ 8
4	/ 10
5	/ 8
6	/ 8
7	/ 10
8	/ 20
Total	/ 80

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DATA AND FORMULAE

Data

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

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\,\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}<c^2>$
mean 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	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

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

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1 A student times the fall of a small metal ball. Data for the time t taken for a ball of mass m to fall a vertical distance h from rest are given in the table below.

h	588 ± 1 cm
m	10 ± 1 g
t	1.1 ± 0.1 s

(a) Use the data to determine a value of the acceleration of free fall, g.

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

(b) The student collects 5 more sets of data at different heights.

Explain how the student can use the data to get a more accurate value of g.

.....

.....

.....

.....

..... [2]

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(c) Use your answer in **(a)** to determine the loss in gravitational potential energy *U* for the ball.

loss in gravitational potential energy = ... J [1]

(d) Hence, express *U* to an appropriate number of significant figures with its uncertainty.

U = ... ± ..... J [3]

[Total: 8]

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2 **(a)** Car A is traveling along a straight path at a constant speed of 8.5 m s^{-1}. When car A passes car B at t = 0 s, car B accelerates uniformly from rest at 2.5 m s^{-2}.

(i) Determine the distance travelled by car B when it overtakes car A.

distance = ... m [2]

(ii) On Fig. 2.1, sketch a well labelled graph to show the variation with time of the displacement of car A and car B.

Fig. 2.1

[2]

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(b) After overtaking car A, car B is traveling at a speed of 11.5 m s^{-1} just before it falls off a cliff of height 6.5 m. The effect of air resistance is negligible.

(i) Determine the angle θ car B makes with the horizontal just before it hits the ground.

θ = ... ° [2]

(ii) Car A subsequently falls off the same cliff as car B.

State and explain how the angle it makes with the horizontal will differ, if any, with that of car B found in **(b)(i)**.

.....

.....

.....

.....

..... [2]

[Total: 8]

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3 **(a)** Explain what is meant by *upthrust*.

……

……

…… [1]

(b) Weather balloons are an important tool for meteorologists. They provide data that is used to improve weather forecasts and to understand the atmosphere.

Fig. 3.1 shows a helium inflated weather balloon tethered to the ground by a rope. The balloon is spherical in shape and has a diameter of 1.5 m.

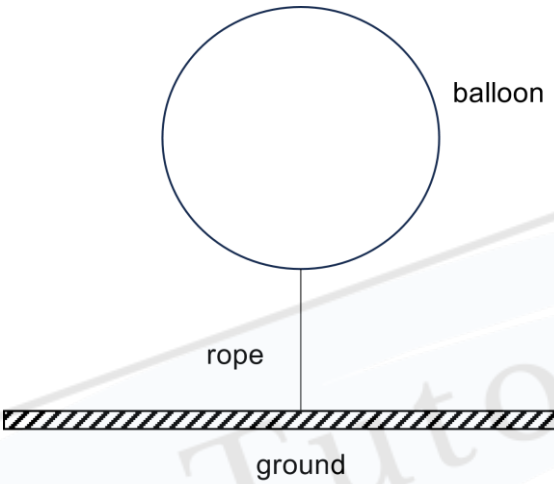

Fig. 3.1

(i) On Fig. 3.1, draw and label the forces acting on the balloon. [2]

(ii) The density of the air surrounding the balloon is 1.3 kg m^{-3}. The mass of the helium filled balloon is 300 g.

Determine the tension of the rope.

tension = …… N [2]

(c) The rope is cut and the balloon rise to an equilibrium altitude of up to 30 km.

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Explain how the balloon rises and reaches this height.

……

……

……

……

……

……

……[3]

[Total: 8]

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4 **(a)** Using energy considerations, distinguish between electromotive force (e.m.f.) and potential difference (p.d.).

.....

.....

.....

.....

..... [2]

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(b) A cell is connected to identical resistors arranged in series as shown in Fig. 4.1.

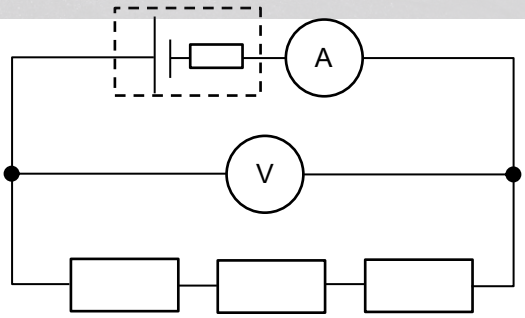

Fig. 4.1

A student recorded both the voltmeter and the ammeter readings as he varied the number of resistors arranged in series. He plotted both the voltmeter and ammeter readings in the grid in Fig. 4.2.

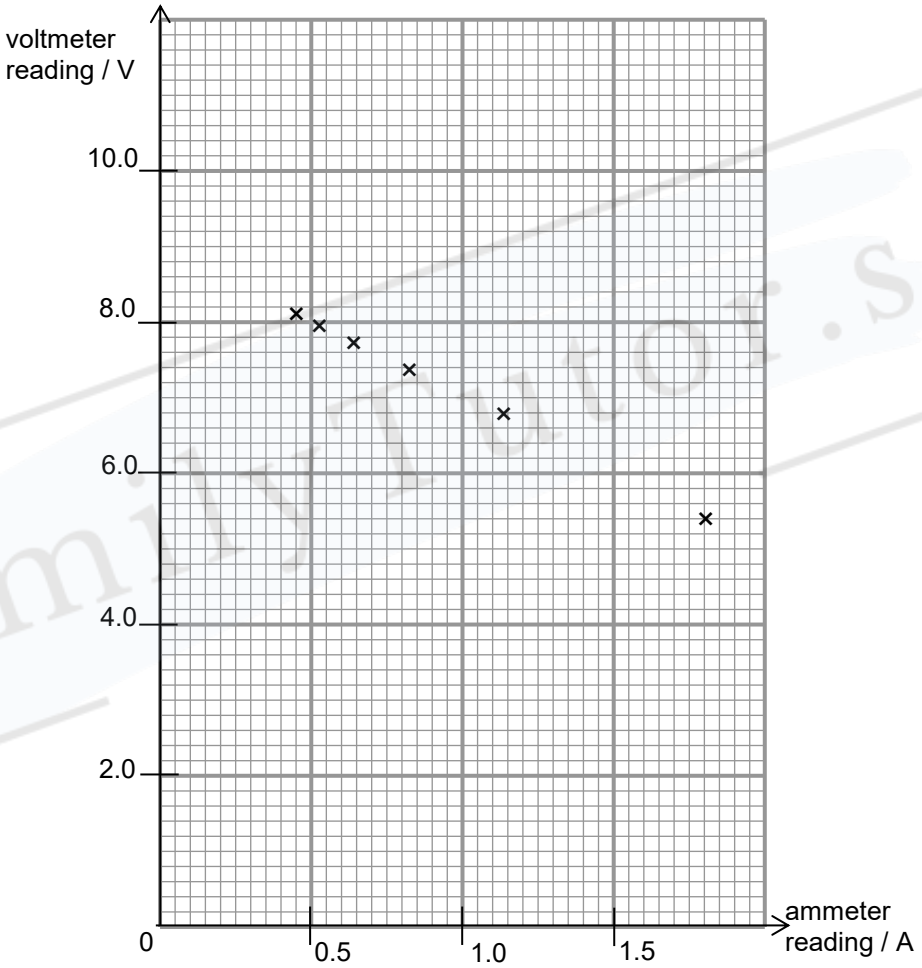

Fig. 4.2

(i) On Fig 4.2, draw the line of best fit for all the points and state the e.m.f. of the cell.

..... [1]

[Turn over

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(ii) Using Fig. 4.2, determine the internal resistance of the cell.

internal resistance = ... Ω [2]

(iii) On Fig. 4.1, draw a component that can be added to the circuit so that the emf of the cell can be obtained directly from the voltmeter reading.

Explain your answer.

.....

.....

.....

..... [2]

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(c) A circuit is set up as shown in Fig. 4.3.

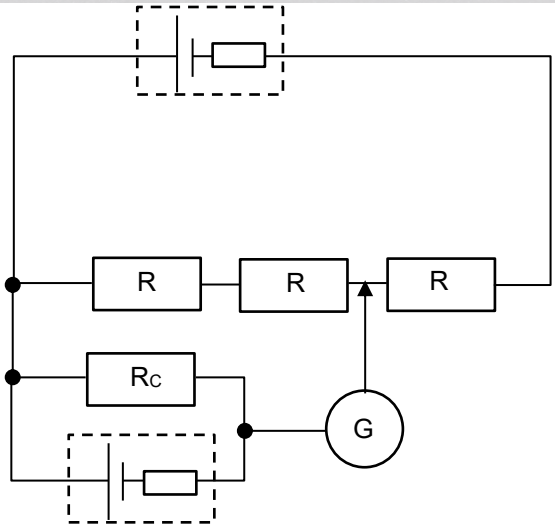

Fig. 4.3

The table below shows the specifications for the components in the circuit.

Internal resistance of cell	15 Ω
External resistor R	25 Ω

The two cells are identical and the galvanometer shows null deflection.

Calculate the resistance R_C.

Rc = …… Ω [3]

[Total: 10]

[Turn over

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5 **(a)** An electron enters a region of uniform magnetic field as shown in Fig. 5.1.

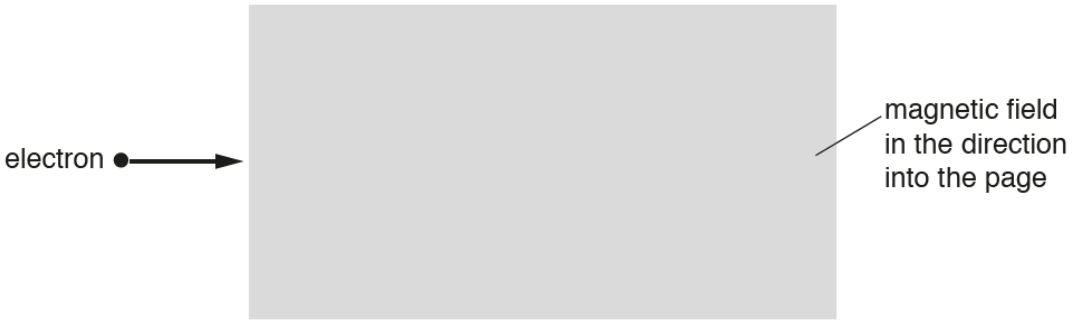

Fig. 5.1

On Fig. 5.1, draw a possible path that the electron will take in the magnetic field. [1]

(b) A thin slice of conducting material has its faces PQRS and VWXY normal to a uniform magnetic field of flux density B of 0.28 T as shown in Fig. 5.2. The side PQ is 20 mm, side PS is 9.0 mm and side PV is 1.0 mm.

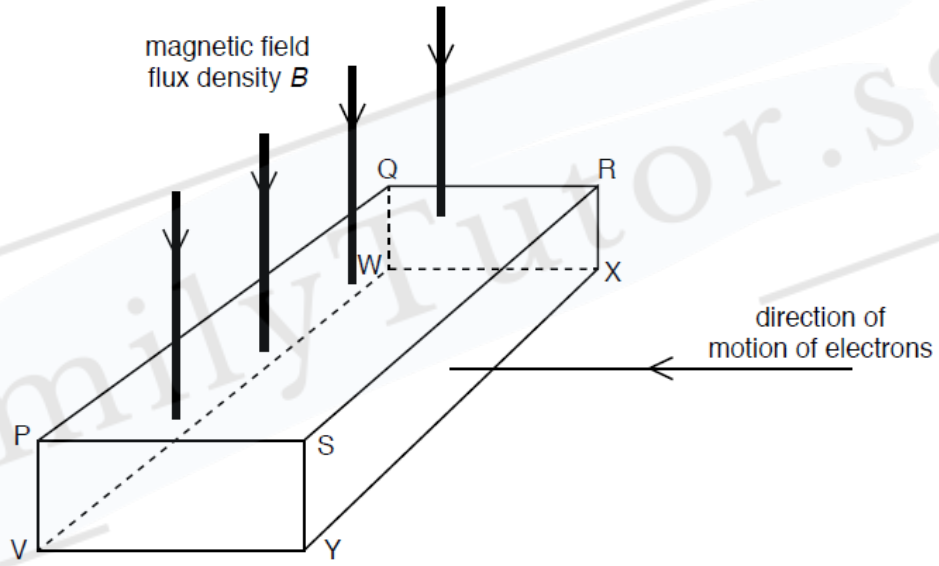

Fig. 5.2 (not to scale)

Electrons enter the slice at right-angles to face SRXY at an average speed of 56 m s^{-1}.

As the electrons flow, a potential difference is produced between two faces of the slice which increases to a steady value called the hall voltage V_H.

(i) State the face of the slice that is at a higher potential.

..... [1]

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(ii) Explain why the hall voltage is produced between two faces of the slice.

……

……

……

…… [2]

(iii) Calculate V_H.

V_H = …… V [2]

(iv) State and explain how the polarity of the hall voltage will change, if any, if the charge carriers are positively charged.

……

……

……

…… [2]

[Total: 8]

[Turn over

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6 Charles' law states that for a fixed amount of ideal gas, the volume is directly proportional to the thermodynamic temperature if the pressure is kept constant.

A student is investigating the validity of Charles' law. The student uses a syringe that has a volume of 100 cm^3 as shown in Fig. 6.1.

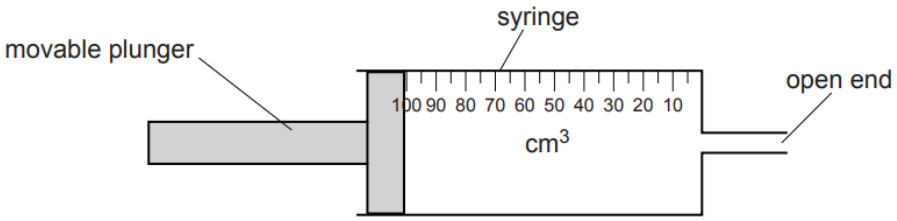

Fig. 6.1

The student moves the plunger of the syringe so that the volume of the air in the syringe is approximately 50 cm^3. The student then seals the open end of the syringe and clamps the syringe so that it is immersed in a large beaker of water, as shown in Fig. 6.2. The plunger is air-tight but free to move up and down.

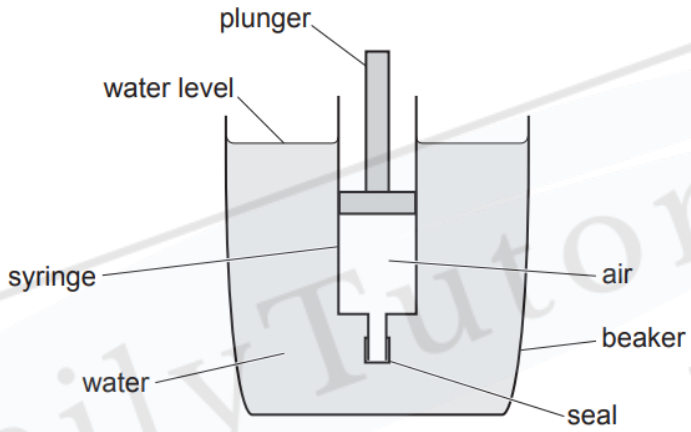

Fig. 6.2

The water in the beaker is heated, and the volume of air in the syringe is recorded at different temperatures of the water.

(a) The student recorded that at a temperature of 41 °C the volume of the air in the syringe was 52.1 cm^3.

Calculate the expected volume of the air in the syringe when the temperature is 58 °C.

expected volume = ... cm^3 [2]

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(b) The student recorded that at a temperature of 58 °C the volume of the air in the syringe was 54.3 cm^3.

Suggest a reason the calculated value in **(a)** is not the same as the experimental value.

……

……

…… [1]

(c) The experimental set-up ensures that the physical quantities, pressure and the amount of gas, remains constant.

Describe how the set-up of the experiment ensures these physical quantities remain constant.

Pressure: ……

……

Amount of gas: ……

…… [2]

(d) Use the kinetic theory to explain the variation of *V* with *T* while pressure remains constant.

……

……

……

……

……

……

……

……

…… [3]

[Total: 8]

[Turn over

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7 **(a)** State what is meant by the *activity* of a radioactive sample.

……

…… [1]

(b) Radon ($^{222}_{86}Rn$) can decay into polonium ($^{218}_{84}Po$) by emitting an alpha radiation as shown.

$$^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He$$

The half-life of radon is 3.8 days.

In a 1.0 g sample of radon, determine

(i) the number of radioactive nuclei,

number of radioactive nuclei = …… [1]

(ii) its initial activity,

activity = …… decay s^{-1} [2]

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(iii) the time taken for its activity to decline to 1.0% of its initial level, and

time = ... s [2]

(iv) the energy that will be released when all the radon has decayed.

Fig. 7.1 shows the masses of the particles.

particle	mass / u
helium	4.002602
polonium	218.008966
radon	222.017576

Fig. 7.1

energy = ... MeV [3]

(c) A Geiger–Müller tube attached to a counter is placed near the sample at the start of the decay. The count rate measured is far lower than that calculated in **(b)(ii)**.

Suggest a possible reason for this.

.....

.....

..... [1]

[Total: 10]

[Turn over

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

Magnetic Confinement Fusion

As the world's demand for energy increases, harnessing energy from the process of nuclear fusion promises to be an attractive long-term solution in addressing future energy problems.

The most widely studied nuclear fusion reaction involves the nuclei of deuterium ($^{2}_{1}\mathrm{H}$) and tritium ($^{3}_{1}\mathrm{H}$) which are isotopes of hydrogen. Each reaction produces an α-particle and a neutron, releasing 17.6 MeV of energy as shown by the nuclear equation below.

$$^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$$

For the positively charged nuclei to fuse, they must be heated to sufficiently high temperatures to overcome the Coulomb barrier. At such temperatures, the atoms in the fuel are ionised, forming a mixture of electrons and nuclei known as a plasma. Maintaining the plasma at this temperature to produce fusion energy requires it to be confined long enough in the reactor and this is achieved using magnetic fields.

Fig. 8.1 shows the magnetic field lines of a magnetic mirror configuration involving two current-carrying coils. When a charged particle is placed between the two coils, it experiences a magnetic force and can be trapped. However, the trapping is not perfect. For instance, if the particle travels along the central axis, it can escape the trap.

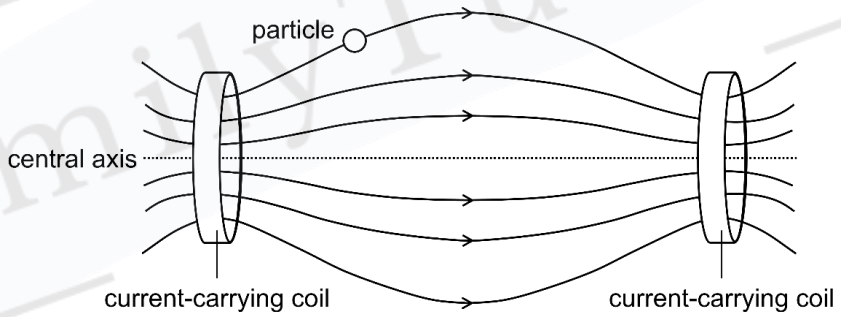

Fig. 8.1

Hence, to prevent the loss of particles, the ends of the magnetic mirror configuration can be joined together to form a torus (doughnut-like shape). Fig. 8.2 shows a cross-section of the toroidal nuclear fusion reactor where *R* is the major radius while *a* is the minor radius of the reactor. Multiple current-carrying coils, known as the toroidal field coils, are used to produce the magnetic field in the plasma.

The toroidal magnetic field causes the charged particles to move in a circular motion about the magnetic field. In addition, when current is sent through the central solenoid, it acts like the primary coil of a transformer, inducing current in the plasma around the torus. The combination of the circular motion in the cross-sectional plane of the torus and translational motion in a direction perpendicular to the plane results in the charged particles moving in a helical path.

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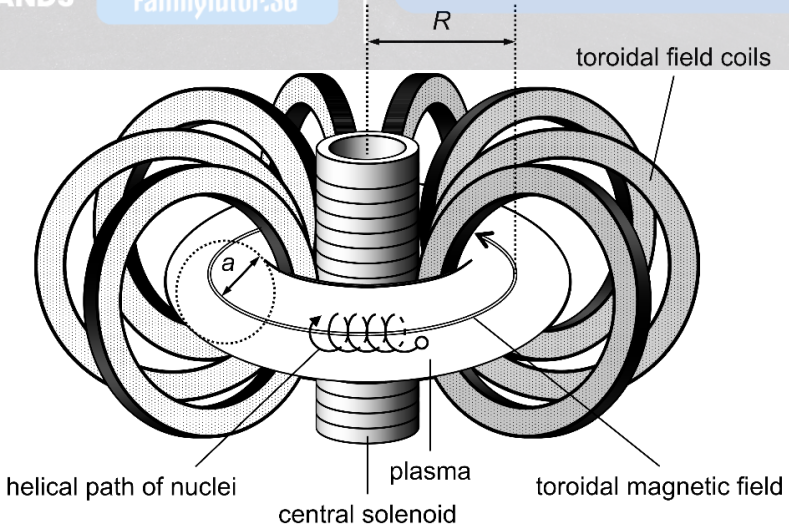

Fig. 8.2

The collisions between the nuclei and the electrons cause a resistance to the flow of charges. Similar to how a current-carrying wire heats up over time, the current in the plasma dissipates power and heats up the plasma in a process known as ohmic heating. Fig. 8.3 shows the variation with temperature of the resistivity of the plasma.

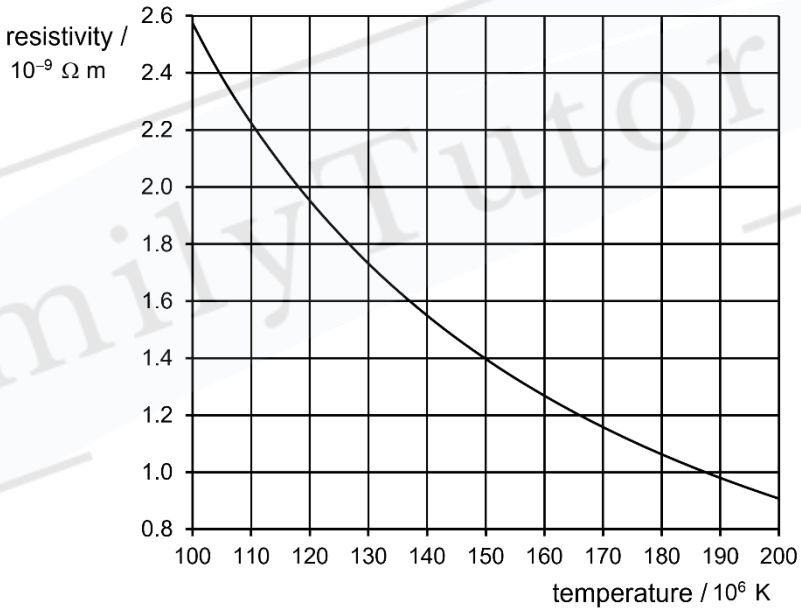

Fig. 8.3

As the resistivity of the plasma decreases when temperature rises, ohmic heating is not sufficient to raise the temperature of the plasma to the required value for fusion reactions. Hence, the plasma is further heated using two external methods – cyclotron resonance heating and neutral beam injection. In cyclotron resonance heating, radio frequency waves are transmitted to the plasma to increase the energy of the particles. In neutral beam injection, electrically neutral particles enter the plasma in a straight-line beam at high speeds and collide with the existing particles to increase the energy of the particles in the plasma.

[Turn over

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Table 8.1 summarises the data for the operation of a proposed nuclear fusion reactor.

Table 8.1

major radius, R	6.2 m
minor radius, a	2.0 m
total number density of deuterium and tritium nuclei, n	10^{20} m^{-3}
toroidal magnetic field, B	5.3 T
plasma current, I	15 MA
average temperature, T	127×10^{6} K
cyclotron resonance heating power, P_{CRH}	20 MW
neutral beam injection heating power, P_{NBI}	33 MW

(a) The binding energy per nucleon for the nuclei in the deuterium-tritium fusion reaction are given in Table 8.2.

Table 8.2

nucleus	binding energy per nucleon / MeV
deuterium $^{2}_{1}$H	1.115
tritium $^{3}_{1}$H	2.833
α-particle $^{4}_{2}$He	7.092

Show that the energy released in this reaction is 17.6 MeV.

[2]

(b) Suggest what is meant by the 'Coulomb barrier' in a nuclear fusion reaction.

……

……

…… [1]

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(c) The particle shown in Fig. 8.1 is a deuterium nucleus travelling perpendicularly into the plane of the paper.

(i) On Fig. 8.1,

1. mark with a letter X a position along the central axis where the magnetic flux density is a maximum, [1]

2. mark with a letter Y a position along the central axis where the magnetic flux density is a minimum, and [1]

3. draw an arrow and label it with a letter F to show the force acting on the deuterium nucleus. [1]

(ii) Explain why a deuterium nucleus that travels along the central axis cannot be trapped by the magnetic mirror configuration.

……

…… [1]

(d) **(i)** Using Faraday's law, explain how varying the current through the central solenoid of a nuclear fusion reactor produces plasma current around the torus.

……

……

……

……

……

…… [3]

(ii) Using Fig. 8.3 and Table 8.1, show that the resistance of the plasma at the operating temperature in the proposed nuclear fusion reactor is $5.6 \times 10^{-9}\ \Omega$.

[2]

[Turn over

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(iii) Hence, calculate the ohmic heating power at the operating temperature in the proposed nuclear fusion reactor.

power = ... W [1]

(e) In cyclotron resonance heating, energy is transferred to the particles most efficiently when the frequency of the electromagnetic waves is equal to the frequency of the circular motion in the helical path of the particles.

Determine the frequency, in MHz, of the electromagnetic waves required for cyclotron resonance heating of deuterium nuclei.

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frequency = ... MHz [3]

(f) Suggest why the particles used for neutral beam injection must be electrically neutral.

.....

.....

..... [1]

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(g) The power gain factor Q of a nuclear fusion reactor is the ratio of the power produced from the fusion reactions to the external heating power supplied to the plasma via cyclotron resonance heating and neutral beam injection.

The fusion power produced per unit volume S is given by

$$S = kn^2E$$

where k is 3.57×10^{-23} m^3 s^{-1} and E is the energy produced for each deuterium-tritium fusion reaction.

Determine Q for the proposed nuclear fusion reactor.
$\left[\text{volume of a torus} = 2\pi^2 Ra^2\right]$

Q = ... [3]

[Total: 20]

End of Paper

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Qn	Suggested MS
1(a)	$s = ut + \frac{1}{2}gt^2$ Since u = 0, $s = \frac{1}{2}gt^2$ $g = \frac{2s}{t^2}$ $g = \frac{2(5.88)}{(1.1)^2}$
	$g = 9.72 \text{ m s}^{-1}$
(b)	t should be recorded for every 100cm of h e.g. 100cm, 200cm till 600cm. Plot the graph for h against t^2 and get a best fit line. Obtain g = 2 × gradient.
	The best fit line reduces/removes the systematic error that might be present if the vertical intercept is non-zero. This results in a more accurate value of g.
(c)	Loss in GPE $= mgh = (0.010)(9.72)(5.88) = 0.571\text{J}$
(d)	$U = m(\frac{2h}{t^2})h$ $U = \frac{2mh^2}{t^2}$ Hence $\frac{\Delta U}{U} = \frac{\Delta m}{m} + 2\frac{\Delta h}{h} + 2\frac{\Delta t}{t}$
	$\frac{\Delta U}{0.571} = \frac{1}{10} + 2(\frac{1}{588}) + 2(\frac{0.1}{1.1})$ $\Delta U = 0.163\text{J}$
	$U \pm \Delta U = (0.6 \pm 0.2)\text{J}$

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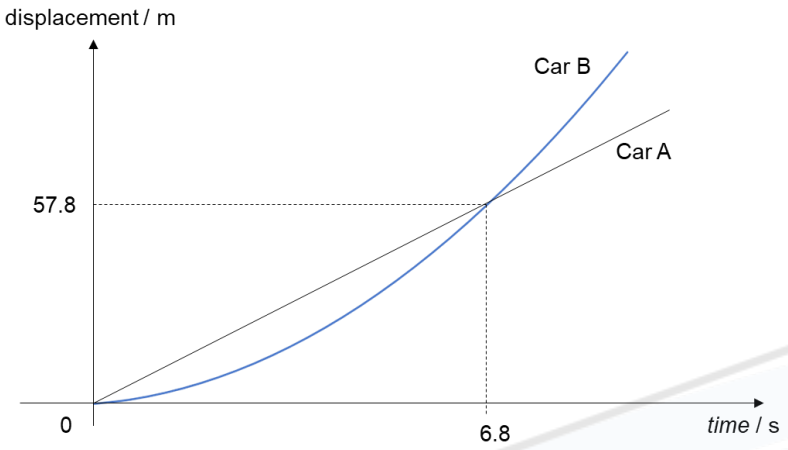
2)(a) (i)	$s_A = vt - (1)$ $s_B = ut + \frac{1}{2}at^2 = 0.5(2.5)(t^2)$ $s_A = s_B$ $8.5(t) = \frac{2.5}{2}(t^2)$ $t = 6.8\ s$
	$s_B = 0.5(2.5)(6.8)^2 = 57.8m$
(ii)	
(b) (i)	Vertical component $v_y^2 = u_y^2 + 2gs_y$ $v_y = \sqrt{2gs_y} = \sqrt{2(9.81)(6.5)} = 11.3\ ms^{-1}$
	$\tan\theta = \frac{11.3}{11.5}$ $\theta = 44.5°$
(ii)	Final horizontal velocity is the smaller
	The other component of the velocity is correct θ will therefore be larger

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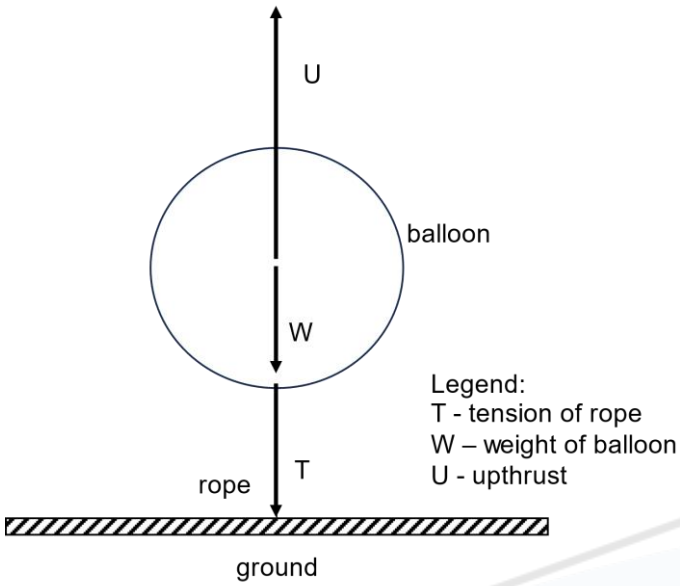
3(a)(i)	It is the resultant vertical upward force exerted by the fluid on an object as the pressure at the bottom surface is greater than that at the top. Upthrust is equal in magnitude and opposite in direction to the weight of the fluid displaced by a submerged or floating object.
3(b)(i)	 B1 – correct direction with labeling B1 – correct length of U, W and T and point of action
(ii)	$U = \rho Vg$ $= (1.3)(\frac{4}{3}\pi(\frac{1.5}{2})^3)(9.81) = 22.54N$
	$U = T + mg$ $T = U - mg$ $= 22.54 - (0.3)(9.81) = 19.6N$
(b)(ii)	Net force upwards as upthrust is more than weight
	As altitude increases, air pressure/density decreases, causing upthrust to decrease
	Upthrust will decrease till its magnitude is equal to weight.

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4(a)	e.m.f. is the amount of non-electrical energy converted into electrical energy per unit charge passing through the terminals of the cell (source).
	p.d. is the amount of electrical energy converted to other forms of energy per unit charge passing from one point to the other.
(b)(i)	Draw best fit line. Emf = 9.0 V
(b)(ii)	Read off two points along best fit line. (0,9.0) and (1.800, 5.4)
	V = E – Ir 5.4= 9.0 – 1.8(r) r = 2.0 Ω
(b)(iii)	Add a switch in correct location.
	When the switch is used, it will result in an open circuit between the resistors and the cell. Since no current flows through the cell, the terminal potential difference is the same as the emf.
(c)	p.d. across 2R = $(\frac{25+25}{3(25)+15})\times E$
	Since galvanometer reads zero, p.d. across 2R = p.d. across R_C $(\frac{25+25}{3(25)+15})\times E = (\frac{R_c}{R_c+15})\times E$
	R_C = 18.8 Ω

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5(a)	
(b)(i)	PSYV
(b)(ii)	Electrons experience a magnetic force.
	The accumulation of the electrons causes a potential difference to be set up.
(iii)	$F_e = F_B$
	$e\frac{V_H}{d} = evB$ $V_H = 0.020 \times 56 \times 0.28$ $= 0.31\,\text{V}$
(b)(iv)	Deflection would be opposite, so positive charges will accumulate on opposite face as before.
	Hence, polarity of the hall voltage will not change.

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6(a)	Apply Charles' law $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $V_2 = \frac{T_2 V_1}{T_1} = \frac{(273.15+58)(52.1)}{(273.15+41)}$
	$V_2 = 54.9\ \text{cm}^3$
(b)	The real gas does not behave like an ideal gas.
(c)	Pressure: Piston is free to move in and out
	Amount of gas: cap stops gas leaving or entering the syringe and the piston seals the gas
(d)	Increase in T causes the molecules to move with higher kinetic energy
	The particle will exert a larger force on the wall as the (rate of) change in momentum when the particle collide with the wall will be larger.
	To ensure pressure stays the same, V must increase so that the frequency of the collisions must decrease

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7)a)	Rate of decay
b)i)	$N = \frac{1}{222} \times 6.02 \times 10^{23}$ $N = 2.71 \times 10^{21}$
ii)	$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{3.8 \times 24 \times 60 \times 60} = 2.11 \times 10^{-6}$
	$A = \lambda N = (2.11 \times 10^{-6})(2.71 \times 10^{21}) = 5.73 \times 10^{15}$
iii)	$A = A_o e^{-\lambda t}$ $0.01 = e^{-\lambda t}$
	$t = -\frac{\ln(0.01)}{\frac{\ln 2}{3.8 \times 24 \times 60 \times 60}}$ $= 2.18 \times 10^6 s$
iv)	$\Delta m = (222.017576 - 218.008966 - 4.002602)$ $= 0.006008u$
	$E = \Delta mc^2$ $= 0.006008(1.66 \times 10^{-27})(3 \times 10^8)^2 = 8.98 \times 10^{-13J}$
	$E = N\Delta mc^2$ $= \frac{(2.71 \times 10^{21}) 8.98 \times 10^{-13}}{1.6 \times 10^{-19}} = 1.52 \times 10^{28} eV = 1.52 \times 10^{22} MeV$
v)	As the area of the GM tube cannot fully enclose the sample and therefore it can only capture a fraction of the total activity

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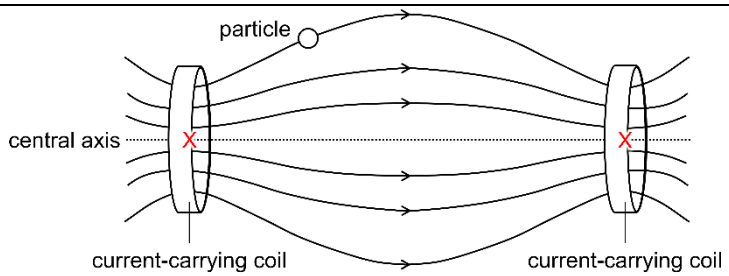
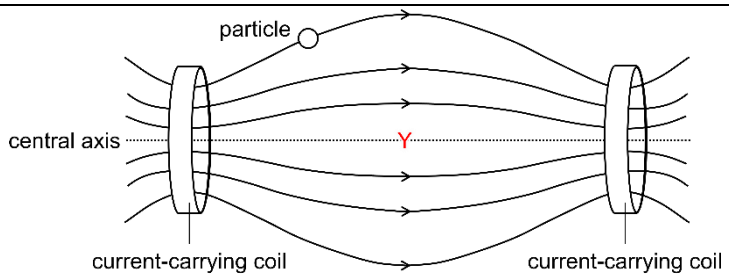
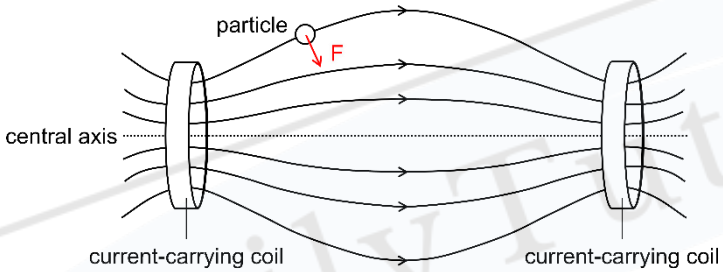
8(a)	$E = 28.368 - 2.230 - 8.499$ $= 17.64$
	$E \approx 17.6$ MeV
(b)	The 'Coulomb barrier' is the electric potential energy due to the electrostatic repulsion between the positively charged nuclei that must be overcome for nuclear fusion to occur.
(c)(i)1.	
(i)2.	
(i)3.	
(c)(ii)	The nucleus will not have a component of velocity that is perpendicular to the magnetic field. Hence, there will be no magnetic force acting on the nucleus.
(d)(i)	Changing the current through the central solenoid changes the magnetic field produced by the central solenoid.
	This changes the magnetic flux linkage in the plasma. By Faraday's law, an e.m.f. is induced in the plasma.
	This causes the charged particles in the plasma to flow around the torus producing plasma current.
(d)(ii)	the resistivity of the plasma is $1.8 \times 10^{-9}\ \Omega$ m
	$R = \frac{\rho l}{A}$ $= \frac{\rho(2\pi R)}{\pi a^2}$ $= \frac{(1.8 \times 10^{-9})(2\pi)(6.2)}{\pi (2.0)^2}$ $= 5.58 \times 10^{-9}$
	$R \approx 5.6 \times 10^{-9}\ \Omega$

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(d)(iii)	$P = I^2R$ $= \left(15 \times 10^6\right)^2 \left(5.6 \times 10^{-9}\right)$ $= 1.26 \times 10^6$ $\approx 1.3 \times 10^6 \text{ W}$
(e)	Magnetic force provides for the centripetal force.
	$Bqv = mr\omega^2$ $= m(r\omega)\omega$ $= mv\omega$ $\omega = \frac{Bq}{m}$ $= \frac{(5.3)\left(1.60 \times 10^{-19}\right)}{2 \times 1.66 \times 10^{-27}}$ $= 2.554 \times 10^8 \text{ rad s}^{-1}$
	$2\pi f = 2.554 \times 10^8$ $f = \frac{2.554 \times 10^8}{2\pi}$ $= 40.65 \times 10^6 \text{ Hz}$ $\approx 41 \text{ MHz}$
(f)	Neutral beams are unaffected by the magnetic fields hence they are able to propagate in a straight line before entering the into plasma.

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(g)	volume of the torus $V = 2\pi^2 Ra^2$ $= 2\pi^2 (6.2)(2^2)$ $= 489.53 \text{ m}^3$
	$S = kn^2E$ $= (3.57\times10^{-23})(10^{20})^2 (17.6\times10^6 \times 1.60\times10^{-19})$ $= 1.0053\times10^6 \text{ W m}^{-3}$
	$Q = \dfrac{SV}{P_{CRH} + P_{NBI}}$ $= \dfrac{(1.0053)(489.53)}{20+33}$ $= 9.29$ ≈ 9.3

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Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

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

PHYSICS **9749/03**

Paper 3 Longer Structured Questions 30 August 2023
2 hours

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

READ THESE INSTRUCTIONS FIRST

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

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

At the end of the examination, fasten all your work securely together.

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

For Examiners' use only	
Section A	
1	/ 12
2	/ 11
3	/ 11
4	/ 12
5	/ 14
Total	/ 60
Section B	
6	/ 20
7	/ 20
Grand Total	/ 80

This paper consists of 26 printed pages

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DATA AND FORMULAE

Data

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

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\,\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}<c^2>$
mean 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	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{½}}$

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Section A

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

1 **(a)** Fig. 1.1 shows two identical balls on a smooth surface. Ball A moves with a speed of v m s^{-1} towards a stationary ball B.

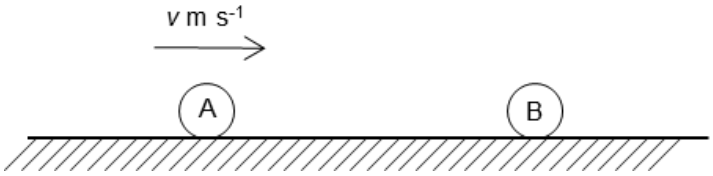

Fig. 1.1

Explain why it is not possible for ball A to move in the opposite direction after colliding with ball B.

……..

……..

……..

……..

…… [2]

(b) Fig. 1.2 shows a 2.5 kg crate moving towards a stationary 2.0 kg crate on a smooth surface.

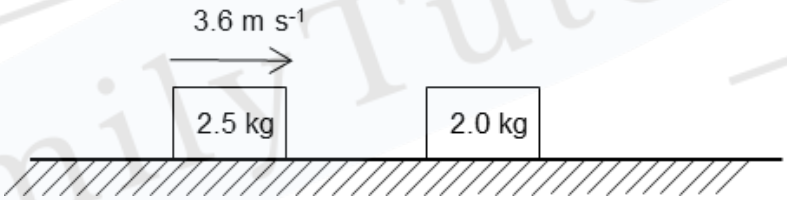

Fig. 1.2

The two crates collide elastically.

(i) Determine the speed of the 2.5 kg crate after collision.

speed = …… m s^{-1} [3]

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(ii) The collision takes place over a period of 0.50 s.

Determine the average force that the 2.5 kg crate exerts on the 2.0 kg crate.

average force = ... N [2]

(c) The crates are carrying tomatoes. A particular 3.0 kg crate has a speed of 1.5 m s^{-1} just before it slides down a 2.0 m high rough slope inclined an at an angle of 30° to the horizontal as shown in Fig. 1.3.

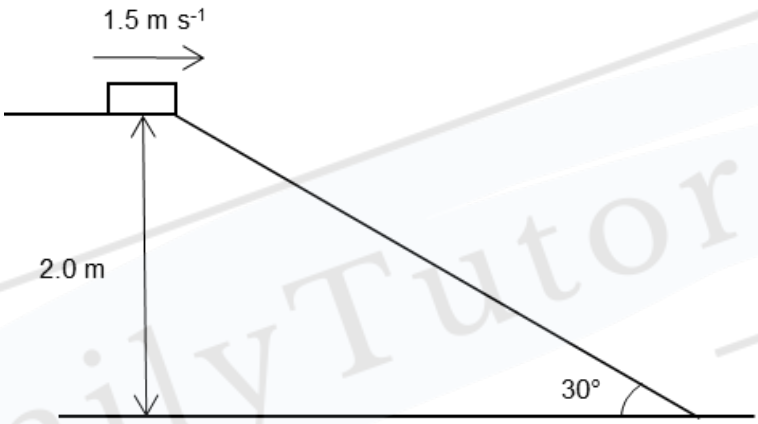

Fig. 1.3

An average frictional force of 15 N is exerted on the crate as it slides down the slope.

(i) Determine the speed of the crate when it reaches the bottom of the slope.

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

[Turn over

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(ii) A co-worker suggested to replace the rough slope with a smooth one so that the crate can reach the bottom of the slope in a shorter time.

Suggest and explain a possible reason why this suggestion should not be implemented.

.....

.....

.....

.....

..... [2]

[Total: 12]

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2 **(a)** Define *electric field strength* at a point.

……

……

……

…… [2]

(b) A positively charged conducting sphere P, isolated in space, has a radius R. The electric field strength at the surface of the sphere is E.

(i) P has a charge of 2.2×10^{-9} C and a diameter of 4.0 cm.

Determine the electric field strength at the surface of the sphere.

electric field strength = …… N C^{-1} [2]

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[Turn over

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(ii) On Fig. 2.1, sketch a graph to show the variation of the electric field strength of the sphere with distance from its centre until 8.0 cm.

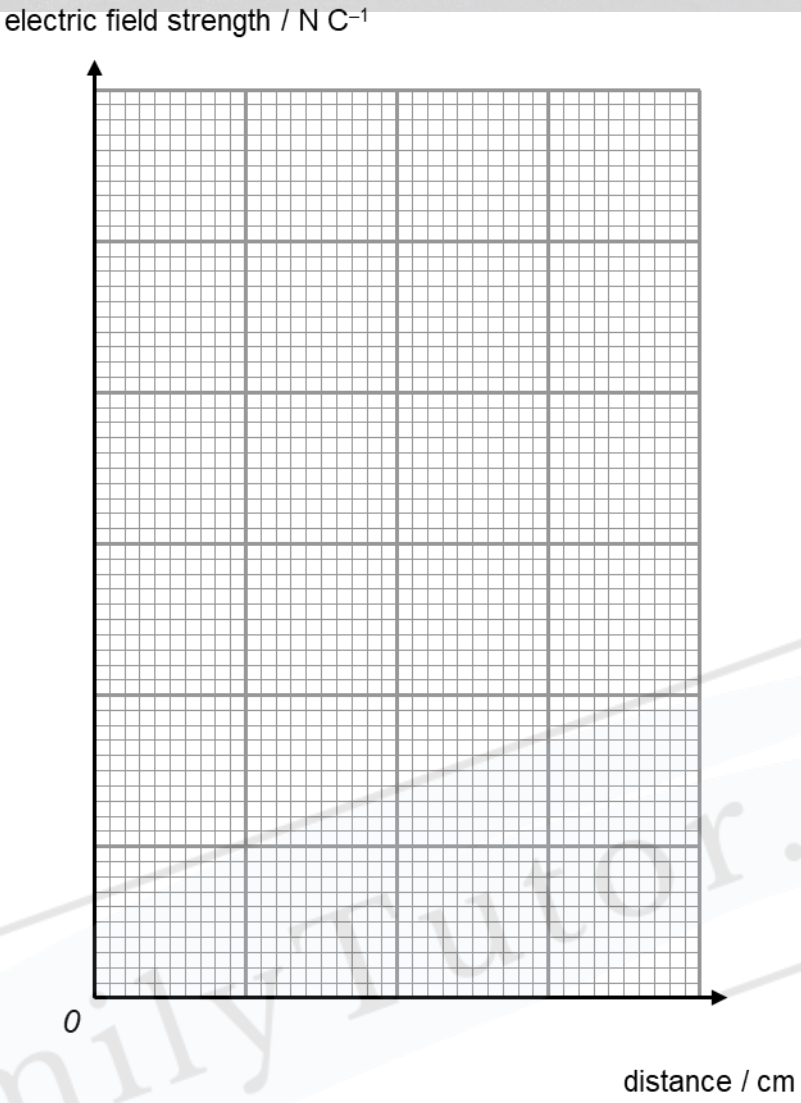

Fig. 2.1

[3]

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(c) Fig. 2.2 shows another positively conducting charged sphere Q, of the same magnitude of charge, placed at a close distance from P.

Fig. 2.2

(i) On Fig. 2.2, draw electric field lines to represent the electric field around the two spheres.

[2]

(ii) Explain why the equipotential lines are always perpendicular to the electric field lines.

.....

.....

.....

.....

.....

..... [2]

[Total: 11]

[Turn over

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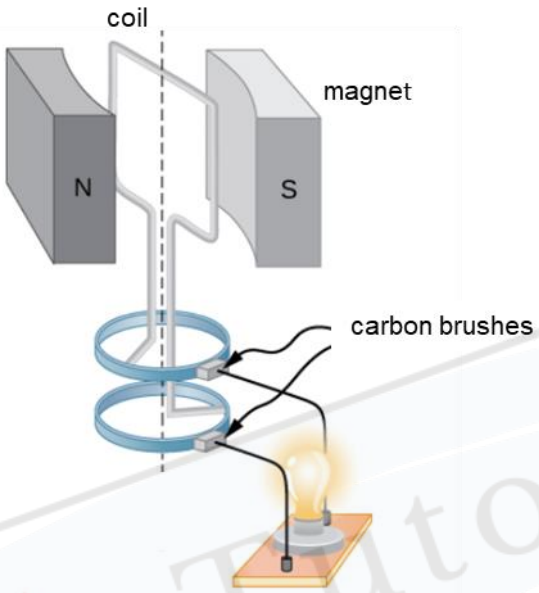
3 **(a)** Explain what is meant by *magnetic flux linkage*.

……

…… [1]

(b) Fig. 3.1 shows a simple generator that is used to generate electricity. A coil of wire of area 265 cm^2 is placed between two permanent magnets. The magnets provide a uniform magnetic flux density of 6.2 T and the coil rotates at a constant angular frequency of 30 revolutions per minute.



Source: https://openstax.org/

Fig. 3.1

(i) Explain how a sinusoidal current is generated in the coil.

……

……

……

……

……

……

…… [3]

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(ii) Show that the maximum magnitude of the e.m.f. induced in the coil is 0.52 V.

[2]

(iii) On Fig. 3.2, sketch the variation with time t of the e.m.f. E generated in the coil. The orientation of the coil, seen from the top view of Fig. 3.1, is illustrated above the graph in Fig. 3.2.

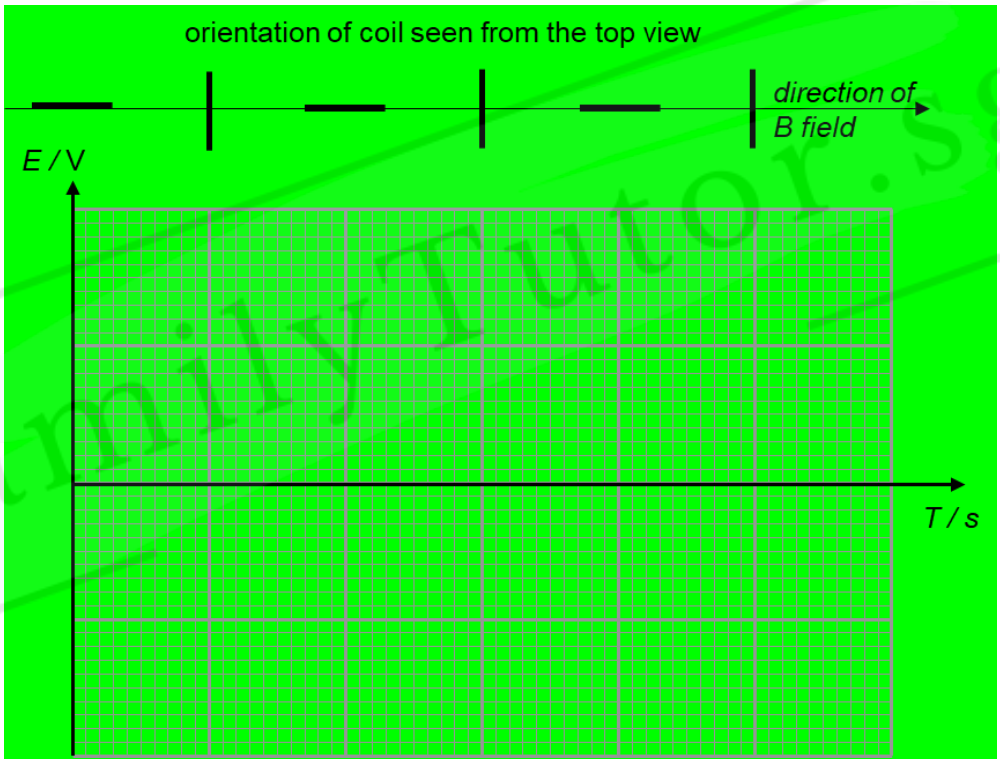

Fig. 3.2

[2]

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(c) The e.m.f. generated in **(b)** is now channelled to the input of a transformer as shown in Fig. 3.3.

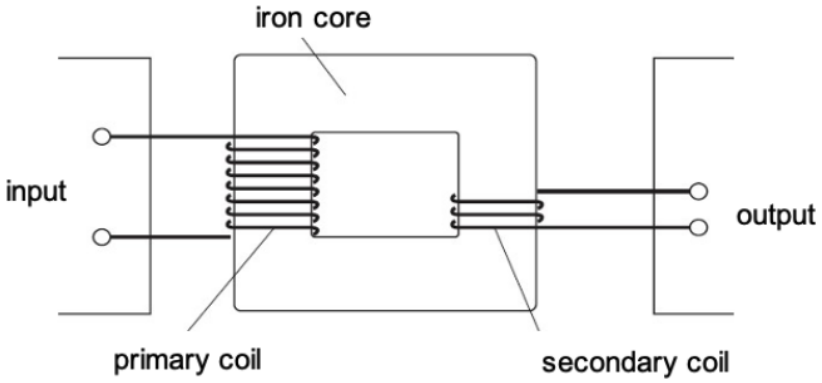

Fig. 3.3

(i) Determine the root-mean-square (r.m.s.) voltage, V_{rms}, in the primary coil.

V_{rms} = ... V [1]

(ii) The output of the transformer is connected to a resistor of resistance 10 Ω. The turns ratio of the transformer $\frac{N_s}{N_p}$ is 0.25.

Determine the r.m.s. current, I_{rms}, across the resistor.

I_{rms} = ... A [2]

[Total: 11]

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4 A 1.2 kg sphere resting on a smooth surface is connected to the side of the wall via a spring with spring constant of 65 N m^{-1} as shown in Fig. 4.1.

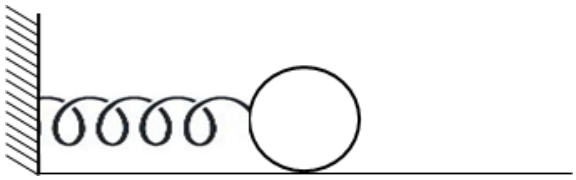

Fig. 4.1

A horizontal force of 8.0 N is exerted on the sphere and the spring is extended by x m.

(a) Determine x.

x = ... m [2]

(b) The force is now removed and the sphere is observed to move in simple harmonic motion.

(i) Determine the maximum kinetic energy of the sphere.

maximum kinetic energy = ... J [2]

(ii) Hence or otherwise, determine the period of the oscillation.

period = ... s [2]

[Turn over

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(iii) On Fig 4.2, sketch the variation with time of the kinetic energy of the sphere.

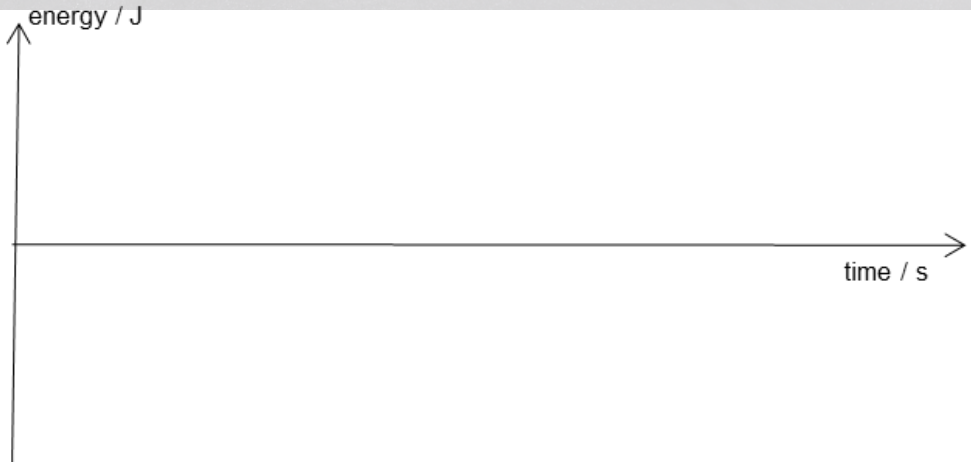

Fig. 4.2

[2]

(iv) Sketch, on Fig 4.3, the variation with displacement of the kinetic energy of the sphere.

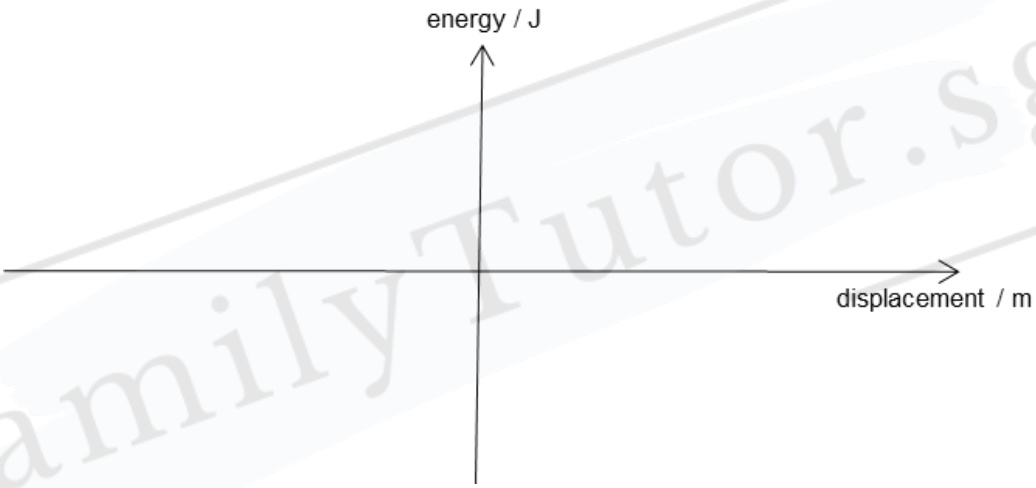

Fig. 4.3

[2]

(v) Sketch on Fig. 4.3, the variation with displacement of the kinetic energy of the sphere if the experiment is repeated on a rough surface. Label this graph as **A**.

[2]

[Total: 12]

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5 **(a)** Explain what is meant by a photon.

……

……

…… [2]

(b) A laser produces light of wavelength 656 nm in an ultrashort pulse with a duration of 9.00×10^{-15} s.

For a single photon in the pulse,

(i) calculate the momentum,

momentum = …… kg m s^{-1} [1]

(ii) determine a value for the minimum uncertainty in momentum.

minimum uncertainty in momentum = …… kg m s^{-1} [2]

(c) Explain how an emission line spectrum provides evidence for discrete energy levels in isolated atoms.

……

……

……

……

……

…… [3]

[Turn over

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(d) When an electron transits from a higher energy level to the energy level –13.6 eV in a hydrogen atom, a photon of frequency 3.19×10^{15} Hz is emitted.

Determine the energy, in eV, of the higher energy level.

energy = ... eV [2]

(e) The radiation emitted from transitions between electron energy levels of the hydrogen atom is incident on the surface of a sheet of metal of work function ϕ in a photoelectric effect experiment.

In order to investigate the relationship between the stopping potential V_s and the wavelength of incident light λ, a line of best fit was drawn from the data collected in the experiment.

Fig. 5.1 shows the variation with $\frac{1}{\lambda}$ of V_s.

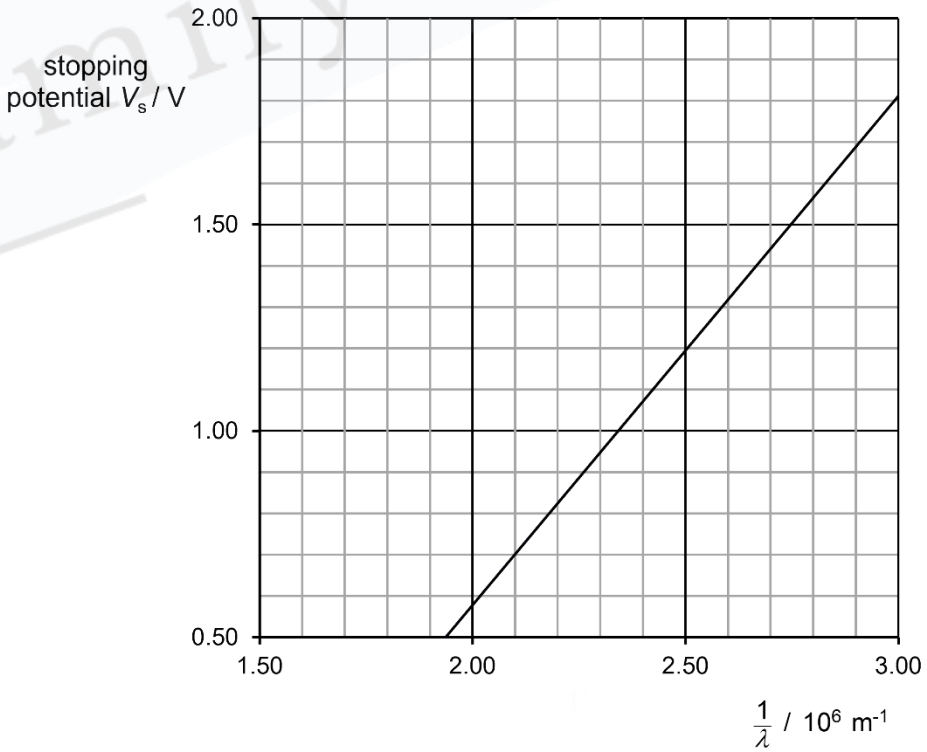

Fig. 5.1

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(i) State an equation that shows the relationship between V_s, λ and ϕ in a photoelectric effect experiment.

…… [1]

(ii) Using Fig. 5.1, determine a value for the Planck's constant.

Planck's constant = …… J s [3]

[Total: 14]

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Section B

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

6 **(a)** The intensity of the light from a monochromatic laser is I_0 and is incident normally on a polarising filter. The polarising plane of the filter is currently vertical. The intensity of the light that emerges from the filter is equal to I_0.

(i) State what the observation suggests about the light from the laser.

.....

..... [1]

(ii) Fig. 6.1 shows the polarising filter rotating slowly about a horizontal axis at right angles to its surface. As the angle θ through which the filter rotates increase from 0° to 360°, the intensity of the emerging light varies.

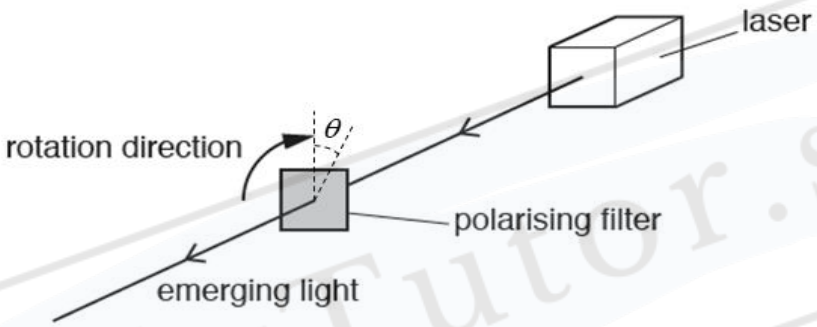

Fig. 6.1

On Fig. 6.2, sketch a graph to show how the intensity of the emergent light varies with the angle θ.

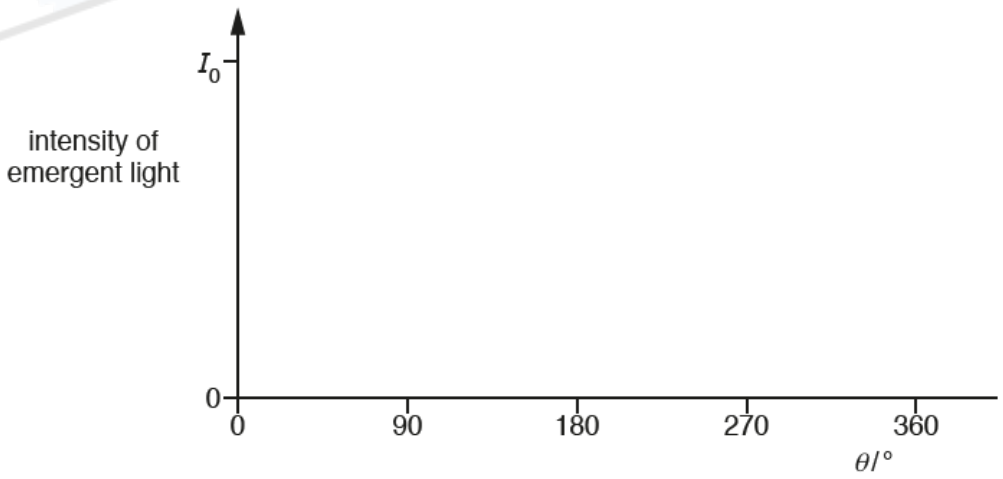

Fig. 6.2 [2]

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(iii) Fig. 6.3 shows light from the same laser reflecting off a surface before passing through the polarising filter. The intensity of the light incident on the polarising filter remains as I_o.

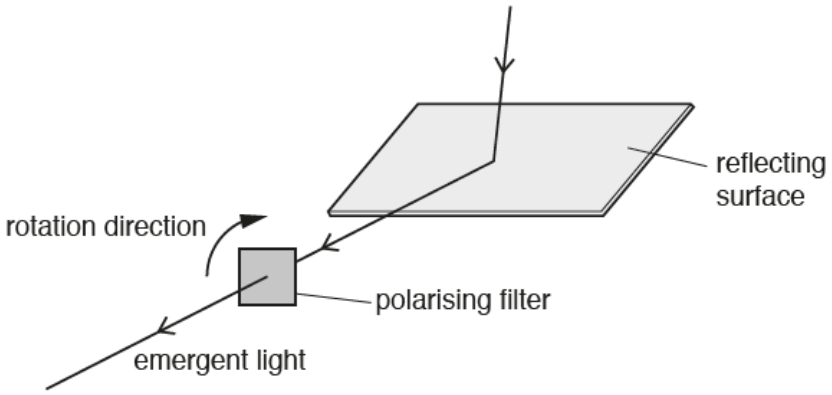

Fig. 6.3

When the polarising plane of the filter is vertical, the intensity of the emergent light is 0.179 I_o. When the polarising plane of the filter is horizontal, the intensity of the emergent light is 0.821 I_o.

Determine the intensity, in terms of I_o, of the emergent light when the polarising direction of the filter is 30° from the vertical.

intensity = ... I_0 [2]

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[Turn over

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(b) Light from the laser in **(a)** is now incident on a double slit. The light emerging from the slits is detected by a light sensor attached to a toy train moving at a constant speed as shown in Fig. 6.4.

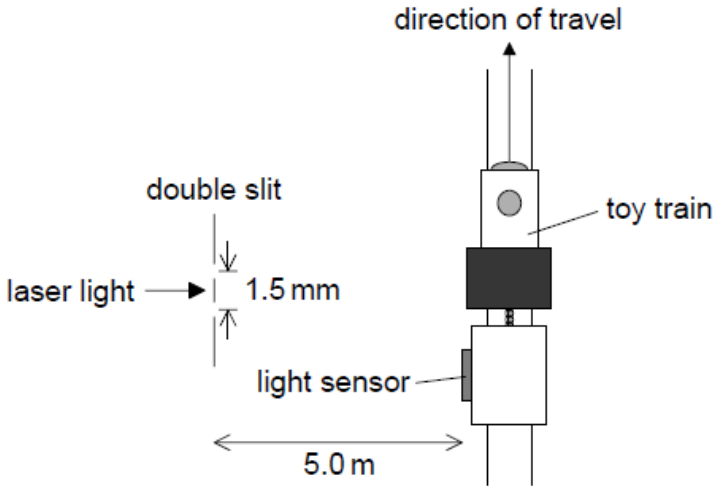

Fig. 6.4

Fig. 6.5 shows the variation with time of the output voltage from the light sensor as the train moves parallel to the slits at a constant speed. The output voltage is proportional to the intensity of light incident on the sensor.

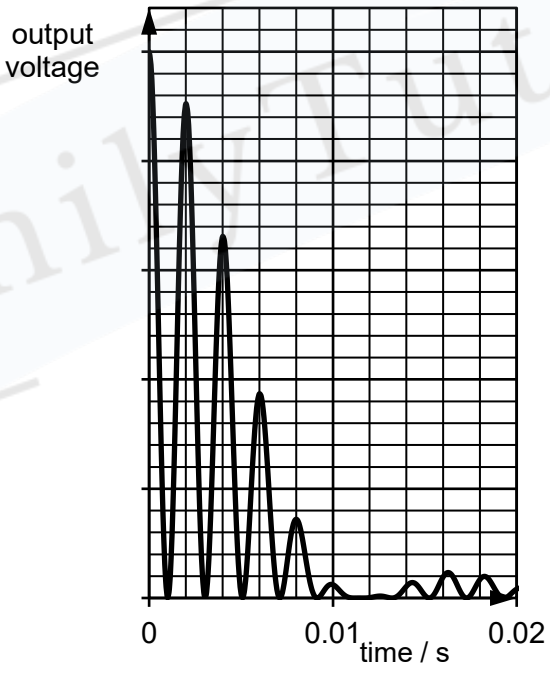

Fig. 6.5

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(i) With reference to the light passing through the slits, explain the variation of the output voltage shown in Fig. 6.5.

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

(ii) The separation between the slits is 1.5 mm and the laser light has a wavelength of 630 nm. The distance between the track and the slits is 5.0 m.

1. Calculate the separation between two adjacent maxima detected by the train.

separation = ... m [2]

2. Hence, determine the speed of the train.

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

[Turn over

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(c) One of two the slits in Fig. 6.4 is now covered. When the train moves across the remaining slit, the first minima is detected when the light sensor is at 0.13 m from the centre of the fringe pattern.

(i) Determine the width of the slit.

width = ... m [2]

(ii) The slit width is now widened.

State the changes that will be observed at the central bright fringe.

.....

.....

.....

..... [2]

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(d) The light sensor on the train is replaced with a sound sensor. The train now travels away from a loudspeaker that is emitting unidirectional sound waves of constant amplitude and frequency towards a reflecting barrier as show in Fig. 6.6.

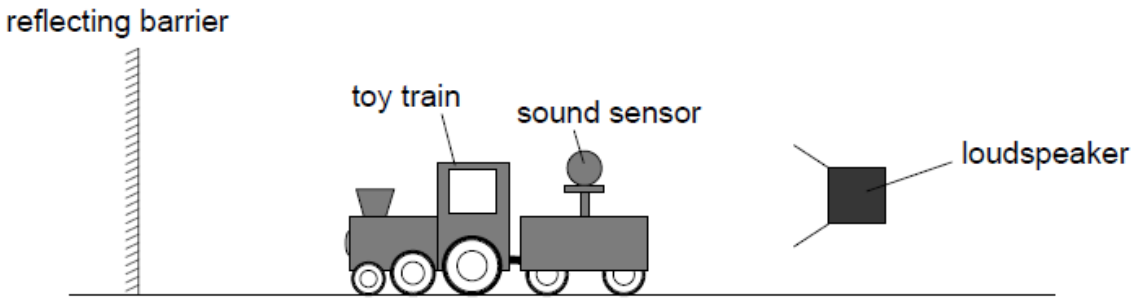

Fig. 6.6

On Fig. 6.7, sketch the variation with time of the output voltage from the sound sensor. Explain your answer.

Fig. 6.7

……

……

……

……

…… [3]

[Total: 20]

[Turn over

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7 **(a)** State what is meant by the *gravitational potential energy* stored between two point masses that are separated by a distance from each other.

……..

……..

…… [2]

(b) The Moon orbits the Earth with a orbital radius of 3.84×10^8 m. The time it takes to complete one orbit is 27.3 days.

(i) Explain what is meant by a *geostationary* orbit.

……

..... [1]

(ii) Hence, explain why the moon is not in a geostationary orbit.

……

..... [1]

(iii) Calculate the angular velocity of the Moon.

angular velocity = …… rad s^{-1} [2]

(iv) Hence or otherwise, determine the mass of the Earth. Show your working clearly.

mass of Earth = …… kg [3]

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(v) The mass of the Earth is M_e.
The mass of the Moon is M_m.
The orbital radius of the Moon is x.

1. Show that the kinetic energy of the Moon is $\frac{GM_eM_m}{2x}$.

[1]

2. Derive an expression for the total energy of the Moon in terms of M_e, M_m and x.

[1]

3. Explain why the total energy of the moon must be less than zero.

……

……

…… [1]

(vi) The Moon is moving away from the Earth at about 3.8 cm per year and the Earth's days are getting longer at about 2 ms per century.

1. State and explain the effect on the total energy of the Moon.

……

……

……

……

…… [3]

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[Turn over

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2. Explain how energy is conserved in the system.

……

……

…… [1]

3. Suggest why this will cause a day on Earth to be longer.

……

……

…… [1]

(vii) Between the Earth and the Moon, the point where the resultant gravitational field strength is zero is 34.6×10^7 m from the centre of the Earth.

A student is provided with the gravitational potential at two positions between the Earth and Moon as shown in the table.

Position	Distance from the centre of the Earth/ m	Gravitational potential/ J kg^{-1}
M	1.0×10^7	-40.2×10^6
N	37.4×10^7	-15.6×10^6

He states the following:

"An object at rest released at N will accelerate towards the Earth since the gravitational potential is lower at M."

Comment on his statement.

……

……

……

……

…… [3]

[Total: 20]

End of Paper

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Qn	Suggested MS
1)a)	If sphere A is to move in the opposite direction, speed of sphere B will have to be higher than the initial speed of sphere A
	which will mean that total kinetic energy after collision has increased, which is not possible
b)i)	$m_{2.5}u_{2.5} + 0 = m_{2.5}v_{2.5} + m_{2.0}v_{2.0}$ $2.5(3.6) + 0 = 2.5v_{2.5} + 2.0v_{2.0}$ $9 = 2.5v_{2.5} + 2.0v_{2.0}$
	Relative speed of approach = relative speed of separation $3.6 = v_{2.0} - v_{2.5}$
	$9 = 2.5v_{2.5} + 2.0(3.6 + v_{2.5})$ $v_{2.5} = \frac{9 - 7.2}{4.5} = 0.4$
ii)	$F_{ave,2.5kg} = \frac{\Delta p}{t} = \frac{p_f - p_i}{t} = \frac{2.5(0.4) - 2.5(3.6)}{0.5} = 16.0N$
	Using N3L, the force on the 2.0 kg crate is also 16.0 N
c)i)	$KE_i + gpe_i = KE_f + gpe_f + WD_f$
	$\frac{1}{2}(3.0)(1.5)^2 + (3.0)(9.81)(2.0) = \frac{1}{2}(3.0)v^2 + 0 + 15.0(\frac{2.0}{\sin 30°})$
	$3.4 + 58.9 = 1.5v^2 + 60$ $v = 1.24ms^{-1}$
ii)	The crate will reach the bottom of the slope with a much higher speed
	The will result in it experiencing a much larger vertical force as it moves from the slope onto the vertical surface, potentially damaging the tomatoes.

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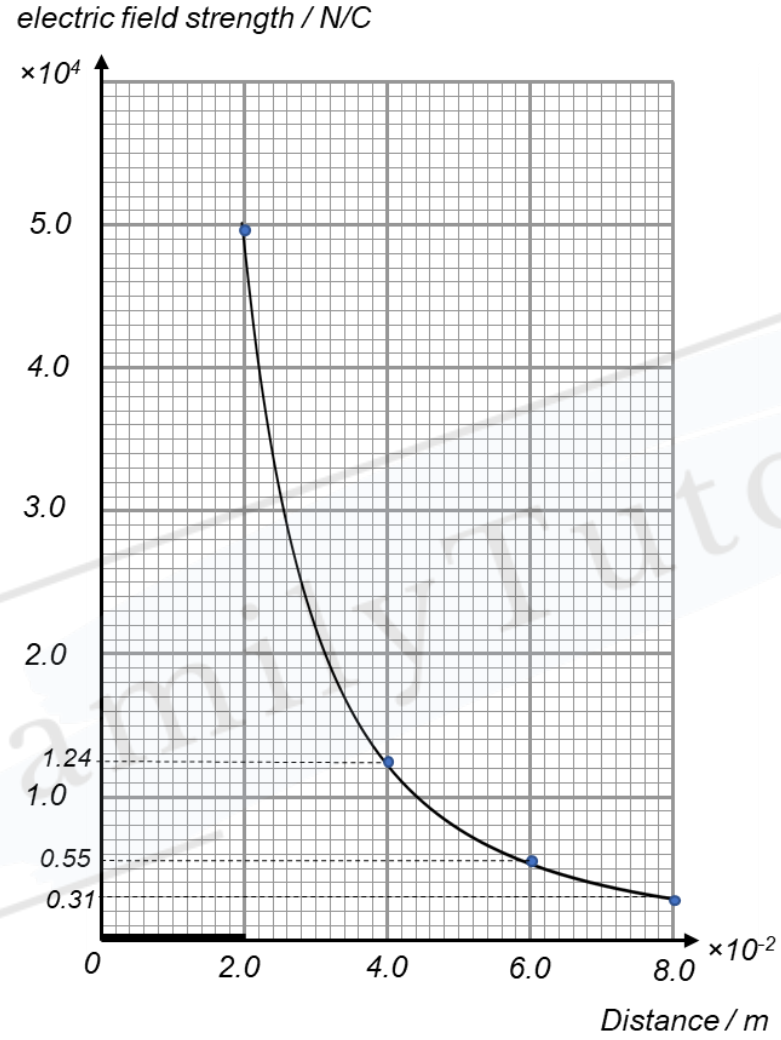
2	
(a)	Electric field strength E at a point is defined as the electric force exerted per unit positive charge
	on a small stationary test charge placed at that point in the electric field.
(b)(i)	$E = \frac{Q}{4\pi E_0 r^2}$ $= \frac{2.2\times10^{-9}}{4\pi(8.85\times10^{-12})(\frac{4.0\times10^{-2}}{2})^2}$
	= 4.94 ×10^4 N C^{-1}
(ii)	

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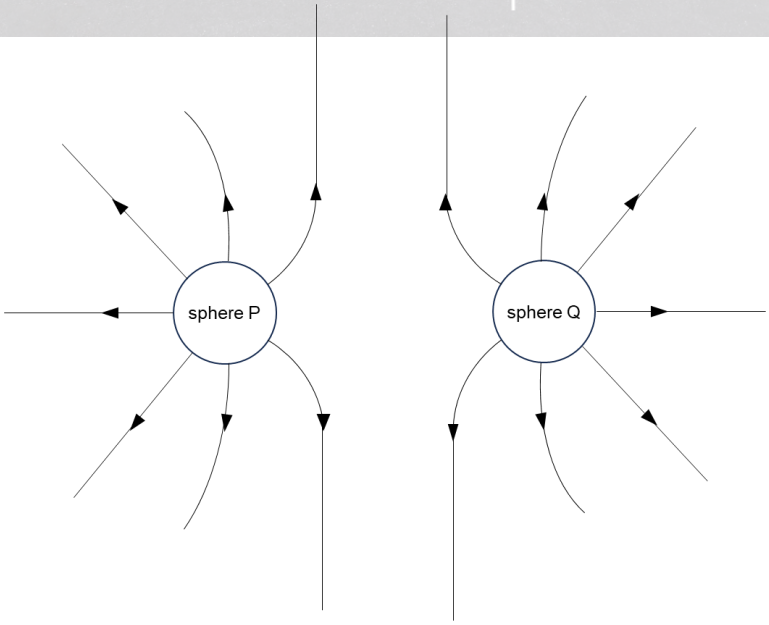
(c)(i)	
(ii)	Electric field strength is the negative potential gradient
	Gradient points in the direction of the greatest change of potential which is the (opposite) direction of the electric field. There is no component of the electric field strength (electric force) parallel to the equipotential line as this will cause a change in electric potential

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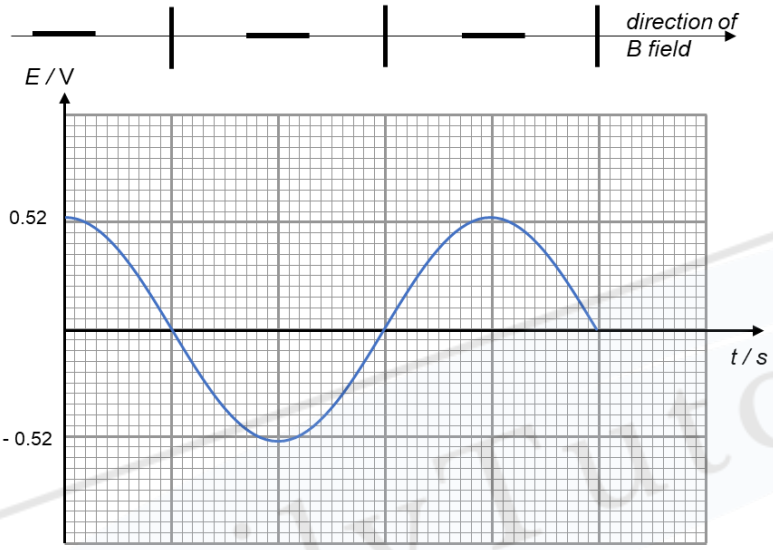
3(a)	The magnetic flux linkage through a whole coil of N turns is the sum of the magnetic flux through the individual turns
(b)(i)	As the coil rotates, the area of the coil perpendicular to the field changes sinusoidally
	causing the magnetic flux linkage to change sinusoidally and a sinusoidal e.m.f. is induced,
	Since the circuit forms a closed loop, a sinusoial current will now follow
(ii)	$E = -\frac{d\Phi}{dt} = -\frac{d}{dt}NBA\cos(\omega t) = \omega NBA\sin(\omega t)$
	$E_{max} = \omega NBA = 2\pi(\frac{30}{60})(6.2)(265\times100^{-2}) = 0.516\,V$
	= 0.52 V
(iii)	orientation of coil seen from the top view 
(c)(i)	$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{0.516}{\sqrt{2}} = 0.365\,V$
(ii)	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$ $0.25 = \frac{V_s}{V_p}$ $V_s = 0.25\times0.365 = 0.09125\,V$
	$I_s = \frac{V_s}{R} = \frac{0.09125}{10} = 9.13\times10^{-3}\,A$

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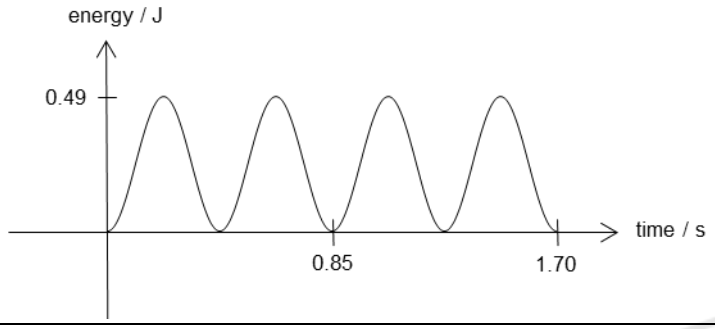
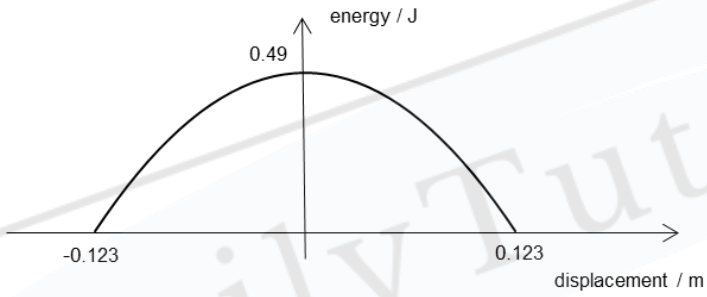
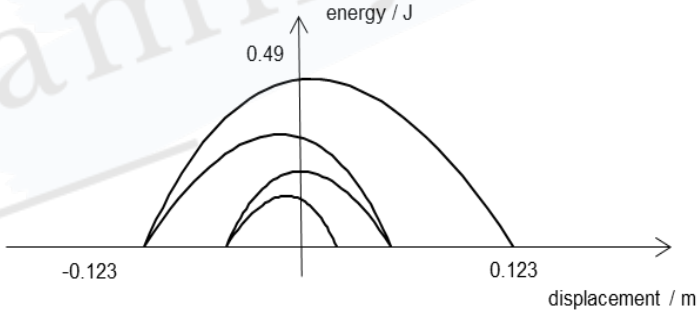
4)a)	$F = kx$ $8.0 = 65x$
	$x = 0.123m$
b)i)	$KE_{max} = PE_{max}$
	$KE_{max} = PE_{max} = \frac{1}{2}kx^2 = \frac{1}{2}(65)(0.123)^2 = 0.49J$
ii)	$KE_{max} = \frac{1}{2}mv_o^2 = \frac{1}{2}m(\omega x_o)^2 = 0.49J$
	$\frac{1}{2}(1.2)(\frac{2\pi}{T}(0.123))^2 = 0.49$ $T = 0.855s$
iii)	
iv)	
v)	

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5(a)	A photon is a quantum of electromagnetic radiation
	whose energy is given by the product of the Planck's constant and its frequency.
(b)(i)	$p = \frac{h}{\lambda}$ $= \frac{6.63 \times 10^{-34}}{656 \times 10^{-9}}$ $= 1.01 \times 10^{-27}$ kg m s^{-1}
(ii)	$\Delta x = c\Delta t$ $= \left(3.00 \times 10^{8}\right)\left(9.00 \times 10^{-15}\right)$ $= 2.70 \times 10^{-6}$ m
	$\Delta x \Delta p \gtrsim h$ minimum $\Delta p \approx \frac{h}{\Delta x}$ $= \frac{6.63 \times 10^{-34}}{2.70 \times 10^{-6}}$ $= 2.46 \times 10^{-28}$ kg m s^{-1}
(c)	When isolated gas atoms are in the excited state, electrons occupying the higher energy levels will spontaneously transit from the higher energy levels to lower energy levels.
	Each transition produces a photon whose energy is equal to the energy difference of the two electron energy levels involved in the transition.
	Discontinuous/discrete coloured lines are produced on a dark background implying only photons of specific energy/wavelength/frequency is emitted, indicating that the energy levels in an isolated atom are discrete.
(d)	$\Delta E = hf$ $= \left(6.63 \times 10^{-34}\right)\left(3.19 \times 10^{15}\right)$ $= 2.115 \times 10^{-18}$ J $= \frac{2.115 \times 10^{-18}}{1.60 \times 10^{-19}}$ eV $= 13.22$ eV
	$E_{\text{higher}} - E_{\text{lower}} = 13.22$ $E_{\text{higher}} = 13.22 + (-13.6)$ $= -0.38$ eV
(e)(i)	$\frac{hc}{\lambda} = \phi + eV_s$
(ii)	$V_s = \frac{hc}{e}\left(\frac{1}{\lambda}\right) - \frac{\phi}{e}$ Plotting V_s against $\frac{1}{\lambda}$, $\frac{hc}{e}$ is equal to the gradient.
	gradient of graph $= \frac{1.80 - 0.70}{(3.00 - 2.10) \times 10^{6}}$ $= 1.222 \times 10^{-6}$ V m

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	$\frac{hc}{e} = 1.222 \times 10^{-6}$ $h = \frac{\left(1.222 \times 10^{-6}\right)\left(1.60 \times 10^{-19}\right)}{3.00 \times 10^{8}}$ $= 6.52 \times 10^{-34}$ J s

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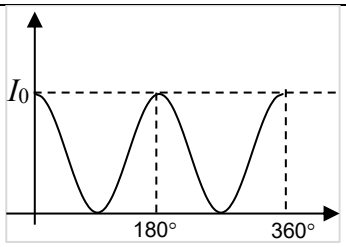
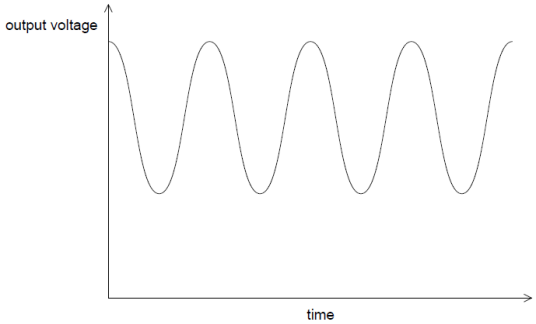
6(a)(i)	The light is polarised in the same direction as the filter's polarising direction / polarised in the vertical direction.
(a)(ii)	
(a)(iii)	$\cos\theta = \sqrt{0.179} \rightarrow \theta = 65.0°$
	$I_0 \cos^2(65.0° - 30°) = 0.67 I_0$
(b)(i)	Light from both slits arrive in phase, it would result in constructive interference; if arrive in π rad out of phase, it would result in destructive interference.
	This corresponds to maximum voltage for constructive and minimum for destructive.
	As the train moves, it would detect alternating high and low voltages / interference pattern.
	Peak decreases due to diffraction.
(b)(ii)1.	$x = \frac{\lambda D}{d}$ $= \frac{(630\times10^{-9})(5.0)}{1.5\times10^{-3}}$
	$x = 2.1\times10^{-3}$ m
(b)(ii)2.	Time between two peaks = $\frac{0.01}{5} = 2\times10^{-3}$ s
	$v = \frac{2.1\times10^{-3}}{2\times10^{-3}}$ $v = 1.05$ m s^{-1}
(c)(i)	$\frac{\lambda}{b} = \frac{0.13}{5.0}$ $b = (630\times10^{-9})\left(\frac{5.0}{0.13}\right)$
	$b = 2.4\times10^{-5}$ m
(c)(ii)	Peak voltages will be higher.
	Width of the central bright fringe will be smaller.
(d)	
	Reflected waves and incidence waves interfere.

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	Same frequency, opposite direction, hence a stationary wave is formed.

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7(a)	Work done to move the masses
	from infinity to the distance of separation/to that point.
(b)(i)	A geostationary orbit is one where the satellite will remain in the same position in the sky relative to the Earth's surface
(b)(ii)	The orbital period of the moon is not 24 hours
(b)(iii)	$T = 27.3 \times 24 \times 60 \times 60 = 2358720$ s
	$\omega = \frac{2\pi}{T} = \frac{2\pi}{2358720} = 2.66 \times 10^{-6}$ rad s^{-1}
(b)(iv)	The gravitational force by the Earth on the Moon provides for the centripetal force.
	$\frac{GM_{Earth}M_{Moon}}{r^2} = M_{Moon}a_{Moon}$ $\frac{GM_{Earth}}{r^2} = r\omega^2$ $M_{Earth} = \frac{r^3\omega^2}{G}$
	$M_{Earth} = \frac{r^3\omega^2}{G}$ $M_{Earth} = \frac{(3.84 \times 10^8)^3 \times (2.6638 \times 10^{-6})^2}{(6.67 \times 10^{-11})}$ $M_{Earth} = 6.02 \times 10^{24}$ kg
(b)(v)1	The gravitational force by the Earth on the Moon provides for the centripetal force. $\frac{GM_eM_m}{x^2} = M_m\frac{v^2}{x}$ $\frac{GM_eM_m}{2x} = \frac{1}{2}M_mv^2$ Kinetic energy $= \frac{GM_eM_m}{2x}$
(b)(v)2	Gravitational potential energy $= -\frac{GM_eM_m}{x}$ Total energy $= -\frac{GM_eM_m}{x} + \frac{GM_{eh}M_m}{2x}$ Total energy $= -\frac{GM_eM_m}{2x}$
(b)(v)3	When the total energy is zero (or more), this implies the Moon is able to escape from the Earth's gravitational field.
(b)(vi)1	As the Moon moves further from the Earth, its orbital radius/x increases
	The total energy increases.
	The potential energy will increase more than the decrease in kinetic energy
(b)(vi)2	Since this is an Earth-Moon system, the Earth loses energy while the Moon gains energy.
(b)(vi)3	As the Earth loses energy, the orbital speed about the Earth axis decreases. Since angular velocity is smaller, the period will be longer.
(b)(vi)	The position where the maximum gravitational potential is between M and N
	The direction of the gravitational field strength at N will be towards the moon

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	It will accelerate towards the Moon instead.

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TEST QUESTIONS AND ANSWER KEYS

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Name: _____ ( ) Class: 23 / _____

ANDERSON SERANGOON JUNIOR COLLEGE

2023 JC2 Preliminary Examination

PHYSICS Higher 2 9749/01

Paper 1 Multiple Choice **Wednesday 20 September 2023**

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 class on the Multiple Choice Answer Sheet.
Shade and write your NRIC/FIN.

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

Read the instructions on the Multiple Choice Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this question paper.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **18** printed pages and **2** blank pages.

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Data

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

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Formulae

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

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1 Which expression involving base units is equivalent to the volt?

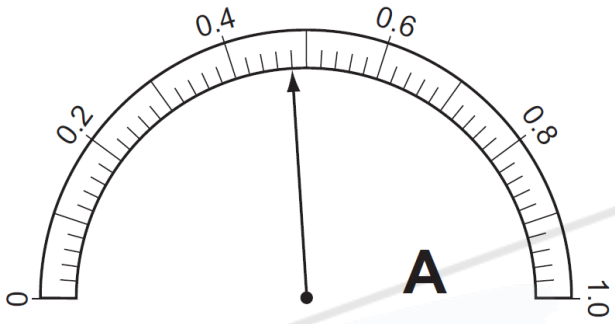
A kg m^2 s^{-1} A^{-1}

B kg m s^{-2} A

C kg m^2 s^{-1} A

D kg m^2 s^{-3} A^{-1}

2 The resistance of an electrical component is measured. The following meter readings are obtained.



What is the resistance?

A 2.5 Ω **B** 2.7 Ω **C** 2500 Ω **D** 2700 Ω

3 A car moves with uniform acceleration along a straight road. Oil leaks from the car at the rate of one drop every two seconds. The diagram shows the distances between three successive oil drops on the road.

What is the acceleration of the car?

A 0.38 m s^{-2} **B** 0.75 m s^{-2} **C** 2.6 m s^{-2} **D** 5.3 m s^{-2}

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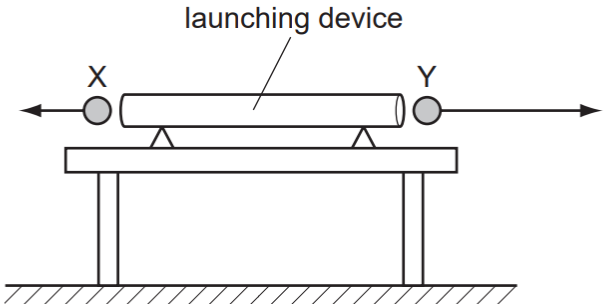
4 A double-ended launching device fires two identical steel balls X and Y at exactly the same time. The diagram shows the initial velocities of the balls. They are both launched horizontally, but Y has greater speed.



Which statement explains what an observer would see?

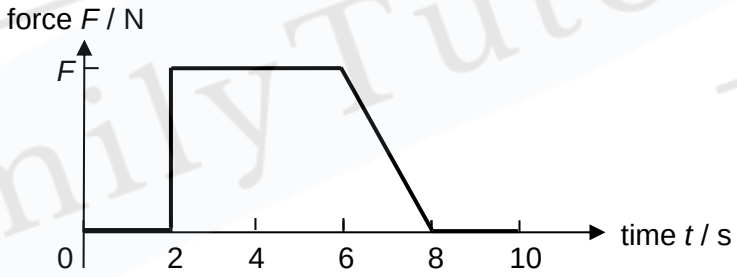
A Both X and Y reach the ground simultaneously, because air resistance will cause both to have the same final speed.

B Both X and Y reach the ground simultaneously, because gravitational acceleration is the same for both.

C X reaches the ground before Y, because X lands nearer to the launcher.

D Y reaches the ground before X, because Y has greater initial speed.

5 The graph shows the variation with time t of a braking force F acting on a 2.0 kg mass. The mass decelerates from an initial speed of 30 m s^{-1} to a final speed of 5.0 m s^{-1}.



What is the maximum force F exerted on the mass during this period of 10 s?

A 5.0 N **B** 10 N **C** 20 N **D** 50 N

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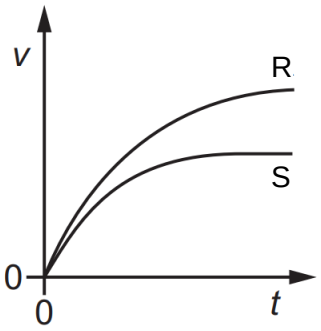
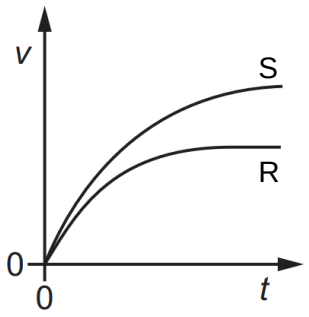
6 A stone S and a foam rubber ball R are identical spheres of equal volume. They are released from rest at time $t = 0$ and fall vertically through the air. Both reach terminal velocity.

Which graph best shows the variation with time t of the speed v of the stone and of the rubber ball?

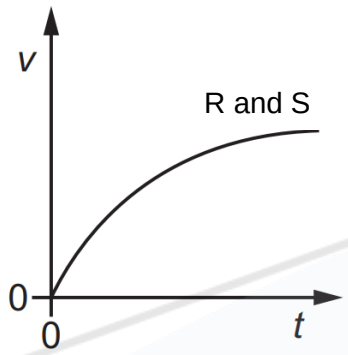
A



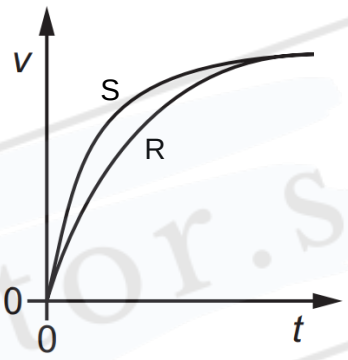
B



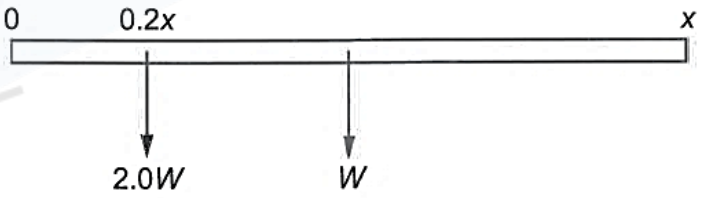
C



D



7 A uniform rod of length x and weight W has a load $2.0W$ suspended at a distance $0.2x$ from one end.



A string is attached to the rod such that the rod is suspended in equilibrium.

The load is now moved so that it is a distance $0.2x$ from the other end of the rod.

How far along the rod does the string need to be moved so that the rod returns to equilibrium?

A $0.2\,x$ **B** $0.3x$ **C** $0.4x$ **D** $0.6x$

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8 Which statement about work done is correct?

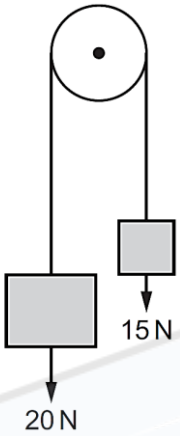
A More work is done to change the speed of an object from 2 m s^{-1} to 3 m s^{-1} than to change the speed of the same object from 1 m s^{-1} to 2 m s^{-1}

B No work is done by a force that slows a moving object.

C The same amount of work is done when lifting an object 1 m at a constant velocity and pulling the same object 1 m across a smooth horizontal surface at a constant velocity.

D When an object is dropped, the force of gravity does no work.

9 A pulley of radius 0.40 m supports weights of 20 N and 15 N by means of a thin string, as shown.

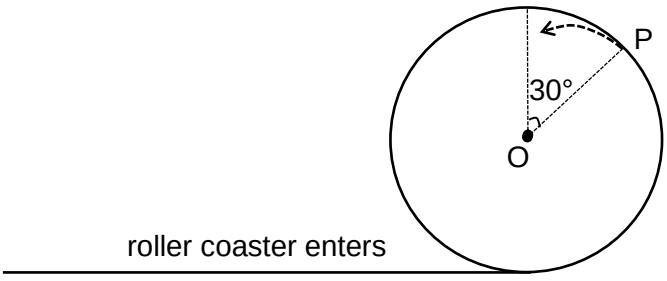


The weights are moved by slowly rotating the pulley clockwise through an angle of 60°.

What is the increase in the total gravitational potential energy of the weights?

A 0.33 J **B** 2.0 J **C** 2.1 J **D** 15 J

10 A toy roller coaster attempts a loop-a-loop. It enters the bottom of loop of radius 1.0 m with insufficient speed. It loses contact at the point P as shown. The line joining P and the centre of the loop O makes an angle 30° with the vertical.



What is the speed at P which the roller coaster just loses contact with the loop?

A 0 m s^{-1} **B** 2.2 m s^{-1} **C** 2.9 m s^{-1} **D** 3.1 m s^{-1}

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11 The acceleration of free fall at the surface of Neptune is approximately equal to the acceleration of free fall at the surface of the Earth. The mass of Neptune is 17 times the mass of the Earth.

What is the value of the ratio $\frac{\text{radius of Neptune}}{\text{radius of Earth}}$?

A 0.059 **B** 0.24 **C** 4.1 **D** 17

12 A car tyre, initially at 25 ºC, has been inflated to a pressure of 200 kPa as indicated by the pressure gauge. This means that the pressure in the tyre is 200 kPa above atmospheric pressure of 100 kPa.

After driving on hot roads, the temperature of the air in the tyre is 50 ºC.

What is the percentage increase in the pressure gauge reading?

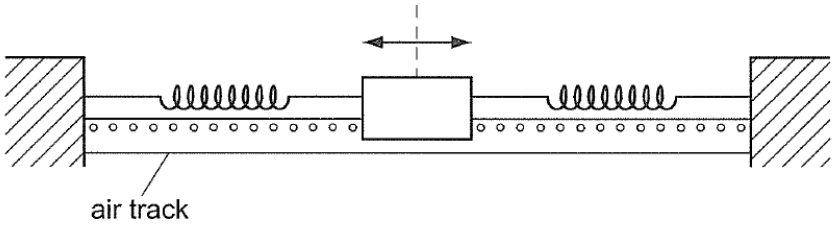
A 8.4 % **B** 12.5 % **C** 100 % **D** 150 %

13 A copper block is placed in thermal contact with an iron block at a higher temperature. The blocks have the same mass, and energy exchange with the surroundings is negligible. There is negligible change in the volume of the blocks.

Which of the following will be true of the magnitudes of the change in internal energy and temperature of each block when thermal equilibrium is reached?

	magnitude of change in internal energy	magnitude of change in temperature
A	Equal	Equal
B	Different	Equal
C	Equal	Different
D	Different	Different

14 A linear air track vehicle held centrally on an air track by two springs makes small simple harmonic oscillations.



When its displacement from equilibrium is 20 mm, its speed is 30 mm s^{-1}.
When its displacement 30 mm, its speed is 20 mm s^{-1}.

What is its speed when its displacement is 25 mm?

A 24 mm s^{-1} **B** 25 mm s^{-1} **C** 26 mm s^{-1} **D** 29 mm s^{-1}

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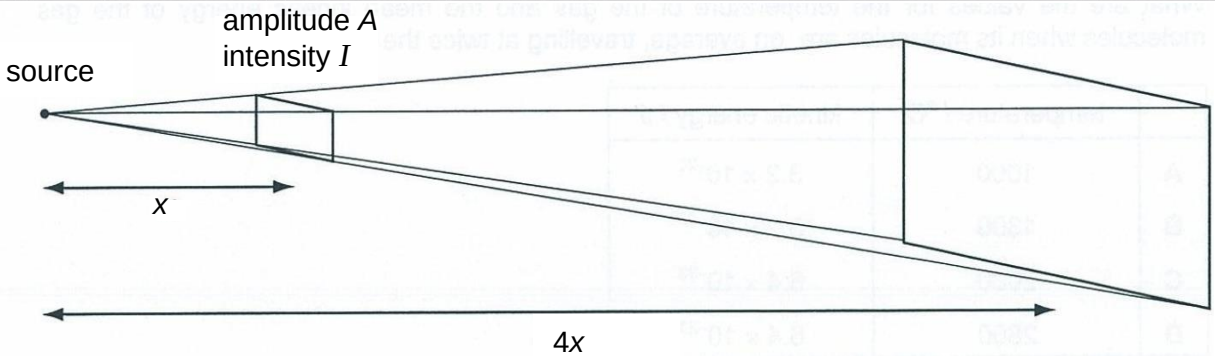
15 Energy from a point source of waves spreads out uniformly in all directions. The amplitude and intensity of the waves at a distance x from the source are A and I respectively, as shown.



Assuming no absorption by the medium through which the waves are travelling, what are the amplitude and intensity at a distance of $4x$?

	intensity at distance $4x$	amplitude at distance $4x$
A	$\frac{I}{16}$	$\frac{A}{4}$
B	$\frac{I}{4}$	$\frac{A}{16}$
C	$\frac{I}{4}$	$\frac{A}{2}$
D	$\frac{I}{2}$	$\frac{A}{4}$

16 Two coherent progressive waves from different sources meet at a point.

Which condition **must** be satisfied for there to be zero resultant amplitude at the point where the waves meet?

A The two waves must be emitted from their sources with the same intensity.

B The two waves must be in phase with each other at the point.

C The two waves must be travelling in opposite directions.

D The two waves must have the same amplitude at the point.

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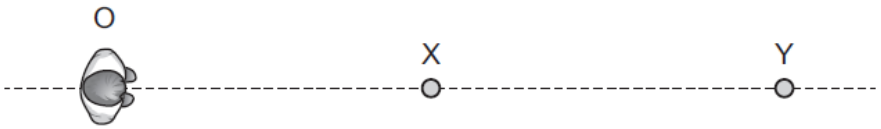
17 Two loudspeakers X and Y emit sound waves that are in antiphase and of wavelength 0.60 m.

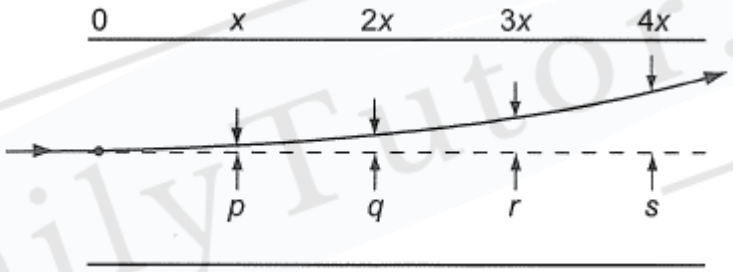
An observer O is able to stand anywhere on a straight line that passes through X and Y, as shown. The observer stands at a point where the sound waves from X and Y meet in phase.



What could be the distances OY and XY?

	distance OY / m	distance XY / m
A	1.25	3.70
B	1.50	1.20
C	2.00	2.50
D	2.20	1.60

18 The diagram shows the path of a horizontal beam of electrons passing through the uniform vertical electric field between two horizontal electrodes. The diagram is not to scale.



The vertical displacements of the beam after travelling through horizontal distances of x, $2x$, $3x$ and $4x$ are represented by p, q, r and s.

Which row represents the values of p, q, r and s?

	p / mm	q / mm	r / mm	s / mm
A	1.0	1.4	1.7	2.0
B	1.0	2.0	3.0	4.0
C	1.0	2.0	4.0	8.0
D	1.0	4.0	9.0	16.0

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19 Two wires, X and Y, are made from the same metal. The diameter of wire Y is twice that of wire X. Wire X, wire Y and a battery are connected in series.

What is the ratio $\frac{\text{average drift speed of free electron in wire X}}{\text{average drift speed of free electron in wire Y}}$?

A $\frac{1}{4}$ **B** $\frac{1}{2}$ **C** $\frac{2}{1}$ **D** $\frac{4}{1}$

20 For an electron beam, the following quantities are known or are easily measured.

- area A when beam hits a target
- beam current I
- accelerating potential difference V
- elementary charge e

Which expression gives the rate of arrival of electrons per unit area on the target?

A $\frac{I}{eA}$ **B** $\frac{IA}{e}$ **C** $\frac{V}{eA}$ **D** $\frac{Ve}{A}$

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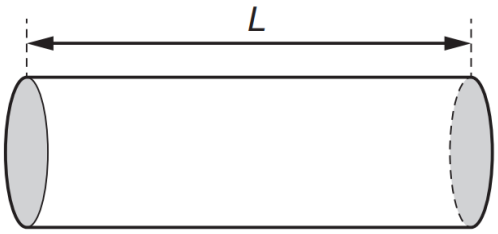
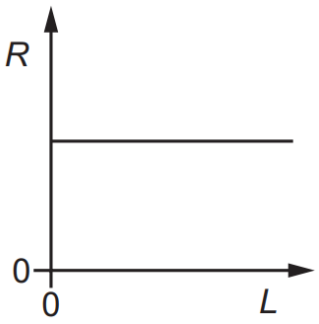
21 A piece of conducting putty (modelling clay) of constant resistivity is formed into a cylindrical shape. The resistance R between its flat ends (shaded) is measured.



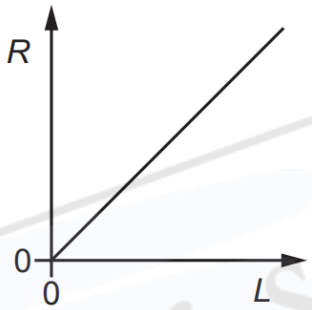
The same volume of putty is re-formed into cylinders of different lengths L, and the resistance R between the flat ends is measured for each value of L.

Which graph best shows the variation of R with L?

A



B



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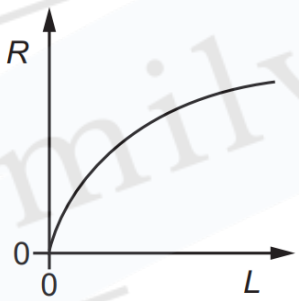

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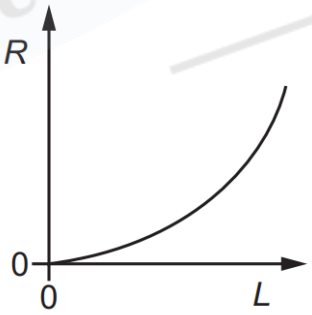

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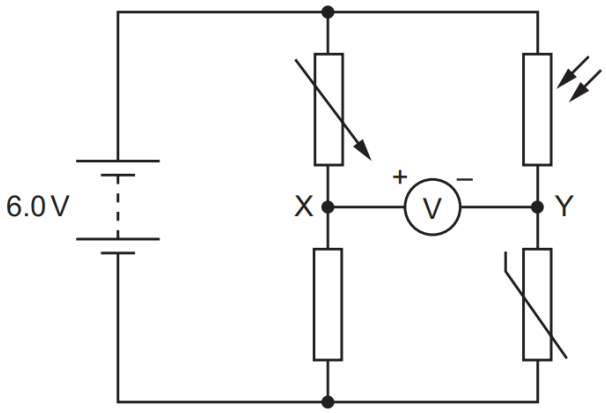
22 A battery of electromotive force (e.m.f.) 6.0 V and negligible internal resistance is connected to a voltmeter and four other components, as shown.

The voltmeter is connected between points X and Y. The positive terminal of the voltmeter is connected to X and the negative terminal of the voltmeter is connected to Y.



Initially, the resistance of each of the four components is 1.0 kΩ.

Which change, on its own, will cause the voltmeter to show a positive reading?

A Decrease the temperature of the thermistor.

B Increase the resistance of the variable resistor.

C Reduce the intensity of light incident on the light-dependent resistor (LDR).

D Replace the fixed resistor with a 500 Ω resistor.

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23 Fig. (a) shows the top view of two long parallel wires, wire X and wire Y, carrying currents I_X and I_Y respectively in a direction perpendicular to the plane of the paper. The distance between wire X and wire Y is *L*.

Fig. (b) shows the variation of the net magnetic field at distances to the right of wire Y along the line joining wire X and wire Y. At a distance *d* from wire Y, the net magnetic field is zero.

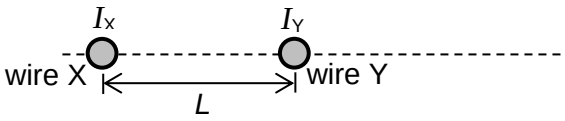

Fig. (a) top view (not to scale)

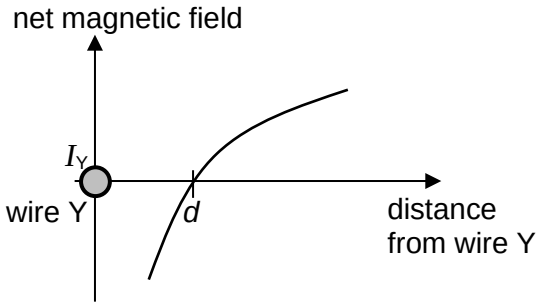

Fig. (b)

Given that the ratio $\frac{I_X}{I_Y}$ is 4.00 and taking the upwards direction to be positive, which of the following gives the relative direction of I_X and I_Y and the value of *L* in terms of *d*?

	relative direction of I_X and I_Y	*L* in terms of *d*
A	I_X and I_Y flow in opposite directions.	*d*
B	I_X and I_Y flow in the same direction.	*d*
C	I_X and I_Y flow in opposite directions.	*3d*
D	I_X and I_Y flow in the same direction.	*3d*

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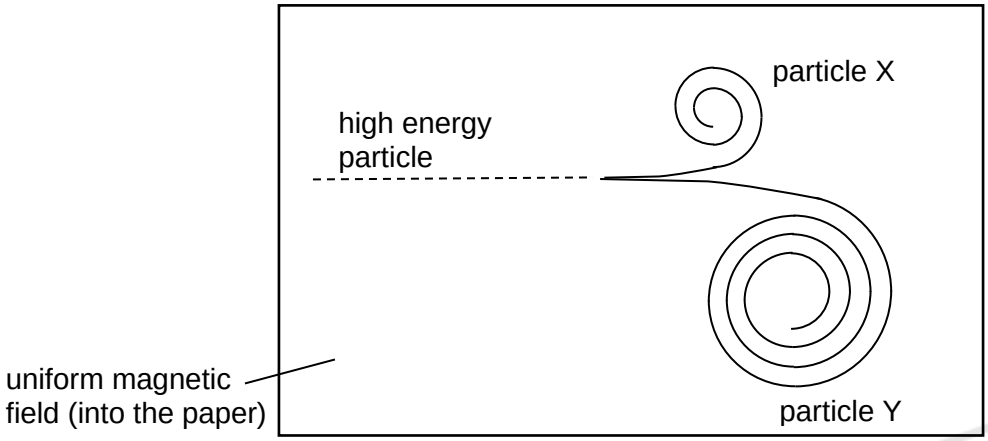
24 A high energy particle which carries no charge enters a region of uniform magnetic field directed into the paper.

The particle subsequently disintegrates to form two particles X and Y which have the same mass and same magnitude of charge. The paths of X and Y are shown in the diagram below and the initial radius of Y is twice the initial radius of X.



Which of the following statements is correct?

A Particle X is negatively charged, and particle Y is positively charged.

B Particle X has a larger momentum than particle Y.

C The speeds of both particles are increasing steadily.

D The ratio of the initial kinetic energy of particle X to particle Y is 0.25.

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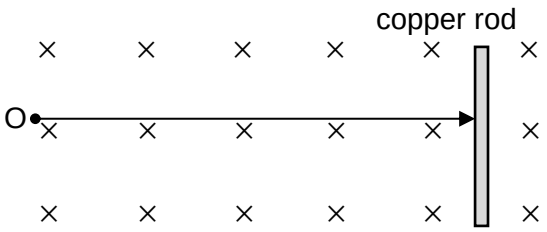
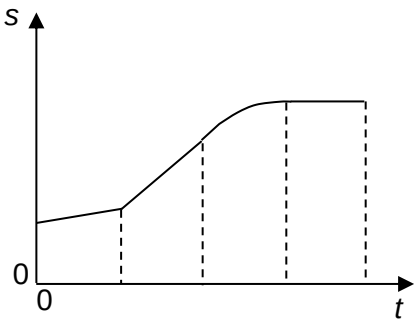
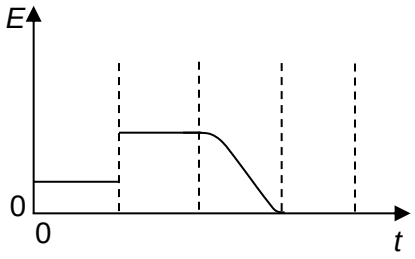
25 A copper rod is moved at right angles to a uniform magnetic field as shown in the diagram. The graph on the right shows the variation with time *t* of the displacement *s* of the copper rod from point O.



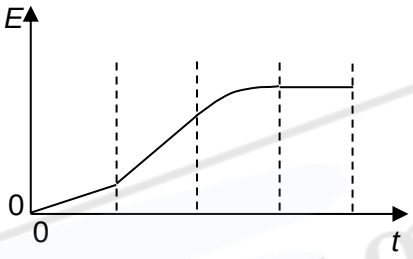


Which graph best shows the variation with time *t* of the e.m.f. *E* induced across the rod?

A



B



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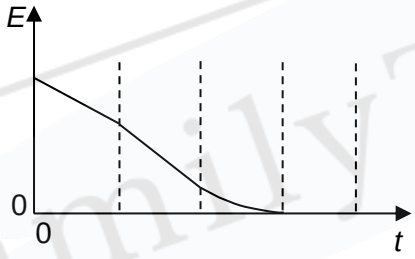

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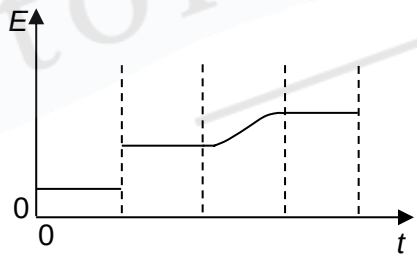
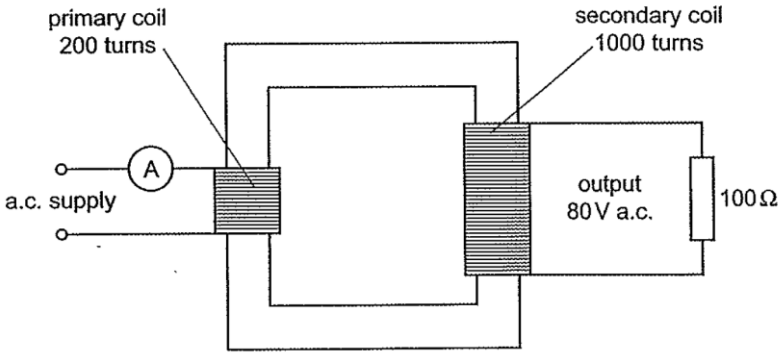


26 A 100% efficient transformer is connected to a sinusoidal a.c. supply.



What is the reading on the ammeter?

A 0.16 A **B** 0.80 A **C** 2.8 A **D** 4.0 A

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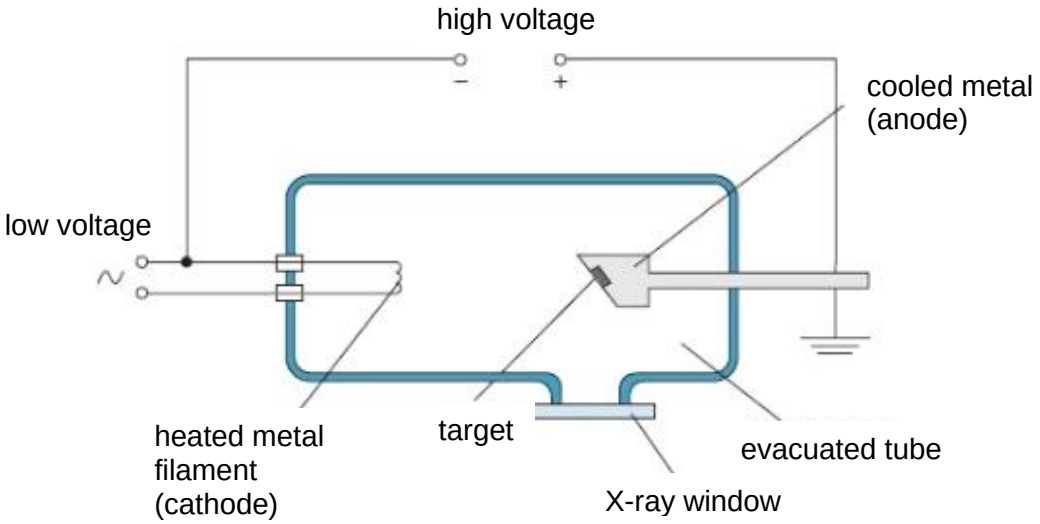
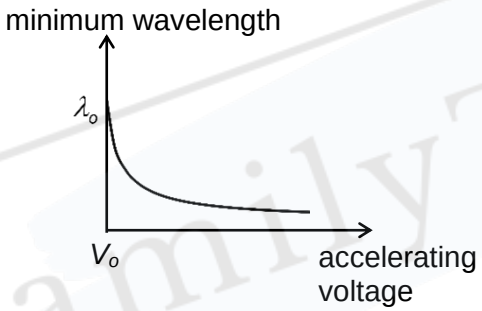
27 In an X-ray tube shown, the high voltage supply accelerates the electrons towards the target. X-rays with a range of wavelengths are emitted from the target.



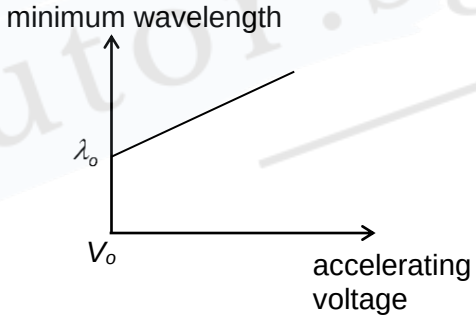
When the high voltage supply is V_o, the minimum wavelength of the x-ray emitted is λ_o.

Which of the following graph shows the variation with accelerating voltage of the minimum wavelength emitted?

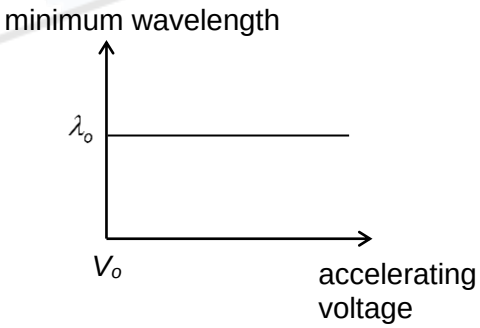
A



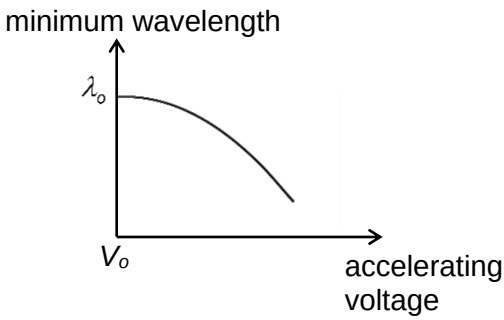
B



C



D



[Turn Over

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28 A monochromatic light source emits a narrow, parallel beam of light of wavelength 546 nm on the cathode of a photocell. The power in the beam is 0.080 W.

If only 1.5% of the photons incident on the cathode liberate electrons, what is the photocell current?

A 0.30 mA **B** 0.53 mA **C** 10.0 mA **D** 35.0 mA

29 In the α-particle scattering experiment, a beam of α-particles is aimed at a thin gold foil. Most of the α-particles go straight through or are deflected by a small angle. A very small proportion are deflected by more than 90°, effectively rebounding towards the source of the α-particles.

Which conclusion about the structure of atoms **cannot** be drawn from this experiment alone?

A Most of the atom is empty space.

B Most of the mass of an atom is concentrated in the nucleus.

C The nucleus contains both protons and neutrons.

D The nucleus is charged.

30 Which of the following radioactive samples has the greatest activity?

	nuclide	amount / mole	half-life / day
A	$^{225}_{89}Ac$	0.003	10
B	$^{228}_{90}Th$	0.1	400
C	$^{228}_{88}Ra$	0.6	2100
D	$^{241}_{94}Pu$	1.0	4800

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Anderson Serangoon Junior College 2023 H2 Physics Prelim P1 Exam Solution

Paper 1 (30 marks) **E – Easy, A – Average, D – Difficult**

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

Easy: 6, Average: 15, Difficult: 9

1	**D** $V = \frac{W}{Q} = \frac{Fs}{It} = \frac{mas}{It}$ Base units of V = $\frac{kg \times ms^{-2} \times m}{A \times s} = kgm^2s^{-3}A^{-1}$	**E**
2	**A** $R = \frac{V}{I} = \frac{1.200}{0.48} = 2.5\Omega$ Reading in ammeter is recorded to 2 dp. For division, the s.f. of calculated data is recorded to the lowest s.f. of the raw data	**A**
3	**B** Using $s = ut + ½ t^2$ $9 = u(2) + ½ a(2)^2$ --- (1) $21 = u(4) + ½ a(4)^2$ --- (2) Solving (1) & (2), a = 0.75 m s^{-2}	**D**
4	**B** Initial vertical velocities for both stones, $u_y = 0$ $s_y = u_y t + ½ gt^2 = ½ gt^2$ Both stones will take the same time to fall through the same height since they experience the same gravitational acceleration g.	**E**
5	**B** Change in momentum = 2(5.0 – 30) = -50 Area under F-t graph = Change in momentum $-F$ x (4 + 6) / 2 = -50 F = 10 N	**A**

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6	**B** Due to smaller weight, a smaller air resistance is needed by the foam ball to achieve zero net for to reach terminal velocity. Hence time required to reach terminal velocity is shorter. So option A and C are eliminated. In addition. since air resistance depends on speed, a smaller air resistance will require a smaller terminal velocity. Hence option D is eliminated.	**D**
7	**C** Tension in string is 3.0*W* (2.0 *W* + 1.0*W*) Let distance between string and CG be *d* Taking moments abouts the CG (which is at 0.5x) (2.0 W) × (0.3x) = (3.0 W) × *d* *d* = 0.2x When load is moved, it will be 0.3x away from the CG (but on the other side) Hence, the string needs to be placed 0.2x from the CG (but on the other side) for rod to be in equilibrium. Distance moved by string = 0.2x + 0.2x = 0.4x	**A**
8	**A** <u>Option A:</u> WD to change speed of object from 2 m s^{-1} to 3 m s^{-1} = ½ m ($3^2 - 2^2$) = ½ m (5) WD to change speed of object from 1 m s^{-1} to 2 m s^{-1} = ½ m ($2^2 - 1^2$) = ½ m (3) So option A is correct. <u>Option B:</u> When an object slows down, there has to be negative work done by a force (opposing the motion of the object). Hence option B is not correct. <u>Option C:</u> When lifting an object 1 m at constant velocity, WD = mgh = mg(1) When moving an object 1 m across a smooth horizontal surface at constant speed, there is no need for a force to keep it at constant velocity. Therefore, WD is zero. Hence option C is not correct. <u>Option D:</u> When an object is dropped, the force of gravity is in the direction of the motion of the object. There is WD by the force of gravity and is given by W×d. Hence option D is not correct.	**A**
9	**C** Distance moved in 60° = 0.40 × $\frac{60}{360}(2\pi)$ = 0.4189 m Since both masses were displaced vertically by 0.4187, the net increase in total GPE of the weights = *m g h* = (20 – 15) / 9.81 × 9.81 × 0.4189 = 2.1 J	**D**

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10	**C** If the roller coaster have lost contact, the normal contact force of track on roller coaster must be zero. Centripetal force will be provided by component of weight pointing towards O, if it just remains in contact. At position P, Component of weight towards O = mg cos 30° To maintain contact, $mg\cos 30° = \frac{mv^2}{r}$ $v = \sqrt{rg\cos 30°}$ $= \sqrt{1.0(9.81)\cos 30°}$ $= 2.91\ \text{m s}^{-1}$ So, option C will be the best option.	**D**
11	**C** $g_N = g_E$ and $g = \frac{GM}{R^2}$ $\frac{GM_N}{R_N^2} = \frac{GM_E}{R_E^2}$ $\frac{R_N}{R_E} = \sqrt{\frac{M_N}{M_E}} = \sqrt{17} = 4.1$	**A**
12	**B** $\frac{p_2}{T_2} = \frac{p_1}{T_1}$ $\frac{p_2}{50 + 273} = \frac{200000 + 100000}{25 + 273}$ p_2 = 325000 Pa Hence the gauge reading is 225 kPa. Percentage increase is (225 – 200) / 200 x 100% = 12.5%	**A**
13	**C** 1st Law of Thermodynamics $\Delta U = Q + W$ Since no work is done by or done on the blocks, $W = 0$ $\Delta U = Q$ Energy exchange with surroundings is negligible, so	**A**

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	Heat gained by copper = Heat loss by iron $Q_{copper} = -Q_{iron}$ $\Delta U_{copper} = -\Delta U_{iron}$ Also, $Q_{copper} = mc_{copper}\Delta\theta_{copper}$ $Q_{iron} = mc_{iron}\Delta\theta_{iron}$ Since $c_{copper} \neq c_{iron}$, $\Delta\theta_{copper} \neq \Delta\theta_{iron}$	
14	**C** $v = \pm\omega\sqrt{x_o^{\,2} - x^2}$ $\frac{30}{20} = \frac{\sqrt{x_0^2 - 20^2}}{\sqrt{x_0^2 - 30^2}}$ $x_0^2 = 1300$ $\frac{v}{30} = \frac{\sqrt{x_0^2 - 25^2}}{\sqrt{x_0^2 - 20^2}} = \frac{\sqrt{675}}{\sqrt{900}} = 0.866$ $v = 0.866 \times 30 = 26 \text{ mm s}^{-1}$	**A**
15	**A** $I \propto \frac{1}{r^2}$ $\frac{I_X}{I_{4x}} = \left(\frac{4x}{x}\right)^2 = 16$ $I_{4x} = \frac{1}{16}I$ $I \propto A^2$ Since $I_{4x} = \frac{1}{16}I$, $\frac{I_{4x}}{I} = \left(\frac{A_{4x}}{A}\right)^2$ $\frac{1}{16} = \left(\frac{A_{4x}}{A}\right)^2$ $\frac{A_{4x}}{A} = \frac{1}{4} \quad \Rightarrow \quad A_{4x} = \frac{A}{4}$	**A**
16	**D** For zero resultant amplitude, two waves of the same type must meet in antiphase and have the same amplitude. When that happens, destructive interference occurs, and the resultant amplitude is the difference between the individual amplitude of the two waves. When two waves are emitted from their sources with the same intensity, they can travel different distances to meet at a point. Since intensity and hence amplitude decreases with distance from the source, they will meet with different amplitude. So Option A is incorrect. Two waves must be in antiphase with each other when they meet, so Option B is incorrect. Two waves do not need to travel in opposite directions for resultant amplitude to be zero. They can travel in any directions, as long as they fulfil the conditions stated in the first paragraph, to give zero resultant amplitude. So Option C is incorrect.	**E**

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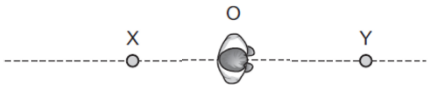
17	**C** Since loudspeakers emit waves that are in antiphase, the condition for waves to meet in phase is path difference = (n + ½) λ For Options A and C, since OY < XY, observer O is in between X and Y as shown.  For Option A, OX = XY – OY = 3.70 – 1.25 = 2.45 m Path difference of the waves from their respective sources to the observer = OX – OY = 2.45 – 1.25 = 1.20 m = 2 λ, so not correct. For Option C, OX = XY – OY = 2.50 – 2.00 = 0.50 m Path difference of the waves from their respective sources to the observer = OY – OX = 2.00 – 0.50 = 1.50 m = 2.5 λ, so correct. For Options B and D, since OY > XY, observer is to the left of X as shown in original diagram. Path difference of the waves from their respective sources to the observer = XY Option B: Path difference = 1.20 = 2 λ, so incorrect. Option D: Path difference = 1.60 m = 2.7 λ, so incorrect.	**D**
18	**D** $y = \frac{1}{2}at^2$ ……..(1) $x = ut$ ……(2) from (1) & (2) $y = \frac{ax^2}{2u^2}$, i.e $y \propto x^2$ $p: q: r: s = x^2: (2x)^2: (3x)^2: (4x)^2$ $= 1: 4: 9: 16$	**D**
19	**D** $I = nevA$ $v = I/neA$ since I , n, e are constants $v \propto 1/A \propto 1/d^2$ $\frac{v_x}{v_y} = \frac{d_y^2}{d_x^2}$ $\frac{v_x}{v_y} = \frac{(2d)^2}{d^2} = \frac{4}{1}$	**E**

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20	**A** Rate of arrival of electrons per unit area = number of electrons per unit time per unit area = $\frac{n}{tA}$, where n is the number of electrons, *t* is time and *A* is area Since current, $I = \frac{ne}{t} \quad \Rightarrow \quad \frac{n}{t} = \frac{I}{e}$ Therefore, rate of arrival of electrons per unit area = $\frac{I}{eA}$	**E**
21	**D** Volume, $V = \pi d^2 L$ When V is constant, $L \propto 1/d^2$ $R = \frac{4\rho L}{\pi d^2}$ $R \propto \frac{L}{d^2} \propto \frac{L}{1/L} \propto L^2$	**A**
22	**C** Option A: Resistance of thermistor increases. By potential divider, p.d across thermistor increases. Hence voltmeter reading is negative. Option B: By potential divider, p.d across fixed resistor will decrease. Voltmeter reading will be negative. Option C: Resistance of LDR increases. By potential divider, p.d across thermistor decreases. Hence voltmeter reading is positive. Option D: same effect as Option B.	**D**
23	**C** Since the net magnetic field at *d* from wire Y is zero, I_X and I_Y flow in opposite directions. $B \propto I$ and $B \propto \frac{1}{r}$ At *d* away from wire Y, $\frac{I_X}{(L+d)} = \frac{I_Y}{(d)}$ $\frac{4}{L+d} = \frac{1}{d}$ $L = 3d$	**D**
24	**D** $Bqv = mv^2 / r$ $v = Bqr / m$	**A**

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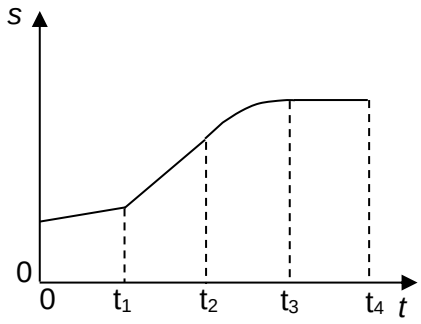
	Since both X and Y have the same mass to charge ratio, $\frac{KE_X}{KE_Y} = \left(\frac{v_X}{v_Y}\right)^2 = \left(\frac{R_X}{R_Y}\right)^2 = \left(\frac{1}{2}\right)^2 = 0.25$	
25	**A** $E = Blv$ Gradient of s-t graph = speed  The speed of the rod between 0 and t_1 is constant and is a positive value. The speed of the rod between t_1 and t_2 is constant and is greater than speed of the rod between 0 and t_1. The speed of the rod between t_2 and t_3 decreases to zero. The speed of the rod between t_3 and t_4 is zero.	**D**
26	**D** $\frac{I_p}{I_s} = \frac{N_s}{N_p}$ $\frac{I_p}{\left(\frac{80}{100}\right)} = \frac{1000}{200}$ $I_p = 4.0$ A	**A**
27	**A** Loss in EPE = Gain in KE = max E_p $eV_{acc} = \frac{hc}{\lambda_{min}}$ $\lambda_{min} = \frac{hc}{e}(\frac{1}{V_{acc}})$ Since hc/e is a constant, the graph should be a curve showing inversely proportional relationship between λ_{min} and V_{acc} .	**A**

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28	**B** $P = \frac{E}{t} = \frac{n_p E_p}{t}$ $\frac{n_p}{t} = \frac{P}{E_p} = \frac{P\lambda}{hc}$ $\frac{n_e}{t} = \frac{1.5}{100}(\frac{n_p}{t}) = \frac{1.5}{100}(\frac{P\lambda}{hc})$ $I = \frac{n_e e}{t} = \frac{1.5}{100}(\frac{P\lambda}{hc})e$ $= \frac{1.5}{100}(\frac{0.080(546\times10^{-9})}{hc})e$ $= 5.27\times10^{-4}$ A $= 0.53$ mA	**A**
29	**C** Option A: can be drawn from the observation that most of the α-particles go straight through or are deflected by a small angle. Option B: can be drawn from the observation that a very small proportion are deflected by more than 90°, effectively rebounding towards the source of the α-particles, so the nucleus must be massive to cause the rebounding of the α-particles. Option C: the deflection and rebounding of α-particles can show that the nucleus is positively charged, but it cannot show that there are neutrons in the nucleus. At the time of the experiment, the neutron has not yet been discovered. Option D: can be drawn from the observation that there are α-particles which are deflected or rebounded.	**E**
30	**A** $A = \lambda N = \frac{\ln 2}{T_{1/2}} N$ where N is the number of molecules in the sample N = n N_A And the A of each can be compared by finding the nuclide with the greatest ratio of $\frac{n}{T_{1/2}}$ Option A: $\frac{n}{T_{1/2}} = \frac{0.003}{10} = 0.0003$ Option B: $\frac{n}{T_{1/2}} = \frac{0.1}{400} = 0.00025$ Option C: $\frac{n}{T_{1/2}} = \frac{0.6}{2100} = 0.00029$ Option D: $\frac{n}{T_{1/2}} = \frac{1.0}{4800} = 0.00020$	**A**

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Name: _____ ( ) Class: 23 / _____

ANDERSON SERANGOON JUNIOR COLLEGE

2023 JC2 Preliminary Examination

PHYSICS Higher 2 9749/02

Paper 2 Structured Questions **Wednesday 13 September 2023**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and class in the spaces 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	
Paper 2 (80 marks)	
1	
2	
3	
4	
5	
6	
7	
8	
Deductions	
Total	

This document consists of **26** printed pages and **2** blank pages.

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Data

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

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Formulae

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

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

1 A spring has an unstretched length of 6.0 cm. The top of the spring is attached to a fixed point.

A brass block of mass 180 g and volume 2.0×10^{-5} m^3 is suspended from the lower end so that the length of the spring increases to 9.6 cm, shown in Fig. 1.1.

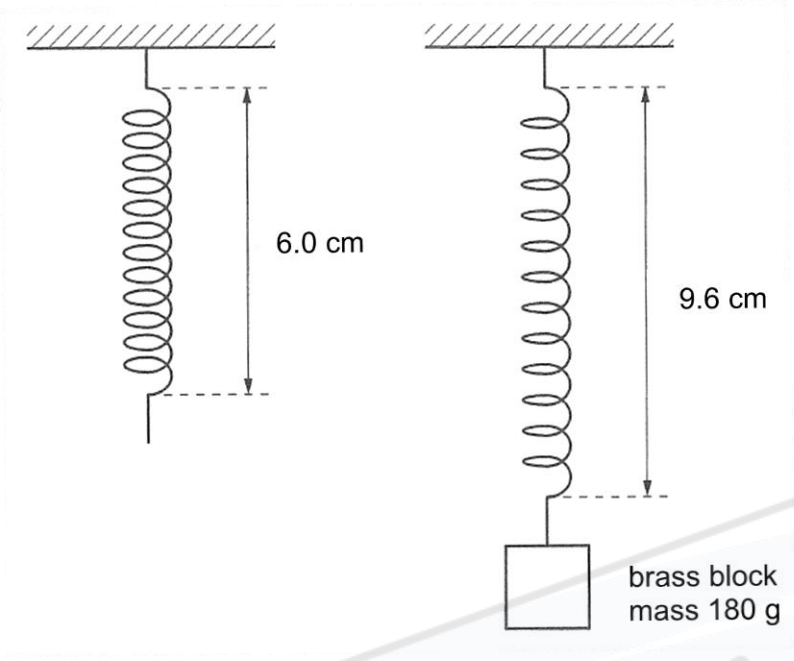

Fig. 1.1

Fig 1.1 is not drawn to scale.

(a) Calculate the force constant of the spring.

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

(b) The percentage uncertainty in the mass is ± 2.0%. The actual uncertainty in each measurement of the length of the spring is ± 1 mm.

Calculate the actual uncertainty in the force constant.

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

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(c) The block is submerged in a liquid of density ρ. The length of the spring is now 9.0 cm, as shown in Fig. 1.2.

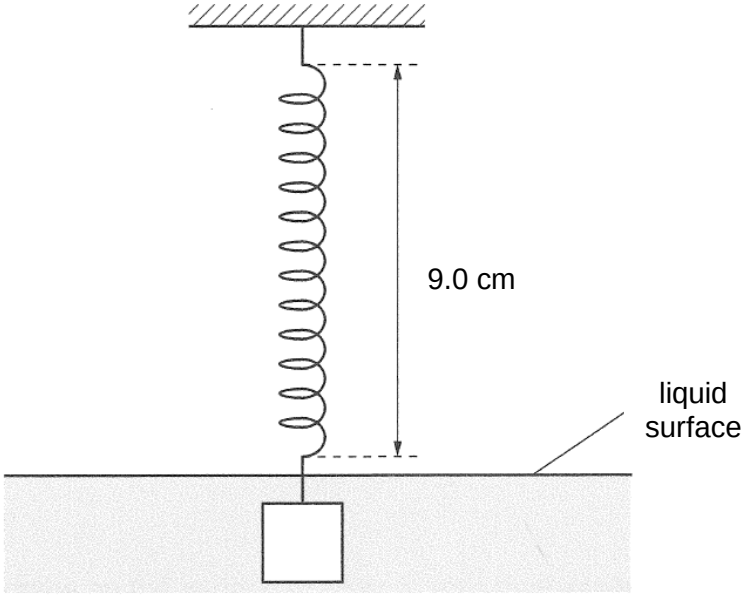

Fig. 1.2

(i) Using the definitions of pressure and density, show that the hydrostatic pressure p at a depth h below the surface of the liquid is given by

$$p = \rho g h$$

where g is the acceleration of free fall.

[2]

(ii) Hence, or otherwise, determine ρ.

ρ = ... kg m^{-3} [3]

[Total: 9]

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2 Two blocks travel directly towards each other along a horizontal, frictionless surface, as illustrated in Fig. 2.1.

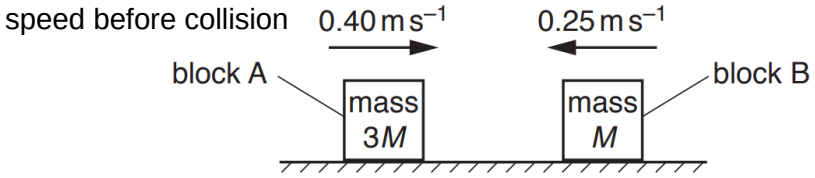

Fig. 2.1

Block A has a mass 3*M* and is moving towards block B with a speed of 0.40 m s^{-1}. Block B has a mass *M* and is moving towards block A with a speed of 0.25 m s^{-1}.

(a) Explain whether, during the collision, it is possible for both blocks to be at rest simultaneously.

……

……

…… [2]

(b) **(i)** After the blocks collide, block A continues its direction of motion and moves off with a speed of 0.20 m s^{-1}.

Calculate the speed of block B after the collision.

speed = ……m s^{-1} [1]

(ii) Use your answer in **(b)(i)**, state and explain the direction of motion of block B.

……

…… [1]

(c) A light plasticine is placed on block A so that the two blocks stick together after collision.

State and explain whether the collision is elastic or inelastic.

……

……

…… [2]

[Total: 6]

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Question 3 starts on the next page.

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3 **(a)** **(i)** Define *gravitational potential* at a point.

……

……

…… [1]

(ii) Suggest why, for small changes in height near the Earth's surface, gravitational potential is approximately constant.

……

……

……

…… [2]

(b) An isolated solid sphere of radius r may be assumed to have its mass M concentrated at its centre. The magnitude of the gravitational potential at the surface of the sphere is ϕ.

On Fig. 3.1, show the variation of the gravitational potential with distance d from the centre of the sphere for values of d from $d = r$ to $d = 4r$.

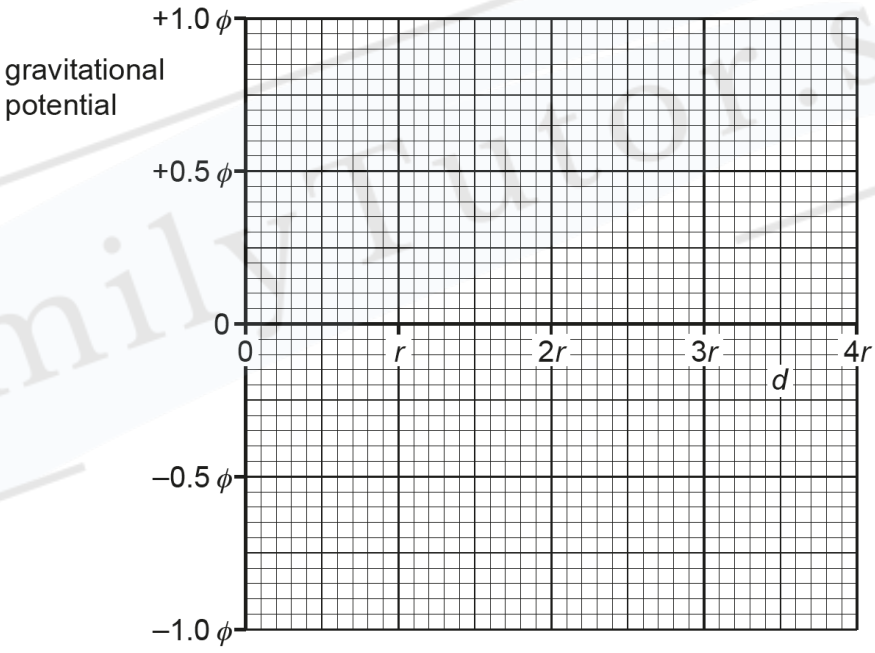

Fig. 3.1

[2]

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(c) The sphere in **(b)** is a planet with radius r of 6.4×10^6 m and mass M of 6.0×10^{24} kg. The planet has no atmosphere.

A rock, initially at rest a long distance from the planet, travels towards its surface.

Calculate the change in speed of the rock as its distance from the centre of the planet changes from $4r$ to $3r$.

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

[Total: 8]

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4 Fig. 4.1 shows the variation with time t of the height h above the ground of an object of mass 36 kg that is undergoing vertical simple harmonic motion.

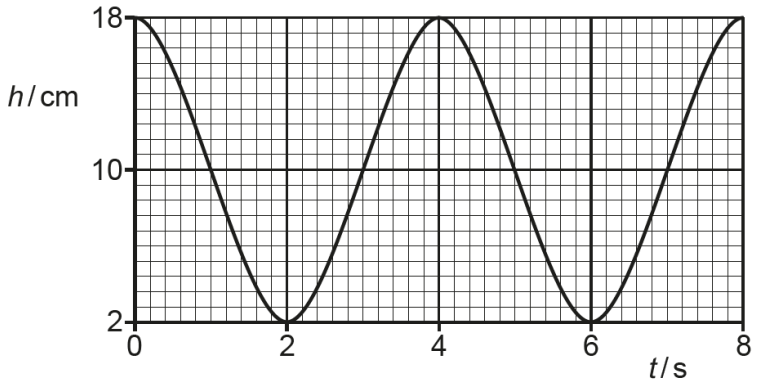

Fig. 4.1

(a) State the defining equation for simple harmonic motion. Identify the meaning of each of the symbols used to represent physical quantities.

……

……

…… [1]

(b) For the oscillations of the object,

(i) show that the angular frequency ω is 1.6 rad s^{-1},

[1]

(ii) determine the total energy E.

E = ... J [3]

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(c) On Fig. 4.2, sketch the variation with h of the kinetic energy E_K of the object.

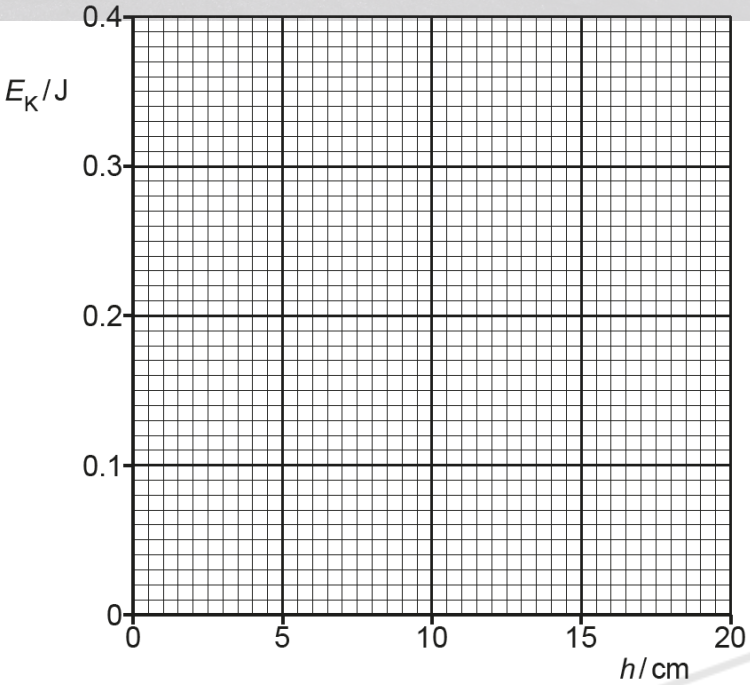

Fig. 4.2

[3]

[Total: 8]

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5 **(a)** State the relationship between electric potential and electric field strength at a point.

……

……

……[2]

(b) Two parallel metal plates A and B are situated a distance 1.2 cm apart in a vacuum, as shown in Fig. 5.1.

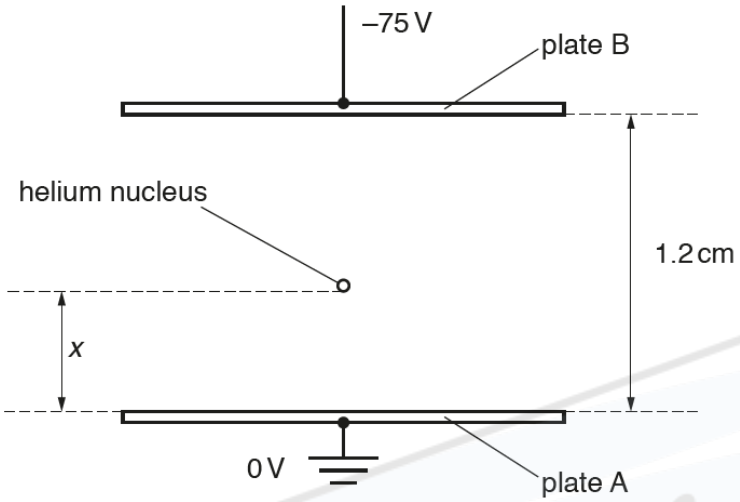

Fig. 5.1

Plate A is earthed and plate B is at a potential of –75 V.

A helium nucleus is situated between the plates, a distance x from plate A.

Initially, the helium nucleus is at rest on plate A where $x = 0$.

(i) On Fig. 5.1, draw an arrow to show the direction of the electric field. [1]

(ii) Determine the magnitude E of the electric field strength.

E = ... V m^{-1} [1]

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(iii) The helium nucleus is free to move between the plates. By considering energy changes of the helium nucleus, explain why the speed at which it reaches plate B is independent of the separation of the plates.

……

……

…… [1]

(iv) As the helium nucleus moves from plate A towards plate B, its distance x from plate A increases.

Calculate the speed of the nucleus after it has moved a distance x = 0.40 cm from plate A.

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

[Total: 8]

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6 **(a)** Explain what is meant by a progressive transverse wave.

progressive ……

……

……

transverse ……

……

……[2]

(b) A wave of frequency f and wavelength λ has speed v.

Using the definition of speed, deduce the equation $v = f\lambda$.

[2]

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(c) Light is polarised when it passes through a sheet of material known as polaroid.

Two sheets of polaroid P and Q are placed close to one another, with their planes parallel, as shown in Fig. 6.1.

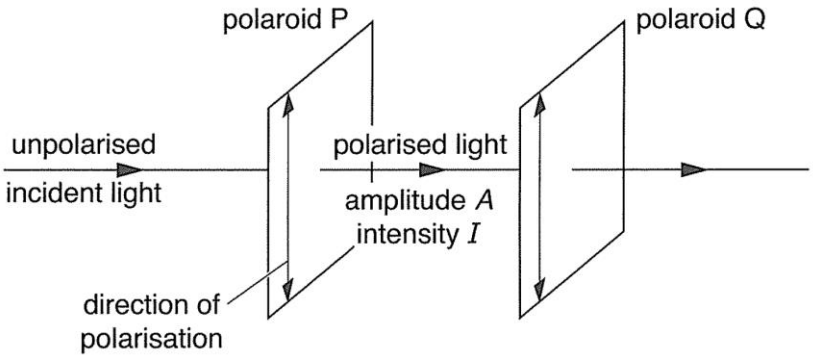

Fig. 6.1

A parallel beam of light passes through polaroid P. The beam, after passing through polaroid P, has amplitude A and intensity I.

(i) The polaroid Q is now rotated about the axis of the light beam, as shown in Fig. 6.2.

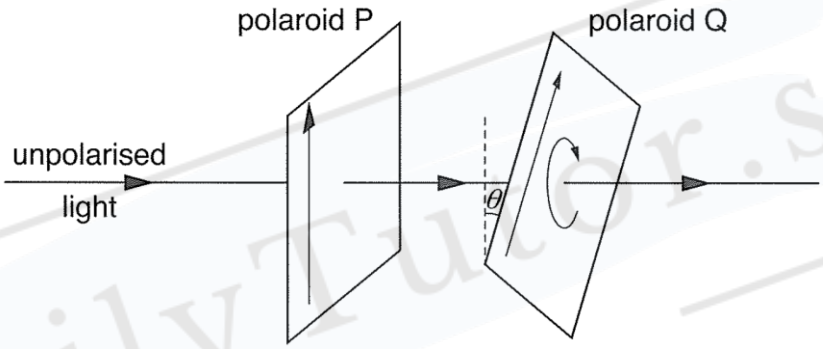

Fig. 6.2

The plane of polaroid Q remains parallel to the plane of polaroid P.

The angle between the direction of polarisation of polaroid P and of polaroid Q is θ.

Complete Table 6.1 to show the amplitude, in terms of A, and the intensity, in terms of I, of the light transmitted through polaroid Q for angle θ equal to 180°, 90° and 60°.

Table 6.1

angle θ	amplitude	intensity
180°		
90°		
60°		

[3]

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(ii) Another polaroid R is placed close to polaroid P and Q, with their planes parallel, as shown in Fig. 6.3.

The polaroid Q is rotated about the axis of the light beam, as shown in Fig. 6.3.

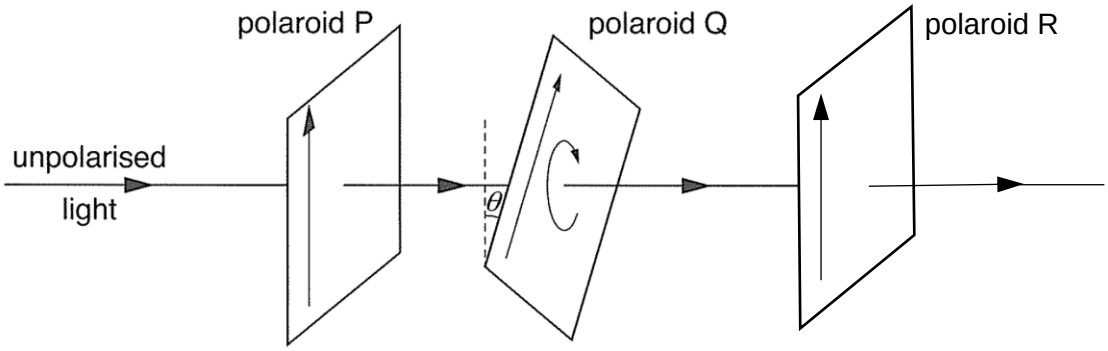

Fig. 6.3

The plane of polaroid Q remains parallel to the plane of polaroid P and R.

The angle between the direction of polarisation of polaroid P and of polaroid Q is θ.

Complete Table 6.2 to show all values of angle θ for the intensity of the light transmitted through polaroid R, that is equal to zero, maximum and $\frac{I}{2}$ respectively, as polaroid Q is rotated from 0° to 180°.

Table 6.2

intensity	θ /°
zero	
maximum	
$\frac{I}{2}$	

[2]

[Total: 9]

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Question 7 starts on the next page.

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7 Fig 7.1 shows an experimental set-up to produce the emission line spectrum of a hydrogen gas.

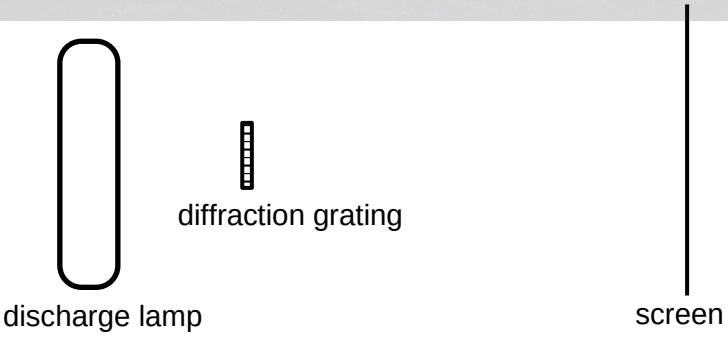

Fig. 7.1

(a) Explain how the line spectrum of hydrogen provides evidence for the existence of discrete electron energy levels in atoms.

……

……

……

……

……[2]

(b) Some of the lines of the emission spectrum of atomic hydrogen for the 1st order maxima are shown in Fig 7.2, which is drawn to scale.

Fig. 7.2 (drawn to scale)

Estimate the wavelength of the photon emitted for emission line labelled X. You can use the equation of d sin $\theta = \lambda$ and assume θ is small such that sin $\theta \approx \tan \theta \approx \theta$ in your answer.

wavelength = ……m [2]

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(c) Fig. 7.3 shows a partially completed diagram depicting the energy levels of a hydrogen atom. The energy changes corresponding to photon emissions of wavelength 486 nm and 434 nm are also shown.

Draw on Fig. 7.3 the energy level that shows the corresponding energy change that gives rise to photons of wavelength 410 nm. Label with appropriate values.

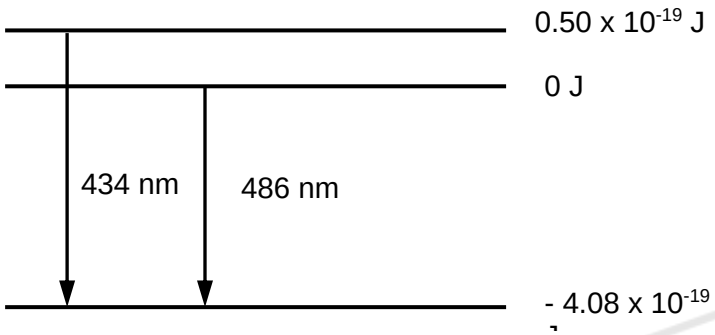

Fig. 7.3

[3]

(d) When each accelerated electron in the discharge tube has a kinetic energy of 4.08×10^{-19} J, they do not cause the excitation of the cool hydrogen gas atoms.

By reference to Fig. 7.3, explain this observation.

……..

……..[1]

(e) Describe a situation in which the electrons mentioned in **(d)** can be shown to have a wave nature.

……..

……..

……..[2]

(f) Determine the de Broglie wavelength of the electrons in the discharge tube that has a kinetic energy of 4.08×10^{-19} J.

wavelength = ……m [2]

[Total: 12]

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8 Read the article and then answer the questions that follow.

Photovoltaic (PV) Efficiency: The Temperature Effect

A photovoltaic (PV) cell absorbs light energy and converts this into electrical energy. A PV panel consists of a large number of photovoltaic cells. A PV system consists of a PV panel and the rest of the circuit to which it is connected.

Temperature generally affects current in an electrical circuit by changing the speed at which the electrons travel. In metals, this is due to an increase in resistance of the circuit that results from an increase in temperature. The opposite effect is seen in semiconductor materials where an increased temperature results in a decrease in resistance due to a change in the number density of charge carriers.

It is important that the equipment associated with a PV panel is appropriate for the context in which it will be used. The current and voltage output of a PV cell is affected by changing weather conditions. A PV system at a higher temperature will have a lower maximum voltage, lower efficiency and lower power output than the same system at a lower temperature.

Engineers must carefully choose the PV system for different temperature environments to ensure that the output voltage is not too high, which could damage the equipment. It is also important to consider the average operating voltage and current of a PV system for safety concerns, equipment capabilities and choices, and to minimize the amount of wire required for construction.

Since PV panels are more efficient at lower temperatures, engineers design systems with active and passive cooling. An example of active cooling is to pump water behind the panels to remove the heat. An example of passive cooling is to let the system be cooled by convection currents in the air.

While it is important to know the temperature of a solar PV panel to predict its power output, it is also important to know the PV panel materials because the efficiencies of different materials have varied levels of dependence on temperature. Therefore, a PV system must be engineered not only according to the maximum, minimum and average environmental temperatures at each location, but also with an understanding of the materials used.

The temperature dependence of a material is described with a temperature coefficient. For monocrystalline PV panels, if the temperature decreases by 1 °C, the voltage increases by 0.48 V, so the temperature coefficient is 0.48 V°C^{-1}. The general equation for estimating the open circuit voltage V of a material at the temperature T of the panel is

$$V = \mu(T_R - T) + V_R$$

where μ is the temperature coefficient, T_R is a reference temperature and V_R is the open circuit voltage at the reference temperature. The temperatures are in degree Celsius.

The variation with voltage of current at two different temperatures for one cell of the panel is shown in Fig. 8.1

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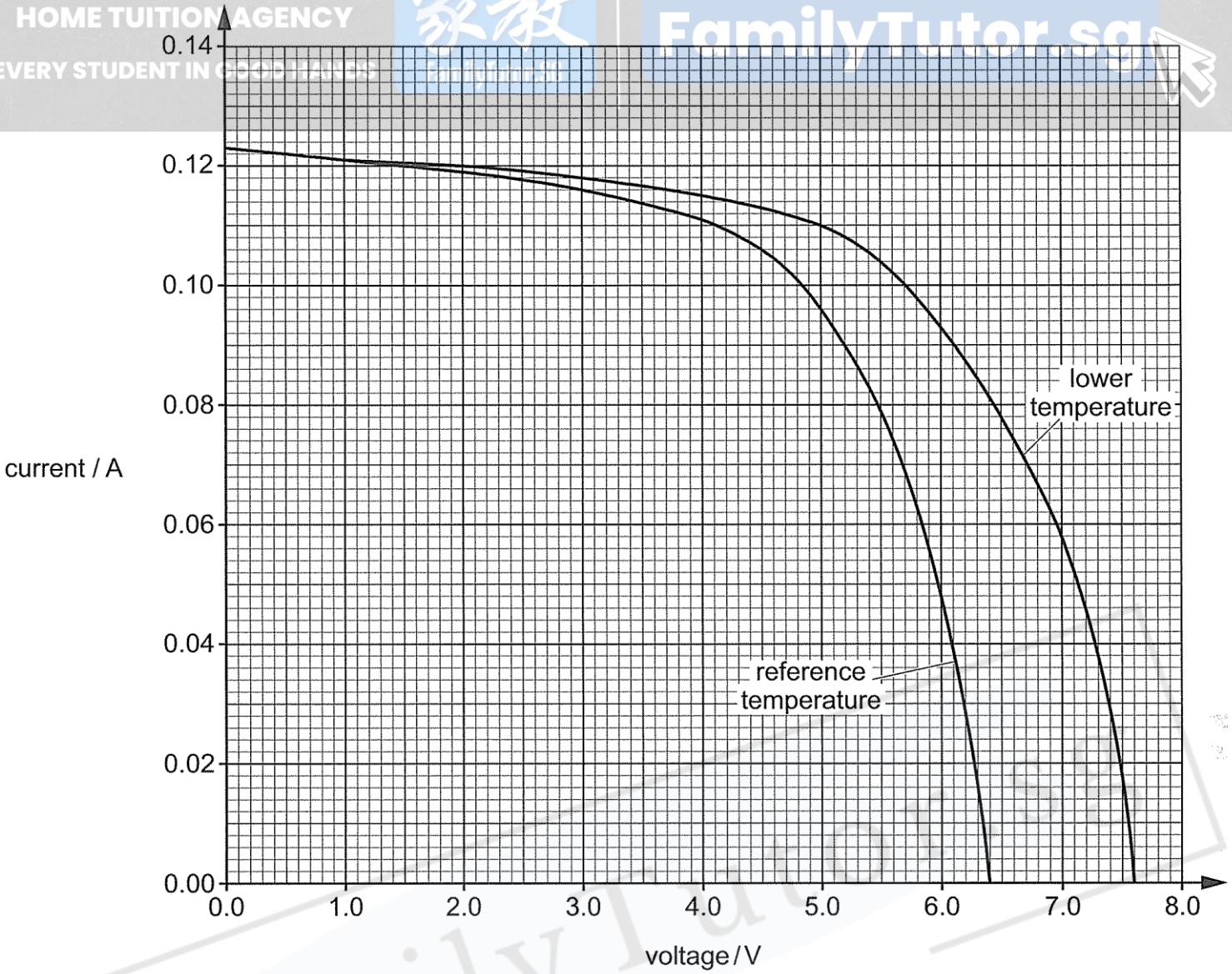

Fig. 8.1

(a) State and explain why the resistance of metals increases with temperature.

……

……

……[2]

(b) The panel produces a much larger voltage or current than an individual cell. State how the cells are connected in a panel so that

(i) the voltage is increased,

……[1]

(ii) the current is increased.

……[1]

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(c) Suggest why engineers do not design systems with active cooling alone.

……

……

……[1]

(d) Suggest how passive air cooling may be enhanced for a PV panel.

……

……

……[1]

(e) **(i)** Use Fig. 8.1 to state the open circuit voltage (e.m.f.) of the PV cell at both the reference temperature and the lower temperature.

V_R = ... V

V = ... V [1]

(ii) Use Fig. 8.1 to describe qualitatively the variation with temperature of the current in the cell.

……

……

……

……

…… [2]

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(iii) Fig. 8.2 shows the variation with temperature T of the open circuit voltage V. Draw the line of best fit. [1]

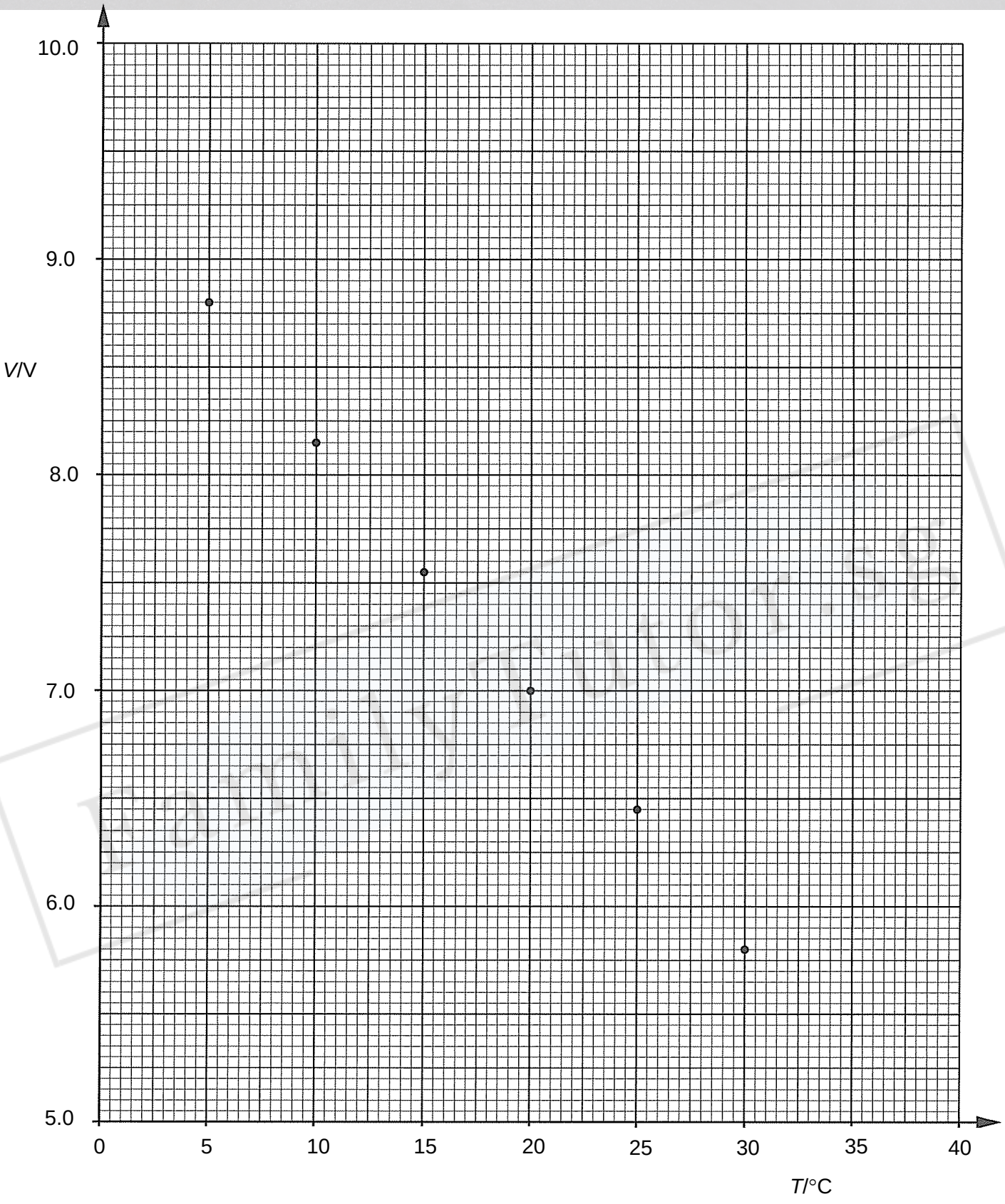

Fig. 8.2

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(iv) Use Fig. 8.2 to determine the constants μ and T_R.

μ = ... V °C^{-1}

T_R = ... °C [4]

(v) Use your answers to **(e)(i)** and **e(iv)** to determine the lower temperature used to obtain the data for Fig. 8.1.

lower temperature = ... °C [1]

(vi) The PV cell is producing 6.0 V at the reference temperature.

On Fig. 8.1, indicate the area which represents the output power of the cell. [1]

(vii) Use Fig. 8.1 to estimate the maximum power output of the PV cell at the reference temperature.

maximum power output = ... W [2]

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(f) **(i)** A PV cell may have multiple layers of different semi-conducting materials. As the number of layers increase, the efficiency of conversion of light energy to electrical energy increases.

Suggest a reason why the efficiency increases.

……

……

…… [1]

(ii) Suggest how the angle between the PV panel and the incident sunlight affects the power output of the PV panel.

……

…… [1]

[Total: 20]

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Anderson Serangoon Junior College 2023 H2 Physics Prelim P2 Exam Mark Scheme

Paper 2 (80 marks) **E – Easy, A – Average, D – Difficult**

ECF	Error carried forward	**SF**	Significant figures error	**M0**	No A marks awarded
AE	Arithmetic error	**BOD**	Benefit of doubt	**^**	More is needed in answer
POT	Power of ten error	**CON**	Contradictory response	**XP**	Wrong physics
TE	Transcription error	**IR**	Irrelevant (part) response		

1a	$k = \frac{F}{e}$ $= \frac{0.180 \times 9.81}{0.036}$ $= 49\ \text{N m}^{-1}$	**A**	C1 A1
1b	$k = \frac{F}{e}$ $\frac{\Delta k}{k} = \frac{\Delta F}{F} + \frac{\Delta e}{e} = \frac{2}{36} + 0.02$ $\Delta k = (\frac{2}{36} + 0.02) \times 49$ $= 3.7$ $= 4\ \text{N m}^{-1}$ *Accept* $\Delta k = \frac{k_{max} - k_{min}}{2}$	**A**	C1 A1
1ci	F is weight of the column of liquid above the area A $p = \frac{F}{A} = \frac{m_{fluid} g}{A}$ $= \frac{(V_{fluid} \rho_{fluid}) g}{A}$ $= \frac{(hA\rho_{fluid}) g}{A}$ $= h\rho g$	**A**	B1 B1 A0
1cii	$U + ke = mg$ $U = mg - ke$ $= (0.180)(9.81) - 49(0.030)$ $= 0.2958$ N $\Delta p\, A = \Delta h\, A \rho g$ $U = V \rho g$ $0.2958 = (2.0 \times 10^{-5})(9.81)\rho$ $\rho = 1500\ \text{kg m}^{-3}$	**A**	C1 C1 A1

2a	The total momentum before collision is <u>non-zero</u>. By COM, (total) <u>momentum is never zero</u>, so <u>not possible</u> for both blocks to be at rest simultaneously.	**A**	M1 A1

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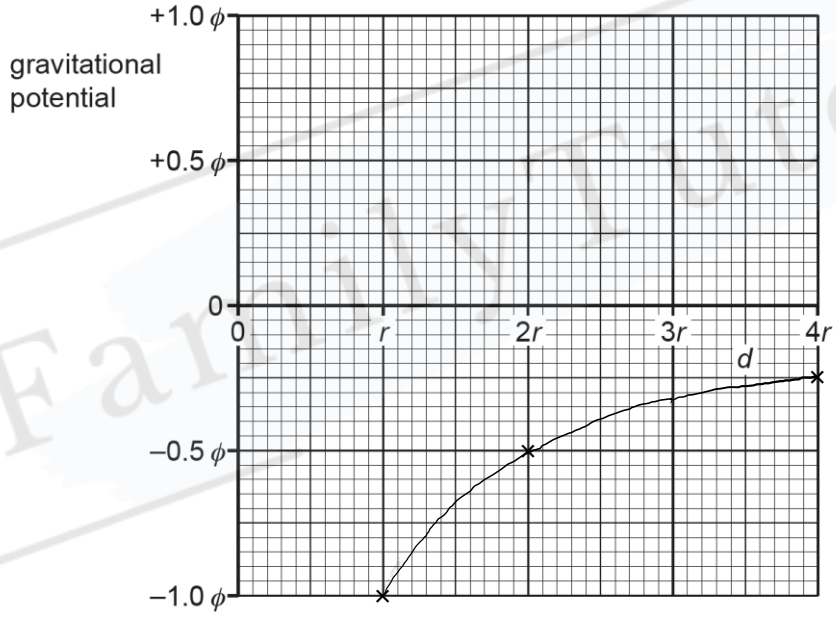
bi	By COLM, taking rightwards as positive (3M x 0.40) – (M x 0.25) = (3M x 0.20) + Mv v =0.35 m s^{-1}	**E**	 A1
bii	To right / away from block A, as direction to the right is taken as positive in **(b)(i)**	**E**	B1
c	relative speeds of approach is non-zero, and relative speeds of separation is zero Relative speed of approach is <u>not equal</u> the relative speed of separation, Hence <u>inelastic</u> collision.	**A**	M1 A1

3ai	work done per unit mass bringing (small test) mass from infinity (to the point)	**E**	B1
3aii	(near Earth's surface change in) height ≪ radius **or** height much less than radius potential inversely proportional to radius **and** radius approximately constant (so potential approximately constant)	**A**	B1 B1
3b	curve from r to $4r$, with gradient of decreasing magnitude and starting at (r, $\pm\phi$) <u>and</u> line passing through ($2r$, $\pm 0.5\phi$) and ($4r$, $\pm 0.25\phi$) line showing potential is negative throughout  	**A**	B1 B1
3ci	Gain in KE = loss in GPE $\frac{1}{2}mv^2 = 0-(-GMm/R)$ At distance R = 3r, $v = \sqrt{\frac{2GM}{3r}} = \sqrt{\frac{2\times 6.67\times 10^{-11}\times 6.0\times 10^{24}}{3\times 6.4\times 10^{6}}} = 6.46\times 10^{3}$ m s^{-1} At distance R = 4r, $v = \sqrt{\frac{2GM}{4r}} = \sqrt{\frac{2\times 6.67\times 10^{-11}\times 6.0\times 10^{24}}{4\times 6.4\times 10^{6}}} = 5.59\times 10^{3}$ m s^{-1} Change in speed = $6.46\times 10^{3} - 5.59\times 10^{3} = 8.7\times 10^{2}$ m s^{-1}	**D**	 C1 C1 A1

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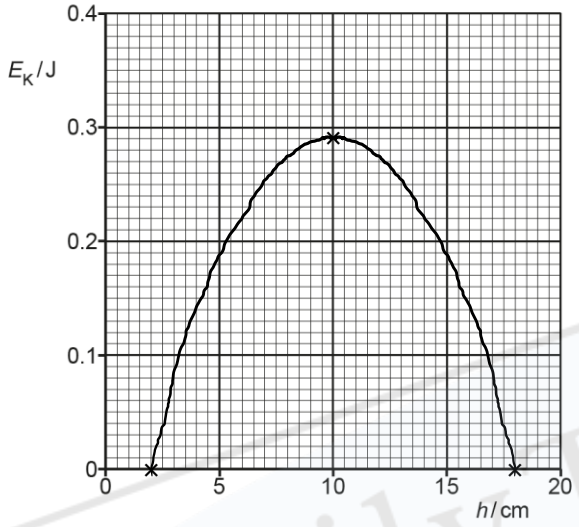
4a	$a = -\omega^2 x$ a = acceleration, x = displacement <u>from equilibrium position</u> and ω = angular frequency	**E**	B1
4bi	$\omega = 2\pi / T$ $= 2\pi / 4.0$ $= 1.57$ $= 1.6$ rad s^{-1}	**A**	 B1 A0
4bii	$E = \frac{1}{2}m\omega^2 x_0^2$ Or $E = \max E_k = \frac{1}{2}mv^2_{max} = \frac{1}{2}m\omega^2 x_0^2$ $= \frac{1}{2} \times 36 \times 1.6^2 \times 0.080^2$ $= 0.29$ J	**A**	B1 C1 A1
4c	<u>dome-shaped curve</u>, starting and ending at $E_K = 0$ maximum E_K shown as 0.29 J, position of peak shown at h = 10.0 cm line intercepts h-axis at h = 2.0 cm and at h = 18.0 cm 	**D**	B1 B1 B1

5a	The field strength at a point equals the <u>negative</u> of the potential gradient there. i.e. the electric potential gradient is the electric field strength the <u>direction</u> of the field is the same as the direction of <u>decreasing</u> potential.	**A**	(B2) B1 B1
5bi	Straight line vertically upward	**E**	B1
5bii	E = V/d $= 75/(1.2 \times 10^{-2})$ $= 6250$ V m^{-1}	**E**	 A1
5biii	gain in kinetic energy (= loss in potential energy) = charge × p.d. **or** $qV = \frac{1}{2}mv^2$ because separation not in expressions so v is independent of separation	**D**	B1 A0
5biv	(at x = 0.40 cm), potential = (–) 75 × 0.40 / 1.2 (= (–) 25 V) $\frac{1}{2}mv^2 = qV$ $\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 25$ Or $a = Vq / dm$ **and** $v^2 = 2as$	**D**	C1 C1

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	$v^2 = (2 \times 75 \times 2 \times 1.60 \times 10^{-19} \times 0.40 \times 10^{-2}) / (1.2 \times 10^{-2} \times 4 \times 1.66 \times 10^{-27})$ $v = 4.9 \times 10^4$ m s^{-1}		(C1) A1

6a	A progressive wave is a wave in which energy is carried from one point to another by means of vibrations or oscillations within the wave. A transverse wave is a wave in which the oscillations of the particles in the wave are at right angles to the direction of transfer of energy of the wave.	**E**	B1 B1
6b	Speed, v is defined as distance travelled divided by the time taken. From the definition of wavelength, λ, in one cycle of the source, the wave energy moves a distance λ. The time taken for one cycle is the time period T. Since $f = 1 / T$, wave speed, v = (total distance / time taken) $v = \frac{\lambda}{T} = f\lambda$	**E**	B1 B1 A0
6ci	<table><tr><td>Angle θ</td><td>amplitude</td><td>intensity</td></tr><tr><td>180°</td><td>A</td><td>I</td></tr><tr><td>90°</td><td>0</td><td>0</td></tr><tr><td>60°</td><td>0.50A</td><td>0.25I</td></tr></table>intensity $\propto \cos^2\theta$	**A**	B1 B1 B1
6cii	<table><tr><td>intensity</td><td>angle θ</td></tr><tr><td>zero</td><td>90°</td></tr><tr><td>maximum</td><td>0°, 180°</td></tr><tr><td>$\frac{I}{2}$</td><td>32.8°, 147°</td></tr></table>Intensity after passing through polaroid Q, $I_Q = I\cos^2\theta$ Intensity after passing through polaroid R $I_R = I_Q\cos^2\theta$ $= I\cos^4\theta$	**D**	 B1 B1
7a	When atoms are excited, the electrons move from a lower energy level to a higher energy level. When the <u>electrons de-excite from a higher level to a lower level, they emit photons with energies corresponding to the differences in energy levels of the atoms,</u> giving rise to line emission spectrum. <u>Since the frequencies of the photons are fixed, the photons emitted have discrete amounts of energies. Hence, energy levels are discrete.</u> <u>*Examiner's comments:*</u> Many students did not explain how the energy of the photon is linked to the energy levels in atoms. A few students described the observations for absorption line spectrum.	**A**	M1 A1

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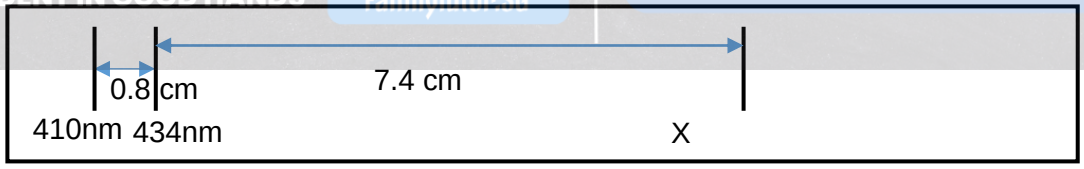
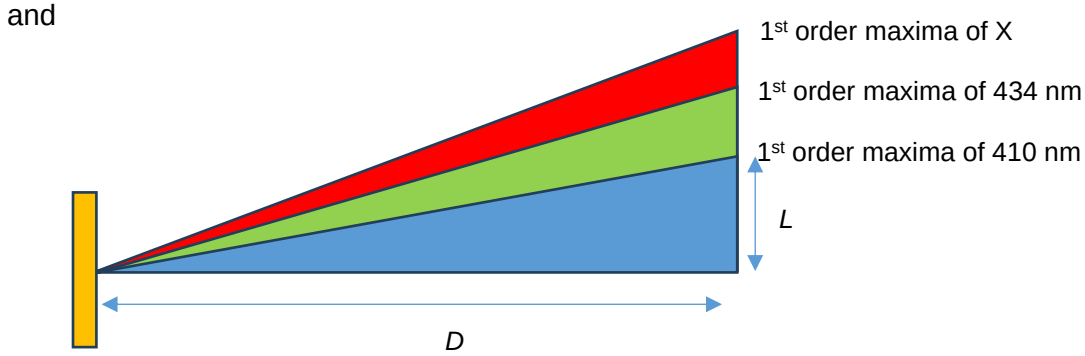
7b	 Since d sin θ = λ for 1st order maxima, and  Diffraction Grating Hence, $d(\frac{L}{D}) = 410\times10^{-9}$ (1) $d(\frac{L+0.008}{D}) = 434\times10^{-9}$ (2) From Equation 1 and 2, L=0.1367 m Using, $d(\frac{L+0.075}{D}) = X$ (3) From Equation 1 and 3, X=635×10^{-9} m Or Using idea of d sin θ = λ and small angle approximation, $\theta \propto \lambda$ Since $\theta \propto \lambda$, $\Delta\theta \propto \Delta\lambda$, $\Delta L \propto \Delta\lambda$ $\frac{434-410}{0.8} = \frac{X-410}{8.2}$ $X = 656$ nm	**D**	M1 A1 (M1) (A1)

7c	Energy of photon with wavelength 410 nm $= \frac{hc}{\lambda}$ $= \frac{(6.63\times10^{-34})(3.0\times10^{8})}{410\times10^{-9}}$ $= 4.85\times10^{-19}$ J *Energy level* $= 4.85\times10^{-19}+(-4.08\times10^{-19})$ $= 0.77\times10^{-19}$ J	**D**	M1 M1

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	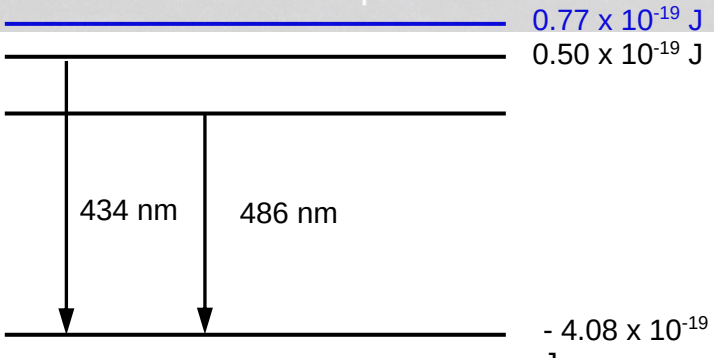		A1
7d	The lowest energy level shown in Fig 7.3 may not be the energy level at ground state.	**D**	A1
7e	When the electrons are directed to pass through a <u>thin carbon film</u>, <u>concentric rings</u> are observed It shows a <u>diffraction pattern</u> that is unique to wave behaviour after passing through the carbon film.	**A**	M1 A1
7f	E_k of electron = $\frac{p^2}{2m}$ $p = \sqrt{2mE_k}$ By de Broglie's equation, $\lambda = \frac{h}{p}$ $= \frac{h}{\sqrt{2mE_k}}$ $= \frac{6.63 \times 10^{-34}}{\sqrt{2(9.11 \times 10^{-31})(4.08 \times 10^{-19})}}$ $= 7.69 \times 10^{-10}$ m	**A**	 C1 A1

8a	greater lattice vibrations more frequent collision of electrons with lattice ions /lower drift velocity of the electrons	**A**	B1 B1
8bi	connect cells in series	**E**	B1
8bii	connect cells in parallel	**E**	B1
8c	Active cooling could fail/active cooling needs energy input, increasing costs or decreasing system output/ difficult to eliminate passive cooling	**A**	B1
8d	site panel so that there is <u>an air gap</u> around it e.g. mounts panels a small distance above the roof/in open space/clear from obstructions/ spaced out in field.	**A**	B1
8ei	6.40 V, 7.60 V (2 dp)	**D**	A1

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8eii	little / no change to current at low voltages at lower temperature, greater current at higher voltage	**A**	B1 B1
8eiii	Best-fit straight line drawn *(See graph below)*	**E**	B1
8eiv	$V = \mu(T_R - T) + V_R$ Plotting a graph of V against T gives gradient= $-\mu$ and y- intercept= $V_R + \mu T_R$ Use of gradient to determine μ (see graph below) Gradient = $\frac{8.65 - 6.05}{6.0 - 28.0}$ =– 0.118 (note the dp of the coordinates) μ = 0.12 (0.118) V °C^{-1} From graph, y-intercept = 9.35, i.e. $V_R + \mu T_R = 9.35$ $6.40 + 0.12T_R = 9.35$ T_R = 25 (24.6) °C	**A**	 C1 A1 C1 A1
8ev	(7.60 = 0.12 (25-T) + 6.40), T = 15 °C	**A**	 A1
8evi	Rectangle drawn below line Correct area indicated (6.0 V and 0.048 A)	**A**	 A1
8evii	Use of area of rectangle or $P = IV$ P_{max} = 4.8 × 0.10 = 0.48 = 0.5 W	**D**	B1 A1
8fi	Better chance of capturing photons/ photons of a greater range of frequencies (contained within sunlight) can be captured	**A**	B1
8fii	Output power increases as angle of incidence on panel decreases / The closer the angle between PV panel and incident sunlight is to 90°, the larger the output power.	**A**	B1

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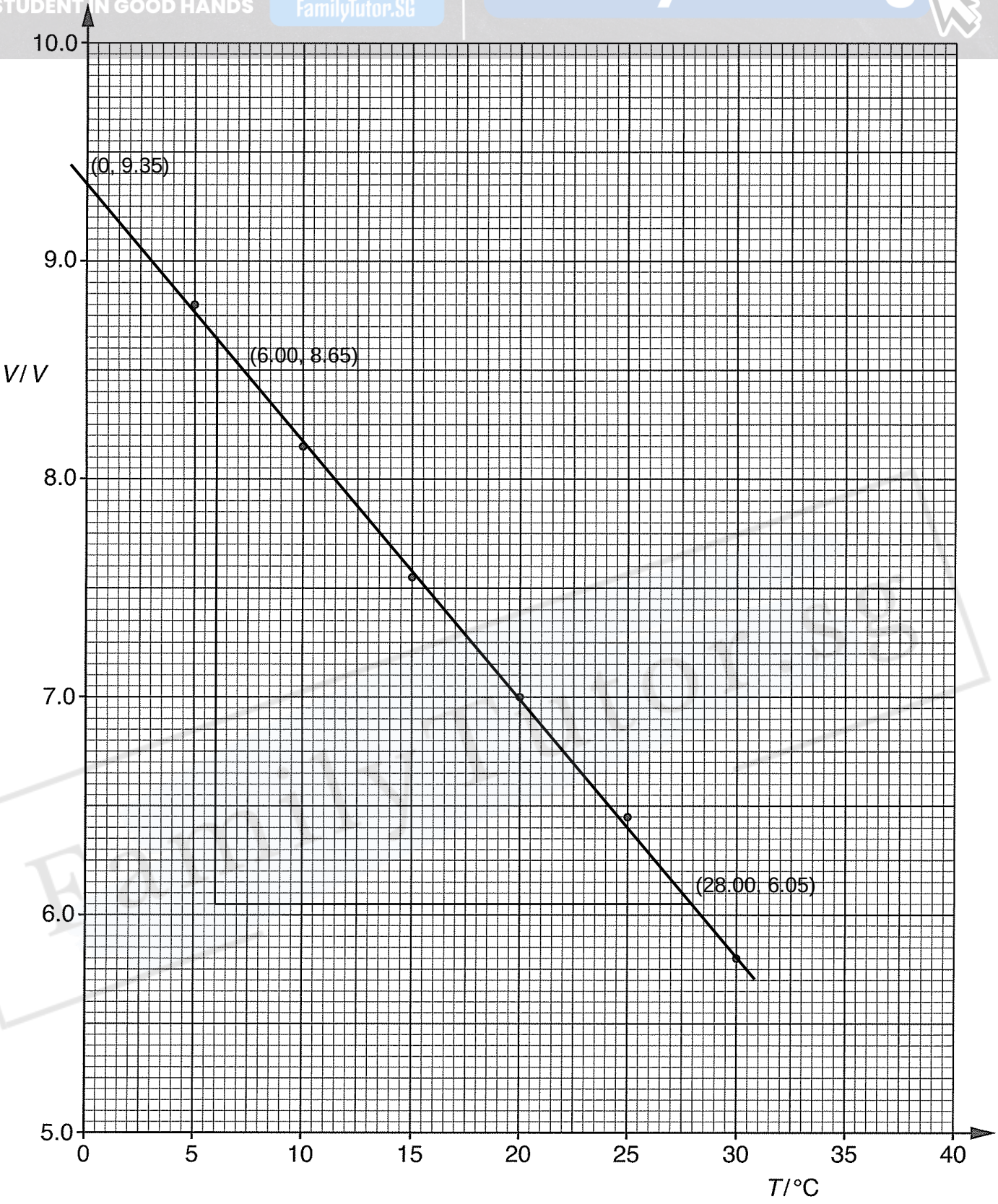

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Name: _____ ( ) Class: 23 / _____

ANDERSON SERANGOON JUNIOR COLLEGE

2023 JC2 Preliminary Exam

PHYSICS Higher 2 9749/03

Paper 3 Longer Structured Questions **Friday 15 September 2023**

2 hours

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

READ THESE INSTRUCTIONS FIRST

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

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

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

For Examiner's Use	
Paper 3 (80 marks)	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Deductions	
Total	

This document consists of **26** printed pages and **2** blank pages.

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Data

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

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Formulae

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

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Section A

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

1 A raindrop falls vertically from rest. The variation with time t of the vertical velocity of the raindrop is shown in Fig. 1.1.

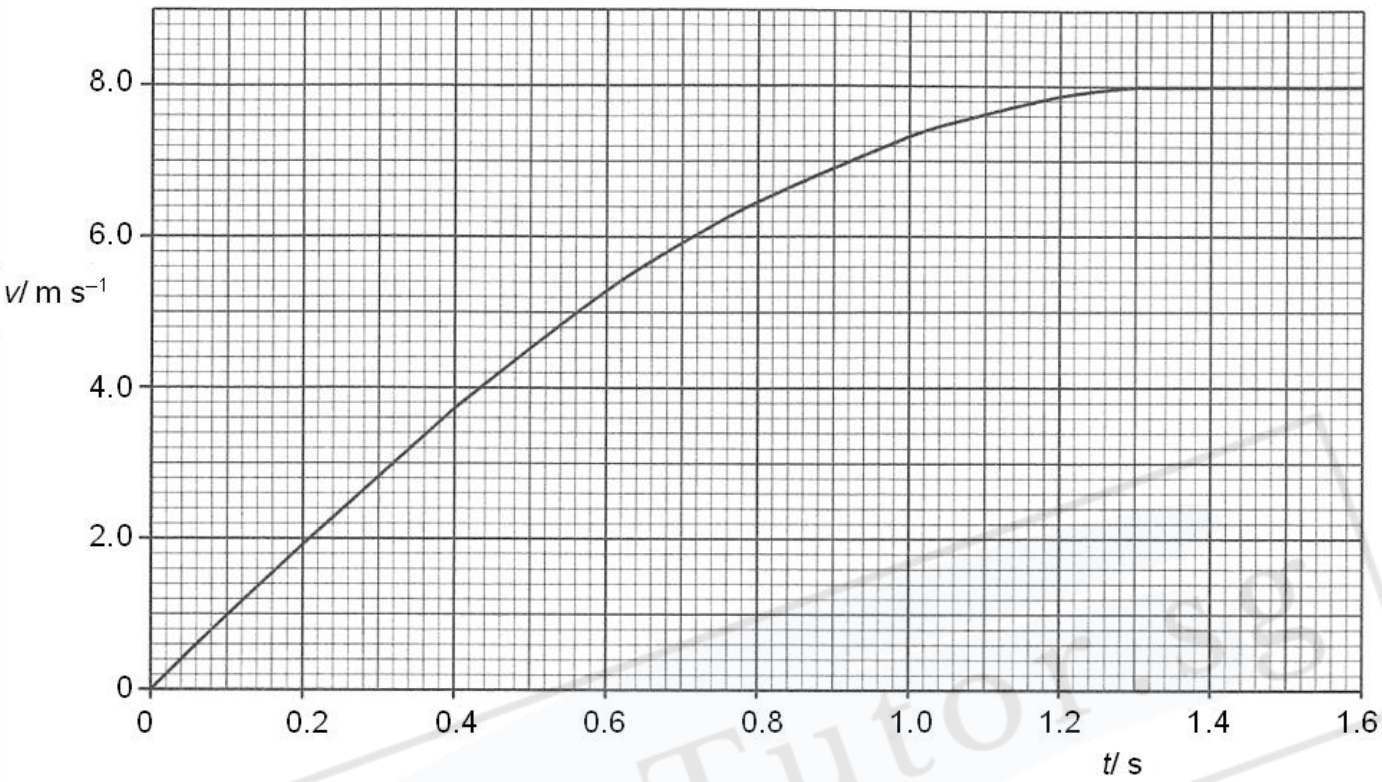

Fig. 1.1

(a) Use Fig. 1.1 to explain how it may be deduced that air resistance varies with speed.

.....

.....

.....

.....

.....

.....[2]

(b) A student suggests that the drag force D on the raindrop of mass m falling with a speed v is given by the expression

$$D = k v^2$$

where k is a constant.

At speed v, the acceleration of the raindrop is a.

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(i) Show that, based on the student's suggestion, and without using data from the graph in Fig. 1.1,

$$(g - a) = \frac{kv^2}{m}$$

where g is the acceleration of free fall.

[2]

(ii) Use information from Fig. 1.1 or otherwise, complete Table 1.2. Show your working clearly.

Table 1.2

velocity v / m s^{-1}	acceleration a / m s^{-2}	$(g - a)$ / m s^{-2}
4.0		
8.0	0	9.8

[2]

(iii) Use the completed Table 1.2 to deduce whether the student's suggestion for velocities of 4.0 m s^{-1} and 8.0 m s^{-1} is correct.

[2]

[Total: 8]

[Turn Over

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2 **(a)** Define *force*.

……

……[1]

(b) Mechanical power P can be calculated using the formula $P = Fv$.

Use the concept of work and the definition of power to show how this formula is derived.

[2]

(c) The engine of a lorry provides 130 kW of power to the lorry's wheels when it is travelling at a constant speed of 25 m s^{-1} along a straight horizontal road.

(i) Show that the resistive force opposing the forward motion of the lorry is 5200 N. Explain your working clearly.

[2]

(ii) Describe, in terms of Newton's third law, the horizontal forces acting on the tyres of the lorry and on the road.

……

……

…… [2]

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(d) The lorry in (c) travels up a straight section of road that is inclined at an angle θ to the horizontal, as shown in Fig. 2.1.

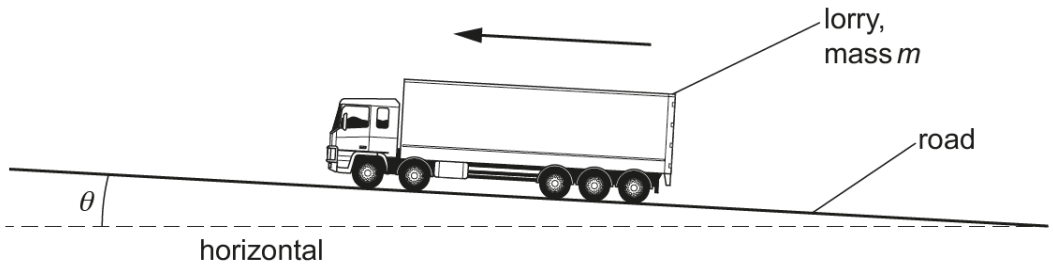

Fig. 2.1 (not to scale)

The total resistive force remains unchanged at 5200 N and the engine now provides greater power to cause an acceleration of 0.15 m s^{-2}. The total mass of the lorry is 36 000 kg. The angle θ is 1.4°.

Determine the total force provided by the engine.

force = ……N [2]

[Total: 9]

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3 **(a)** Two identical cars are moving around a horizontal track. One car follows path X and the other follows path Y, as shown in Fig. 3.1.

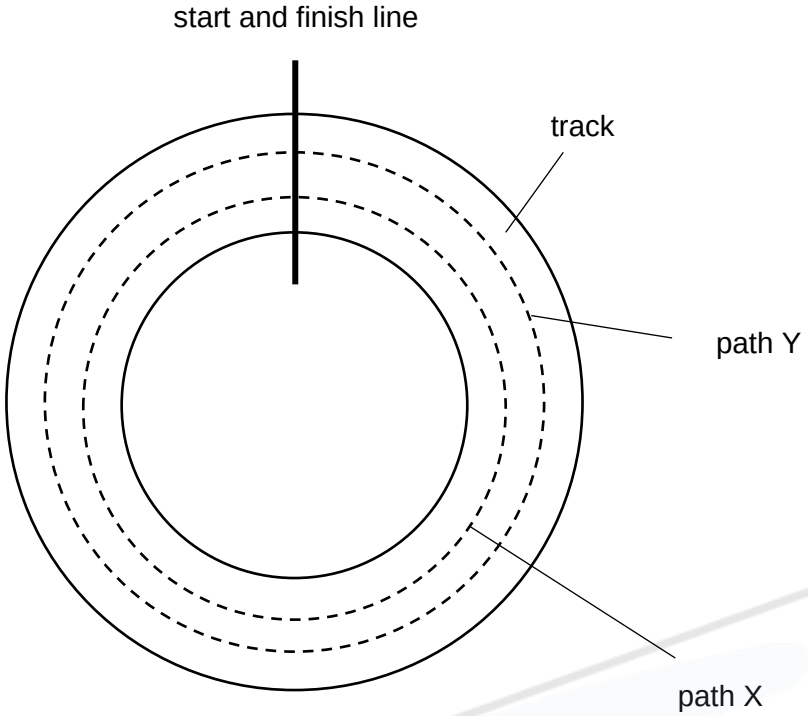

Fig. 3.1

The maximum lateral friction force that the cars can experience without sliding is the same for both cars. Each car is travelling at its maximum speed at which it can move without sliding.

State and explain whether the magnitude of the acceleration and maximum speed of the car on path Y is less than, greater than or same as the car on path X.

acceleration

……

……

……

maximum speed

……

……

……[4]

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(b) Jupiter has close to eighty moons, of which eight of them are in approximately circular orbits. Jupiter has a mass M_J, radius R_J and a Jupiter-day is approximately 0.417 Earth-days.

The orbital radii and periods of two of the moons of Jupiter are tabulated in Table 3.1. The orbital radii and the orbital periods of these moons are expressed in units of R_J and Earth-days respectively.

Table 3.1

name of Moon	orbital radius / R_J	orbital period / Earth-days
Amalthea	2.62	.....
Thebe	3.18	0.676

(i) Show that the period T of a circular orbit around Jupiter, expressed in terms of the radius of the orbit R is given by

$$T = \sqrt{\frac{4\pi^2 R^3}{GM_J}}.$$

[2]

(ii) Using the data provided in Table 3.1, determine the orbital period for Amalthea.

orbital period = …….Earth-days [2]

(iii) A *stationary orbit* refers to a circular orbit around a planet in which a moon would appear stationary to an observer on the planet's surface.

Using the data provided in Table 3.1, explain whether it is possible for the moon Thebe to be in a stationary orbit around Jupiter.

……

……

……[2]

[Total: 10]

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4 The apparatus shown in Fig. 4.1 may be used to demonstrate a stationary wave.

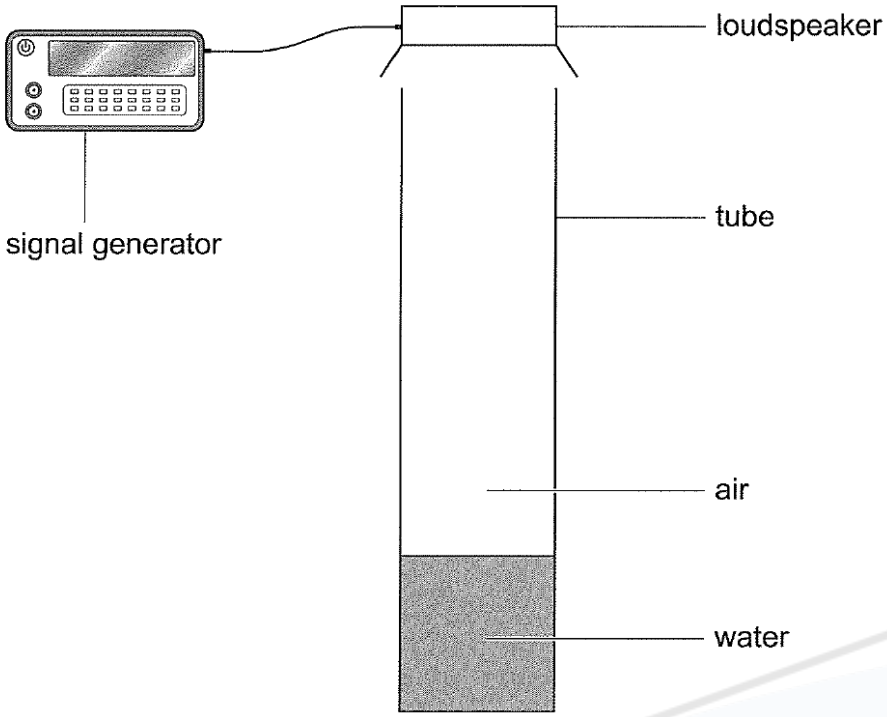

Fig. 4.1

(a) Apart from changing the frequency, state how the apparatus shown in Fig. 4.1 may be adjusted to allow a stationary wave to form.

……..

……..... [1]

(b) When the loudspeaker is emitting sound of frequency 480 Hz, the minimum length of the column of air is 18 cm for a stationary wave to be produced.

Calculate the speed of sound in the air column.

speed of sound = ……m s^{-1} [2]

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(c) The frequency of the sound from the loudspeaker in Fig. 4.1 is increased until the next stationary wave is produced.

(i) On Fig. 4.2, draw a representation of the stationary wave that is produced. Label any nodes N and any antinodes A.

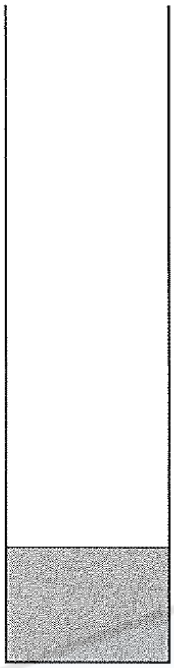

Fig. 4.2

[3]

(ii) Describe the movement of the air particles at the open top of the air column.

……

……

…… [2]

(iii) Determine the frequency of the sound.

frequency = ……Hz [2]

[Total: 10]

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5 Fig. 5.1 shows the *I*–*V* characteristics for two 12 V filament lamps A and B.

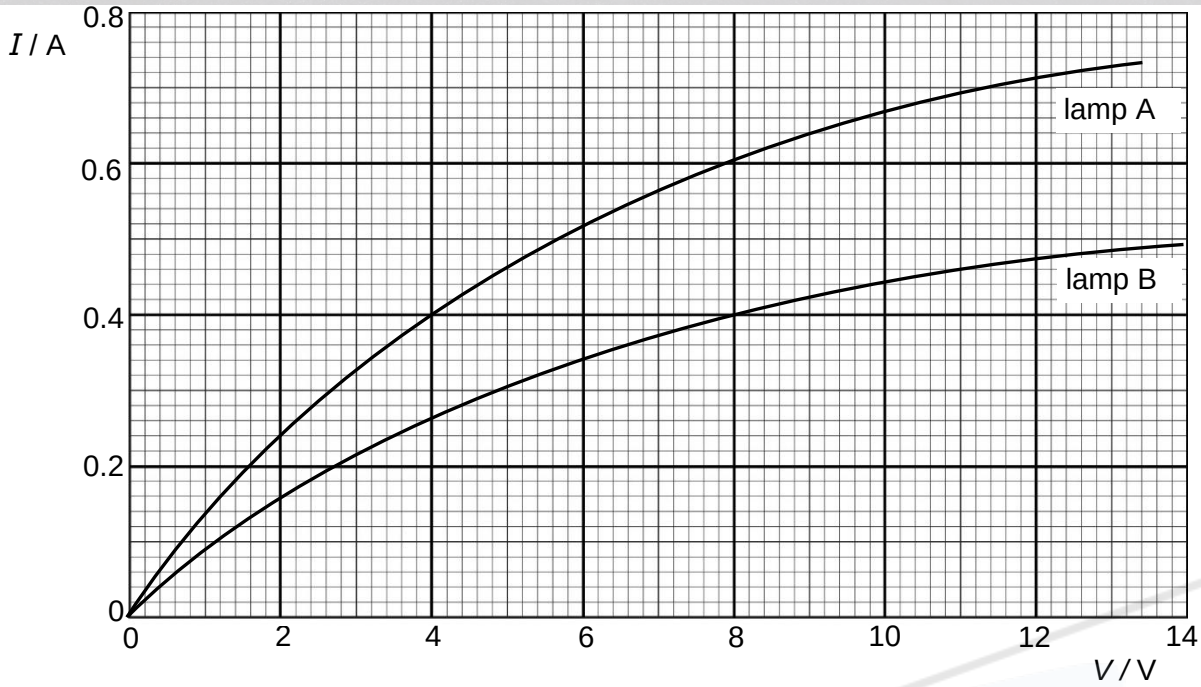

Fig. 5.1

(a) Explain the shape of the graph for filament lamp.

.....

.....[2]

(b) The two lamps are now connected in series with a 12 V battery with negligible internal resistance as shown in Fig. 5.2.

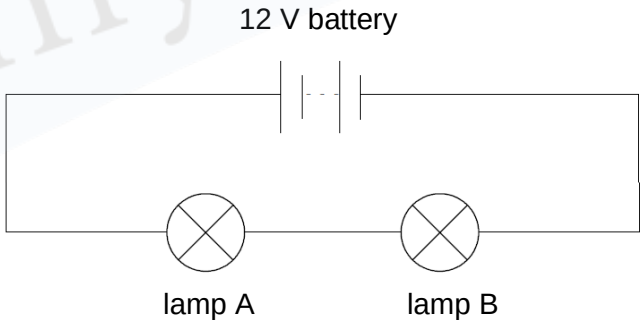

Fig. 5.2

(i) Use Fig. 5.1 to deduce the total current from the battery. Explain your deduction.

.....

.....

.....[2]

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(ii) Compare the power dissipated by the two lamps.

……

……

……[2]

(c) A uniform resistance wire XY of length 80 cm is connected to the circuit as shown in Fig.5.3.

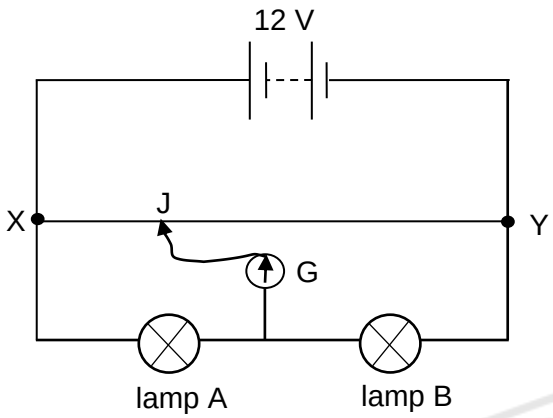

Fig. 5.3

The movable contact J can be connected to any point along the wire XY.

Calculate the length XJ required to produce zero current in the galvanometer G.

XJ = ……..m [2]

[Total: 8]

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6 **(a)** A coil of wire consisting of two loops is suspended from a fixed point as shown in Fig. 6.1.

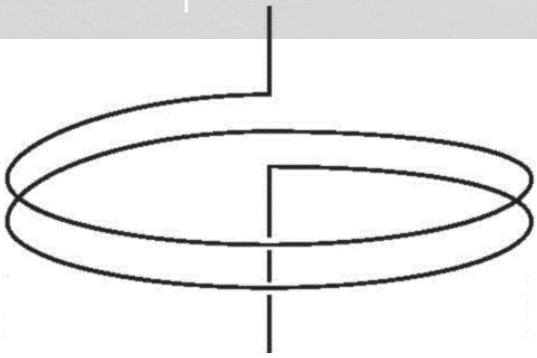

Fig. 6.1

The coil is connected into a circuit such that the lower end of the coil is free to move.

Explain why, when a current is switched on in the coil, the separation of the loops of the coil decreases.

……

……

……

……

…… [2]

(b) Fig. 6.2 shows a current balance in which a frame ABCD rests on conducting pivots. Arm AB is placed between a pair of strong magnets.

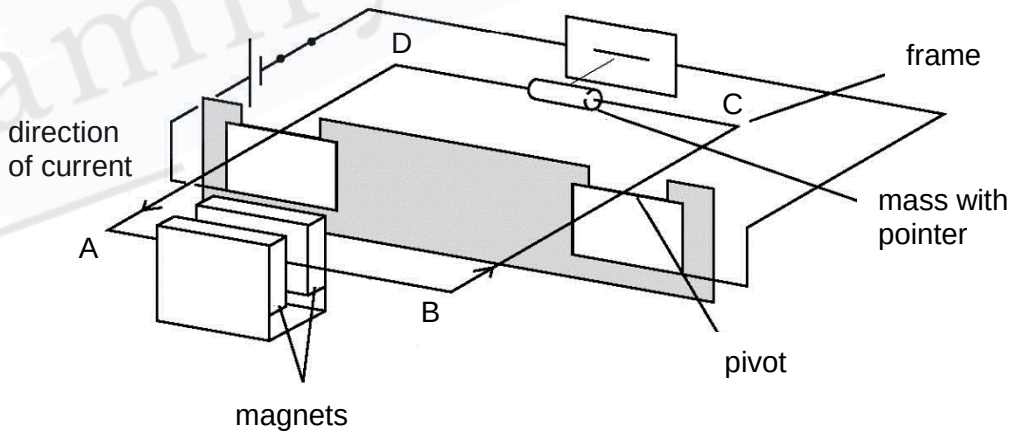

Fig. 6.2

When there is current of 4.5 A in arm AB of the frame, a mass must be added to arm CD to restore balance.

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(i) State and explain the direction in which the magnetic force must be acting on the arm AB.

……

……

……

…… [2]

(ii) Arm AB has a length of 4.6 cm inside the uniform magnetic field. The magnetic force acting on arm AB is 24 mN.

Calculate the magnetic flux density of the uniform magnetic field.

magnetic flux density = …… T [2]

[Total: 6]

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7 Nuclear fission products are usually radioactive and give rise to a series of radioactive products. Each decay product has its own half life, but eventually a stable nuclide is reached.

One such fission product and its decay products is shown as below:

$$^{143}_{54}\text{Xe} \rightarrow ^{143}_{55}\text{Cs} \rightarrow ^{143}_{56}\text{Ba}$$

The half-lives of Xenon-143 and Caesium-143 are 0.511 s and 1.79 s respectively.

(a) Suggest why the number of Caesium-143 nuclei inside the nuclear reactor increases initially and decreases subsequently.

……

……

…… [2]

(b) Explain why Xenon-143 does not decay faster when heated.

……

…… [1]

(c) Suggest two reasons why a detector placed near to a sample of Xenon-143 would record a count rate much larger than the expected activity of Xenon.

1. ……

……

2. ……

…… [2]

(d) Xenon-143 decayed to Caesium-143 through β-particle emission. Although a lead container was used to contain Xenon-143 and it provides adequate shielding for the β- particle emission, some X-ray radiation can be detected outside the lead container. Explain why.

……

……

……

……

…… [4]

[Total: 9]

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Section B

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

8 **(a)** A mercury-in-glass thermometer is initially at 23.0 °C. It is used to measure the temperature of an insulated beaker of water that is at 37.4 °C. The bulb of the thermometer is inserted into the water, and the water is stirred until the reading on the thermometer becomes steady.

The mass of water in the beaker is 18.7 g.
The mass of mercury in the thermometer is 6.94 g.
The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.
The specific heat capacity of mercury is 0.140 J g^{-1} K^{-1}.

(i) Calculate, the final steady temperature indicated by the thermometer in the water.

temperature = ... °C [3]

(ii) It may be assumed that negligible heat is lost to the surroundings during the measurement of the temperature of the water, due to sufficient insulation provided by the beaker.

State one other assumption that you have used in your calculations in part **(a)(i)**.

……

…… [1]

(iii) Suggest **one** change that could be made to the design of the thermometer that would enable it to give a more accurate measurement of temperature.

……

…… [1]

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(iv) Explain why the thermometer in **(a)** does **not** provide a direct measurement of thermodynamic temperature.

……

……

…… [2]

(v) Thermodynamic temperature T may be determined by the behaviour of a type of substance for which T is proportional to the product of pressure and volume.

State the name of this type of substance.

…… [1]

(b) A sealed container of fixed volume V contains N molecules, each of mass m, of an ideal gas at pressure p. The gas is supplied with thermal energy Q.

(i) Explain why the internal energy of the gas is equal to the total kinetic energy of the molecules.

……

……

…… [2]

(ii) Explain, with reference to the first law of thermodynamics, why the increase in internal energy of the gas is Q.

……

……

…… [2]

(iii) Use the information in **(b)(ii)** to show that the specific heat capacity c of the gas is given by

$$c = \frac{3k}{2m}.$$

[3]

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(iv) The container in **(b)** is now replaced with one that does not have a fixed volume. Instead, it now has a movable frictionless piston.

Suggest, with a reason, how the specific heat capacity of the gas would now compare with the value in **(b)(iii)**.

……

……

……

…… [2]

(v) The piston in **(b)(iv)** is now moved so that the gas expands, without supplying thermal energy.

Use kinetic theory to explain whether this will cause a change in the temperature of the gas.

……

……

……

…… [3]

[Total: 20]

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9 **(a)** Define *magnetic flux linkage*.

.....

.....

..... [2]

(b) A solenoid of diameter 6.0 cm and 540 turns is placed in a uniform magnetic field as shown in Fig. 9.1.

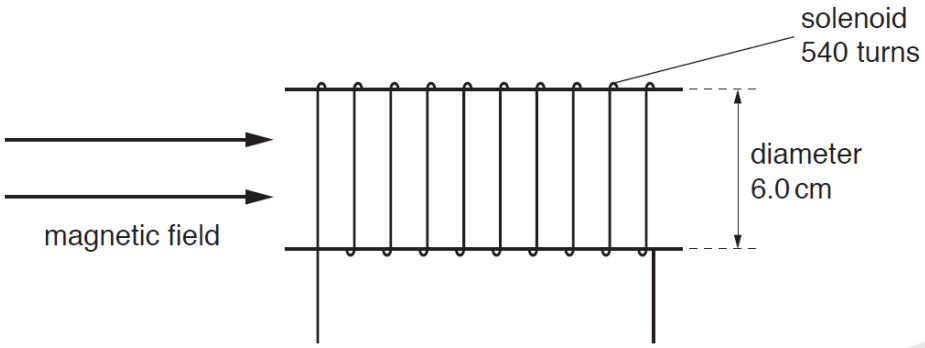

Fig. 9.1

The variation with time t of the magnetic flux density is shown in Fig. 9.2.

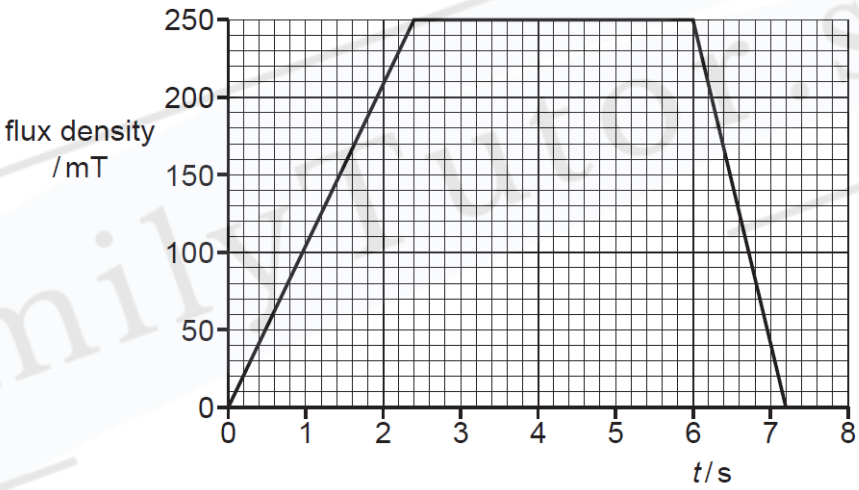

Fig. 9.2

Calculate the maximum magnitude of the induced electromotive force (e.m.f.) in the solenoid.

e.m.f. = ... V [3]

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Question 9 continues on the next page.

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(c) A thin copper sheet X is supported on a rigid rod so that it hangs between the poles of a magnet as shown in Fig. 9.3.

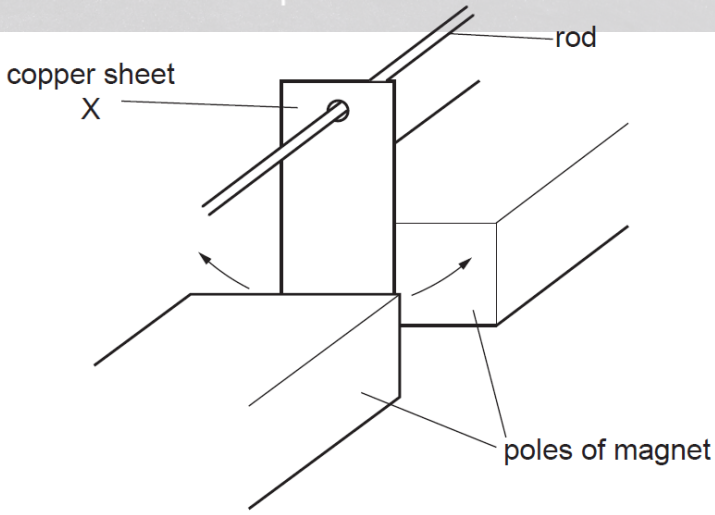

Fig. 9.3

Sheet X is displaced to one side and then released so that it oscillates. A motion sensor is used to record the displacement of X.

A second thin copper sheet Y replaces sheet X. Sheet Y has the same overall dimensions as X but is cut into the shape shown in Fig. 9.4.

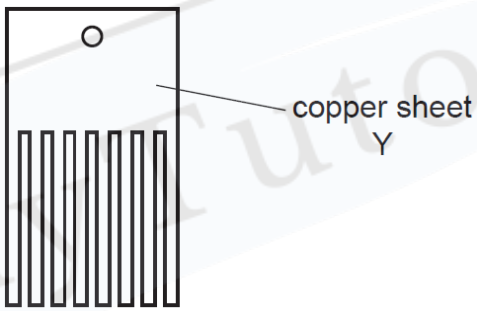

Fig. 9.4

The motion sensor is again used to record the displacement.

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The graph in Fig. 9.5 shows the variation with time t of the displacement s of each copper sheet.

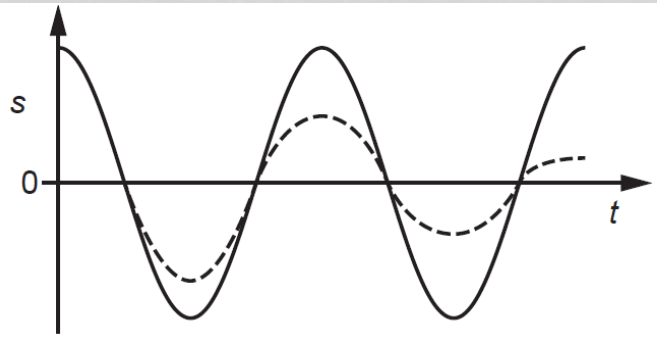

Fig. 9.5

(i) State the name of the phenomenon illustrated by the gradual reduction in the amplitude of the dashed line.

……..... [1]

(ii) Deduce which copper sheet is represented by the dashed line. Explain your answer using the principles of electromagnetic induction.

……

……

……

……

……

……

……..... [4]

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(d) The output potential difference (p.d.) of an alternating power supply is represented by

$$V = 320 \sin(100\pi t)$$

where V is the p.d. in volts and t is the time in seconds.

The power supply is connected to resistor R of resistance 120 Ω and an ideal diode in the circuit shown in Fig. 9.6.

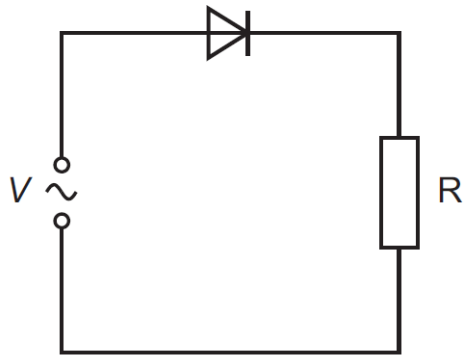

Fig. 9.6

(i) Sketch on Fig. 9.7, from time t = 0 to time t = 40 ms.

1. the variation with time t of the p.d across the source,

2. the variation with time t of the p.d across the R,

3. the variation with time t of the p.d across the diode.

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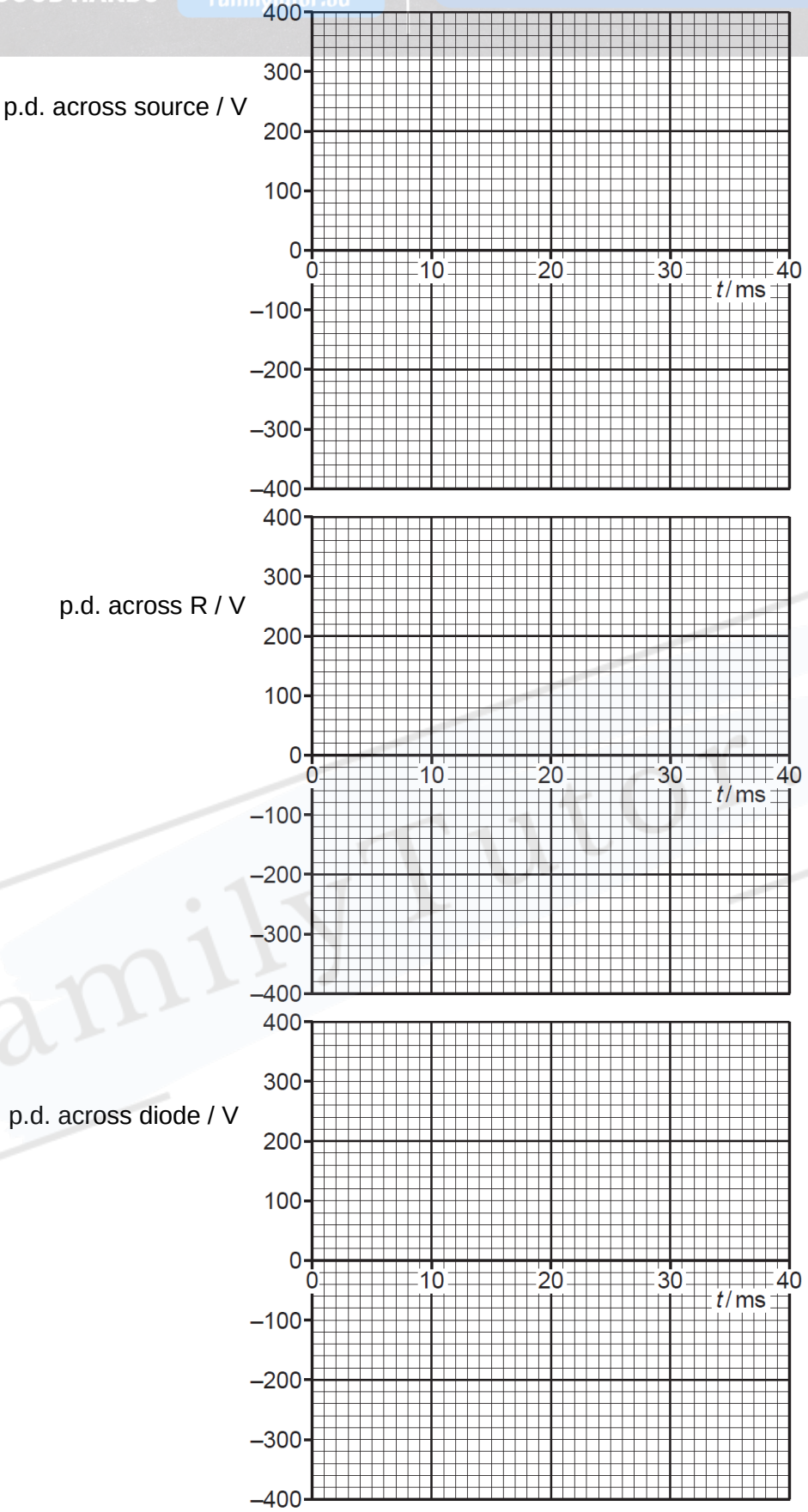

Fig. 9.7

[5]

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(ii) Determine the average power dissipated in the resistor R.

power = ……W [2]

(iii) Define the *root-mean-square (r.m.s.) current.*

……...

……...

…… [1]

(iv) Determine the r.m.s current in the resistor R.

r.m.s current = ……A [2]

[Total: 20]

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Anderson Serangoon Junior College 2023 H2 Physics Prelim P3 Mark Scheme

Paper 3 (80 marks) **E – Easy, A – Average, D – Difficult**

ECF	Error carried forward	**SF**	Significant figures error	**M0**	No A marks awarded
AE	Arithmetic error	**BOD**	Benefit of doubt	**^**	More is needed in answer
POT	Power of ten error	**CON**	Contradictory response	**XP**	Wrong physics
TE	Transcription error	**IR**	Irrelevant (part) response		

1a	Gradient is not constant so acceleration changes with speed Hence resultant force changes with speed Resultant force consist of weight and air resistance and weight is constant (hence can be deduced that air resistance varies with speed).	**A**	M1 A1 A0
1bi	Fnet = $mg - kv^2$ Using N2L, F_{net} = ma $mg - kv^2$ = ma m$(g - a) = kv^2$ $(g-a) = \frac{kv^2}{m}$	**A**	 B1 B1 A0
1bii	At v = 4.0 m s^{-1} Gradient= $\frac{6.0-2.8}{0.68-0.28} = \frac{3.2}{0.40} = 8.0$ a = 8.0 m s^{-2} $g - a$ = 9.81 – 8.0 = 1.8 (or 1.81)	**A**	 M1 A1 A0
1biii	From **b(i),** $(g-a) = \frac{kv^2}{m}$, $\frac{(g-a)}{v^2} = \frac{k}{m}$ should be a constant for 4.0 m s^{-1}, $\frac{(g-a)}{v^2} = \frac{1.8}{4.0^2} = 0.11$ or 8.0 m s^{-1}, $\frac{(g-a)}{v^2} = \frac{9.8}{8.0^2} = 0.15$ Hence, values of $\frac{(g-a)}{v^2}$ are not the same, suggestion is incorrect.	**A**	M1 A1

2a	The resultant force acting on a body is the rate of change of momentum of the body and acts in the direction of the change in momentum.	**E**	A1
2b	Work W is the product of a force F and a displacement s in the direction of the force. Since Power P is the rate of doing work, Hence, P = W/t = Fs/t = Fv	**A**	 B1 B1 A0

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2ci	At constant speed, no net force acting on lorry. Hence, magnitude of driving force is equal to that of resistive force on lorry. Driving force, F = P/v = 130 000/25 = 5200 N	**A**	M1 M1 A0
2cii	Friction between tyres of lorry and road exerts a backward force on the road. By Newton's third law, road surface exert a forward force of equal magnitude on tyres.	**A**	B1 B1
2d	F - mg sin θ – R = ma F = 36000(9.81 sin 1.4) + 5200 + (36000)(0.15) = 19228 N = 19000 (19200) N	**A**	 C1 A1

3a	Centripetal acceleration: Car on path X and Y has the same acceleration Both experienced the same centripetal force at maximum speed since the centripetal force is provided by the (maximum lateral) friction force. As both cars are identical and hence have the same mass, they will have the same centripetal acceleration. Maximum speed: Car on path Y will have a bigger maximum speed. $F = \frac{mv^2}{r}$ $v = \sqrt{\frac{Fr}{m}}$ Since *F* and *m* are the same for both cars, $v \propto \sqrt{r}$. Since radius of path Y is bigger than that of X, maximum speed of car on path Y is larger.	**A**	 M1 A1 M1 A1
3bi	For circular motion, centripetal force on moon of mass *m* is provided by the gravitational force due to Jupiter on moon, $\frac{GM_J m}{R^2} = mR\omega^2$ $G\frac{M_J m}{R^2} = mR(\frac{2\pi}{T})^2$ $\Rightarrow T = \sqrt{\frac{4\pi^2 R^3}{GM_J}}$ where ω is the angular velocity of moon.	**A**	M1 M1 A0
3bii	Since $T^2 \propto R^3$, $\left(\frac{T_{Th}}{T_{Am}}\right)^2 = \left(\frac{R_{Th}}{R_{Am}}\right)^3 \Rightarrow \left(\frac{0.676}{T_{Am}}\right)^2 = \left(\frac{3.18}{2.62}\right)^3$ T_{Am} = 0.506 Earth-days	**A**	 M1 A1

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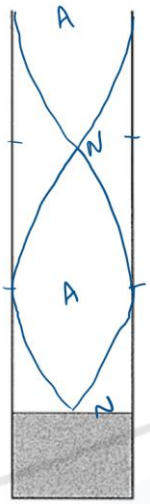
3biii	Since the orbital period of Thebe is not the same as the rotation period of Jupiter, So not in stationary orbit. Or orbital period of Thebe = 0.676 Earth-days, not the same as a Jupiter-day which is approximately 0.417 Earth-days, so not (possible to be) in stationary orbit.	**D**	M1 A1 (M1) (A1)

4a	Change in depth of water.	**E**	B1
4b	$L = \lambda/4$ $v = f\lambda$ So, $v = f(4L)$ $= 480 \times 4 \times 0.18$ $= 345.6$ m s^{-1} $= 346$ (350) m s^{-1}	**A**	 C1 A1
4ci	 A node at the water surface and an antinode at the open end of the air column Length of air column equals ¾ of wavelength of the stationary wave, with total of 2 nodes and 2 antinodes labelled correctly Correct sinusoidal shape (only award when both M marks are scored)	**A**	 M1 M1 A1
4cii	Vibrate along axis of the tube, Vibrate with maximum amplitude.	**A**	B1 B1
4ciii	$L = ¾\ \lambda$ so $\lambda = 4/3\ L = \lambda'/3$ where λ' is the wavelength in part **(b)** Since $v = f\lambda$, $f = 3\ f'$ where f' is the frequency in part **(b)** $f = 3 \times 480 = 1440$ Hz	**D**	 C1 A1

5a	As temperature (of the filament) increases with *V* the resistance of the lamp increases hence V/I ratio increases.	**A**	M1 A1
bi	From *I*-*V* graph, find the common current when the individual p.d. of each lamp sum up to 12 V. *I* = 0.40 A (± 0.01 A)	**A**	B1 B1

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bii	Current is the same, but p.d. across lamp B is higher than that of lamp A OR resistance of lamp B is higher than resistance of lamp A Using $P = IV$, lamp B will have greater power dissipation.	**A**	M1 A1
c	From bi, V_A = 4.0 V , V_B = 8.0 V For zero current in the galvanometer G, k(XJ) = 4V where k = 12/0.80 XJ = (4/ 12) x 0.80 = 0.27 (0.267) m OR For zero current in the galvanometer G XJ = [4/(4+8)] x 0.80 = 0.27(0.267) m	**A**	 C1 A1 (C1) (A1)

6a	Each coil acts as a current-carrying conductor in the magnetic field of the neighbouring turn Magnetic field (due to current) in one loop cuts / is normal to the current in second loop. By Fleming's left-hand rule, there will be a (magnetic) force on the second loop towards the first loop. (By Newton's third law, this gives rise to mutual attraction between the loops.) Hence, separation decreases.	**A**	 M1 M1 A0
6bi	Mass exert a downward force on the frame. / mass exert a (clockwise) moment on the frame For frame to have no net moment about pivot (or for the frame to be in rotational equilibrium), magnetic force must act downwards on near side of frame.	**A**	B1 A1
6bii	$F = BIL$ $24 \times 10^{-3} = B \times 4.5 \times 4.6 \times 10^{-2}$ B = 0.116 T = 0.12 T	**A**	 C1 A1

7a	When the rate of decay of Xe-143 is faster than that of Cs-143, the number of Cs-143 increases. When the rate of decay of Xe-143 decreases, as number of Xe-143 decreases, till it is below the rate of decay of Cs-143, the number of Cs-143 decreases. Or When the rate of decay of Cs increases, as number of Cs increases, till it is above the rate of decay of Xe, the number of Cs-143 decreases	**A**	B1 A1 (A1)
7b	Due to the **spontaneous** nature of radioactivity decay, the rate of decay is unaffected by external environment such as surrounding temperature.	**A**	A1
7c	The number of radiations does not just come from Xenon, but also from Caesium. The count rate may include background radiation.	**A**	B1 B1
7d	β-particles have high speeds/energy	**D**	B1

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	when charged particle is accelerated/slowed down electromagnetic radiation is produced β-particles stopped in the lead produce X-ray radiation which escapes.		M1 A1 B1

8ai	Heat lost by water = heat gained by mercury $m_{water}c_{water}\Delta T_{water} = m_{mercury}c_{mercury}\Delta T_{mercury}$ (18.7) (4.18) (37.4 – T) = (6.94) (0.140) (T – 23.0) T = 37.2 °C	**A**	C1 C1 A1
8aii	The glass of the thermometer OR the beaker containing the water have negligible heat capacity or gained negligble heat.	**A**	B1
8aiii	Use a liquid with a lower (specific) heat capacity (than mercury), or Use a smaller mass of mercury.	**A**	B1
8aiv	It depends on properties of a real substance, and 0 °C is not absolute zero	**D**	B1 B1
8av	Ideal gas	**E**	B1
8bi	Internal energy is the sum of the kinetic energy due to the random motion of the molecules and the potential energy Ep due to intermolecular forces between them. For ideal gas, no forces between molecules, so the potential energy of molecules is zero. Hence internal energy of the gas is equal to the total kinetic energy of the molecules	**A**	B1 B1 A0
8bii	Increase in internal energy = Q + work done, Constant volume so no work is done.	**A**	B1 B1
8biii	Q = NmcΔT U = (3/2) NkT, so ΔU = (3/2) NkΔT Q = ΔU, so NmcΔT = (3/2) NkΔT Hence, $c = \frac{3k}{2m}$	**D**	M1 M1 A1 A0
8biv	Gas expands and does work (against the atmosphere pressure) (For the same temperature rise), more (thermal) energy is needed, so larger specific heat capacity.	**A**	M1 A1
8bv	Speed of air molecules decreases on impact with moving piston. Since the kinetic energy (of molecules) is proportional to (thermodynamic) temperature, Kinetic energy (of molecules) decreases, so temperature decreases.	**D**	B1 B1 B1

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9a	The Magnetic Flux Linkage in a coil is the product of the area of the coil and the number of turns in the coil and the component of the magnetic flux density perpendicular to that area.	**E**	M1 A1
9b	t = 1.2 s e.m.f = $\frac{\Delta NBA}{t} = \frac{540 \times 0.250 \times \pi \times 0.030^2}{1.2}$ = 0.32 V	**A**	B1 C1 A1
9ci	light damping	**E**	A1
9cii	sheet cuts (magnetic) flux and causes induced emf (induced) emf causes (eddy) currents (in sheet) either currents (in sheet) cause resistive force or currents (in sheet) dissipate energy <u>smaller currents</u> in Y or <u>larger</u> currents in X, so dashed line is X	**D**	B1 B1 B1 B1
9di1	sinusoidal waves with amplitude 320 V and two time periods shown, each of 0.020 s $\omega = \frac{2\pi}{T}$ $T = \frac{2\pi}{100\pi}$ = 0.020 s	**A**	B1 B1
9di2	If 9di1 is positive sine function shown, sinusoidal half waves in positive V only for the first half of cycle and (peak at 320 V, line at zero for second half of cycle (two time periods shown, each of 0.020 s) If 9di1 is negative sine function shown, then vice versa – line at zero for first half cycle, then sinusoidal half waves in negative V only for second half cycle.	**D**	 B1 B1
9di3	If 9di1 is positive sine function shown, line at <u>zero for first half</u> of cycle and <u>sinusoidal half waves in negative V only for the second half</u> of cycle. (peak at 320 V two time periods shown, each of 0.020 s) If 9di1 is negative sine function shown, then vice versa –sinusoidal half waves in negative V only for first half cycle, then line at zero for second half cycle.	**D**	 B1
9dii	Average power P = ½ (V_{rms}^2/R) Or ½(P_o/2) = [½ $(\frac{320}{\sqrt{2}})^2$]/120	**A**	C1

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	= 210 (213) W Or Average power P = ½(P_o/2)		A1
9diii	The root-mean-square p.d is defined as <u>the steady direct current</u> which produces <u>heat at the same rate</u> as the alternating current across a given resistor.	**E**	B1
9div	Average power = $I_{rms}^2 R$ $I_{rms} = \sqrt{\frac{213}{120}}$ = 1.33 A Accept ecf Or $I_{rms} = \frac{V_{rms}}{R} = \frac{V_o}{2R}$	**A**	C1 A1

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PHYSICS 9749/1

Paper 1: Multiple Choice Questions **September 2023**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name and tutorial group on this cover 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.

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

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DATA

speed of light in free space	c	=	3.00×10^{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}

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FORMULAE

uniformly accelerated motion	s	$= ut + \frac{1}{2}at^2$
	v^2	$= u^2 + 2as$
work done on / by a gas	W	$= p\Delta V$
hydrostatic pressure	p	$= \rho gh$
gravitational potential	ϕ	$= -\frac{Gm}{r}$
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	$= R_1 + R_2 + ...$
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	$= x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	$= \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	$= \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	$= \mu_o nI$
radioactive decay	x	$= x_0 \exp(-\lambda t)$
decay constant	λ	$= \frac{\ln 2}{t_{\frac{1}{2}}}$

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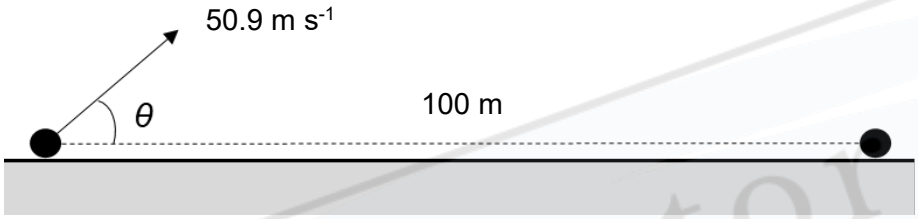
1 A man of mass 75.2 kg uses a set of weighing scales to measure his mass three times. He obtains the following readings.

	mass / kg
reading 1	80.2
reading 2	80.1
reading 2	80.2

Which statement describes the precision and accuracy of the weighing scales?

A not precise to ± 0.1 kg and accurate to ± 0.1 kg
B not precise to ± 0.1 kg and not accurate to ± 0.1 kg
C precise to ± 0.1 kg and accurate to ± 0.1 kg
D precise to ± 0.1 kg and not accurate to ± 0.1 kg

2 An object is launched with a speed of 50.9 m s^{-1} at an angle θ above the horizontal, as shown.



The ground is level. The object lands on the ground 100 m from its initial launch position.

What is the value of the angle θ?

You may need to make use of the double angle formula: $\sin(2\theta) = 2\sin\theta\cos\theta$

A 2.8° **B** 5.5° **C** 11° **D** 79°

3 Two spheres with different masses are initially moving towards each other with the same speed. The two spheres collide elastically.

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

A The two spheres can be at rest at the same time because they were initially moving in opposite directions.

B The two spheres can be at rest at the same time because momentum is always conserved in an elastic collision.

C The two spheres cannot be at rest at the same time at any point in time because the total momentum of the system is not zero.

D The two spheres cannot be at rest at the same time at any point in time because energy is always conserved in an elastic collision.

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4 A rower is sitting on a boat in the middle of a calm lake.

Which of the following forces forms a Newton's third law pair with the upthrust acting on the boat?

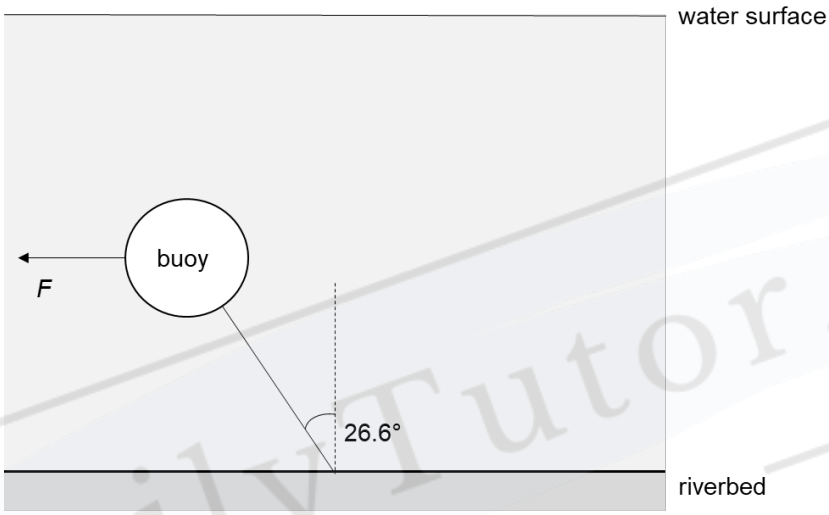
A The weight of the boat alone.

B The weight of the rower alone.

C The combined weight of the boat and the rower.

D The force of the boat on the lake's water to displace some of the lake's water.

5 A fully submerged buoy is tethered by a rope to a riverbed. The current of the river exerts a constant horizontal force of *F* on the buoy causing the rope to make an angle of 26.6° to the vertical, as shown. The buoy is in equilibrium.



The buoy has a volume of 0.500 m^3 and a density of 390 kg m^{-3}.

The river water has a density of 1000 kg m^{-3}.

What is the force *F* exerted by the river current on the buoy?

A 1500 N **B** 3830 N **C** 6000 N **D** 9810 N

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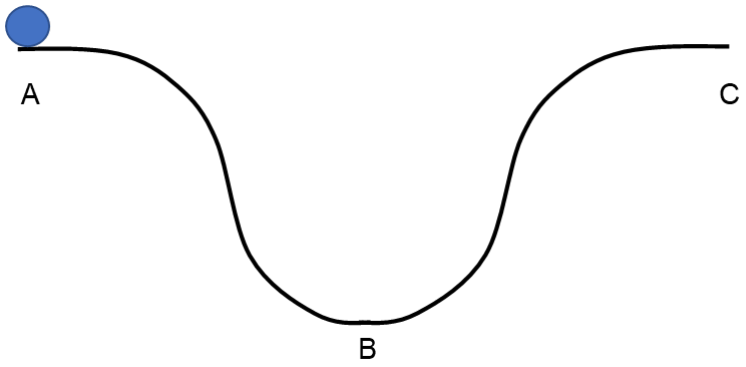
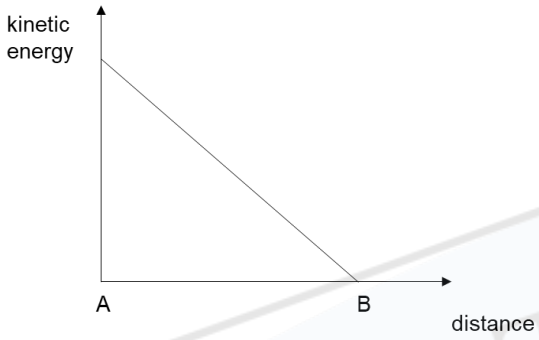
6 An object moves along a frictionless track from A to C, through B, which is the lowest point of the motion.

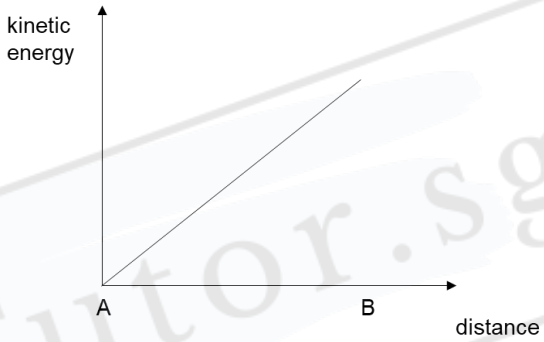


Which graph shows how the kinetic energy of the object varies with the vertical distance from A?

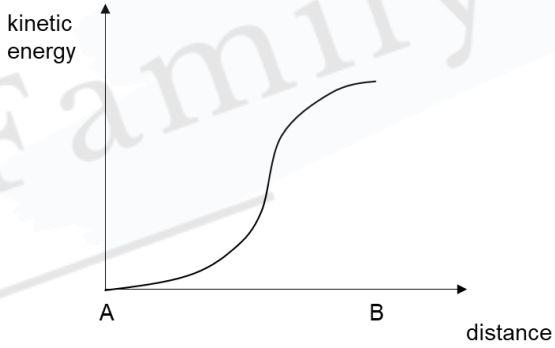
A



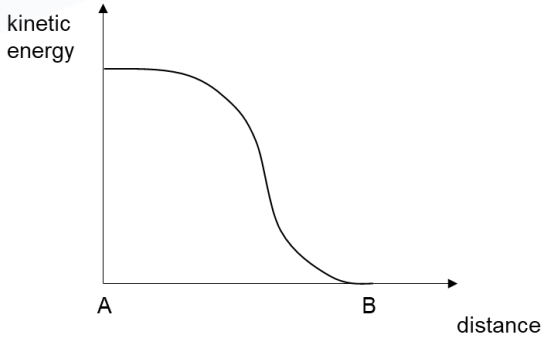
B



C



D



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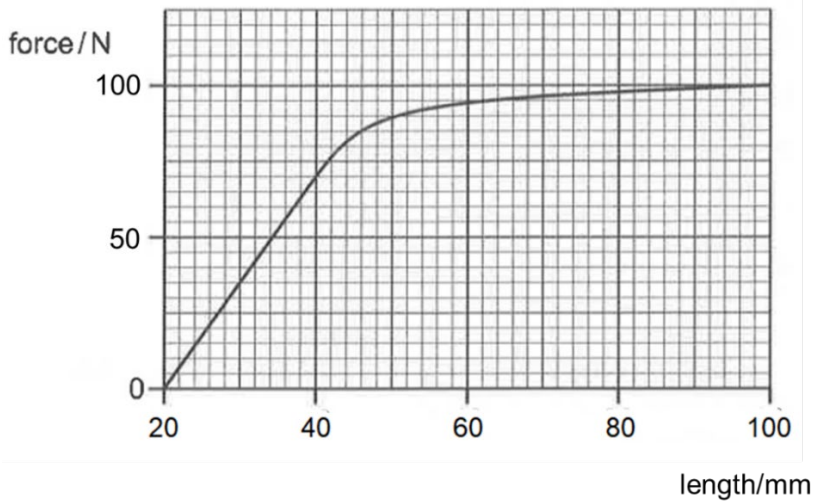
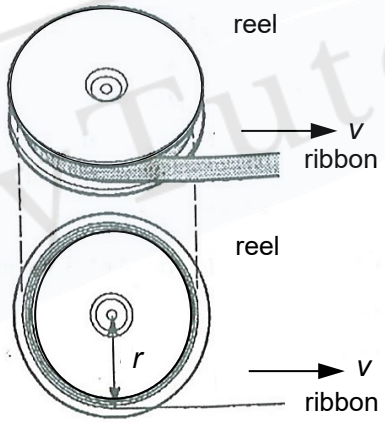
7 A rubber strip is stretched by a force. The graph of the applied force against its length is shown.



What is the work done in stretching the strip to the first point where it no longer obeys Hooke's Law?

A 0.70 J **B** 6.3 J **C** 700 J **D** 6300 J

8 A ribbon, wound around a reel, is pulled and rotates about its centre. The ribbon leaves the reel at a constant v and at a variable distance r from the centre of the reel as shown.



What is the relationship between the angular velocity of the reel and the variable distance r from the centre of the reel?

A Angular velocity is proportional to $\frac{1}{r^2}$.

B Angular velocity is proportional to $\frac{1}{r}$.

C Angular velocity is proportional to r.

D Angular velocity does not depend on r.

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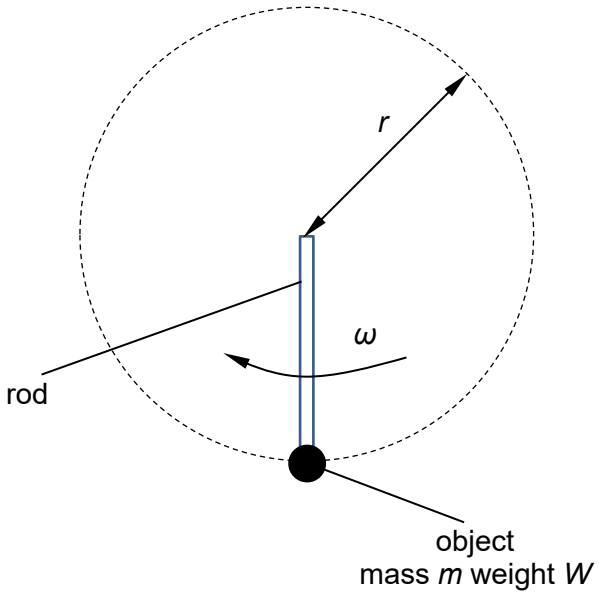
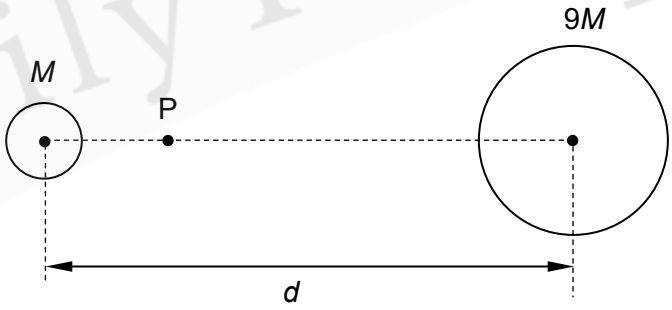
9 An object of mass *m* and weight *W* is fixed to one end of a light rod which rotates in a vertical circle of radius *r*. The object has an angular velocity ω when it is vertically below the centre of the circle.



What is the tension in the rod acting upwards on the object when the object is vertically below the centre of the circle?

A $W + mr\omega^2$ **B** $W - mr\omega^2$ **C** $mr\omega^2 - W$ **D** $mr\omega^2$

10 Two isolated stars, of mass *M* and 9*M*, are separated in space by a distance *d* between the centres of the stars.



Point *P* is a point, between the centres of the stars, where the gravitational field strength is zero.

What is the gravitational potential at P?

A $-\frac{10GM^2}{d}$ **B** $-\frac{16GM}{d}$ **C** $-\frac{20GM^2}{d}$ **D** $-\frac{32GM}{d}$

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11 The International Space Station (ISS) orbits the Earth with uniform speed, above the Earth's atmosphere, at a constant height 420 km above the Earth's surface.

What statement about the ISS is correct?

A There is no gravitational force on the ISS.

B The resultant force on the ISS is in the direction it is moving.

C The ISS is not accelerating.

D The acceleration of the ISS is less than 9.81 m s^{-2}.

12 A weather balloon, initially stationary on the ground, contains an ideal gas with an internal energy of 500 J. The balloon is then launched into the air, reaching a certain altitude Y where the potential energy of the gas has increased by 100 J and its kinetic energy is 250 J.

Assuming the balloon is tied tightly and there is no heat transfer or work done on the ideal gas, what is the internal energy of the gas when the balloon is at that altitude Y?

A 150 J **B** 350 J **C** 500 J **D** 850 J

13 A sealed container is filled with an ideal gas which is initially at a temperature of 50 °C. The root-mean-square (r.m.s.) speed of the gas molecules at this temperature is measured to be 400 m s^{-1}.

If the temperature of the gas is increased to 100 °C, what is now the r.m.s speed of the gas molecules?

A 430 m s^{-1} **B** 460 m s^{-1} **C** 570 m s^{-1} **D** 800 m s^{-1}

14 Which of the following is **not** an example of resonance?

A A flag flaps at a larger amplitude when blown by a stronger wind.

B A glass sheet shattering when exposed to certain frequencies of sound.

C A bottle filled with water producing a loud sound when air is blown over its mouth.

D A washing machine strongly vibrating when the drum rotates at a certain speed.

15 When a spring-mass system is displaced by an initial displacement *X* and released, it moves in a simple harmonic motion with a maximum momentum of *p*.

The same spring-mass system is now displaced by an initial displacement of 0.5*X*.

What is the new maximum momentum of its motion, in terms of *p*?

A 0.25*p* **B** 0.5*p* **C** 2*p* **D** 4*p*

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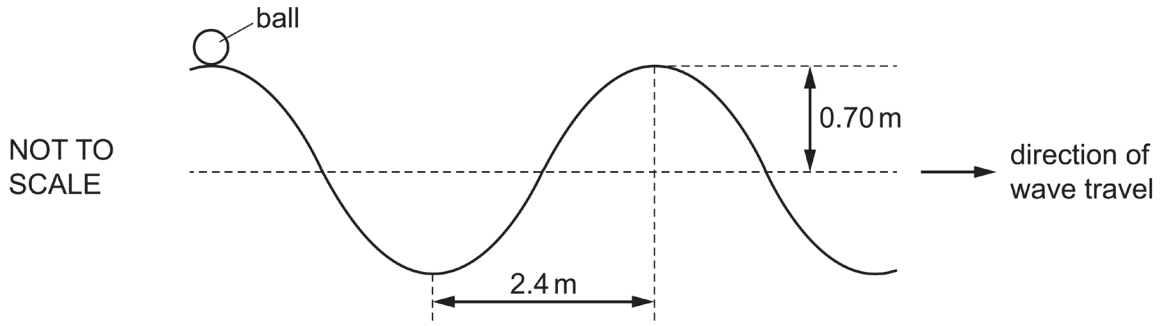
16 A transverse water wave is moving along the surface of some water. This causes a ball to move vertically without moving horizontally as it floats upon the surface. At one instant, the ball is at the position shown.

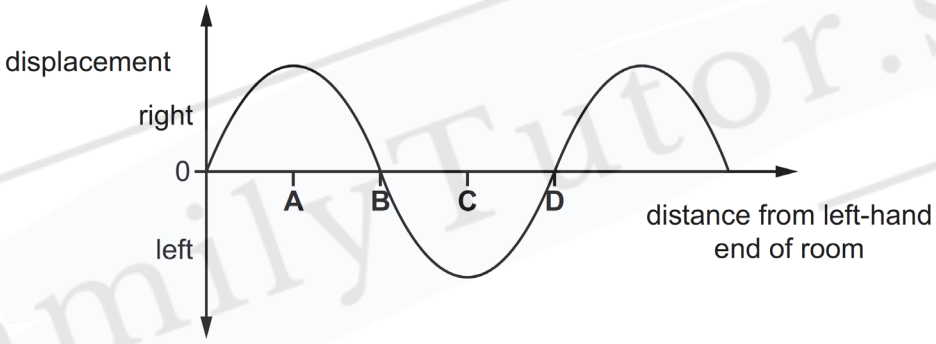


The wave has a frequency of 0.20 Hz and an amplitude of 0.70 m. The distance between a trough and an adjacent peak is 2.4 m.

What is the distance travelled by the ball in a time of 20 s?

A 5.6 m **B** 9.6 m **C** 11.2 m **D** 19.2 m

17 A sound wave travels from left to right across a room. The variation with distance across the room of the displacement of the air molecules at one instant is shown. At which distance will the air pressure be lowest?



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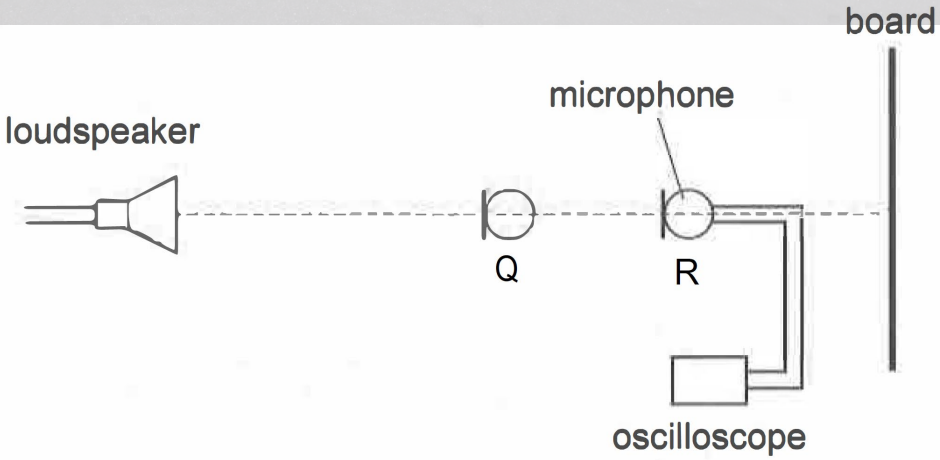
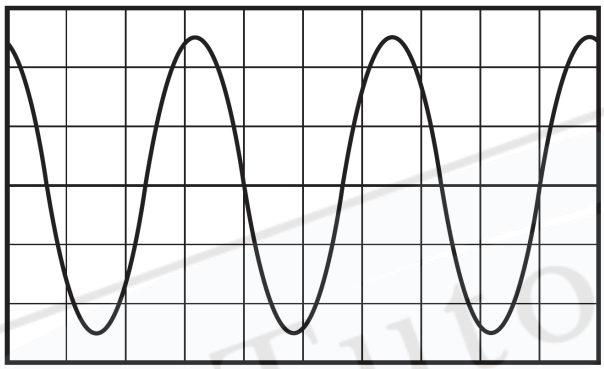
18 Stationary sound waves are investigated using the apparatus shown.



Q and R are adjacent positions of the microphone that give maximum amplitude on the oscilloscope, as shown.



oscilloscope screen when microphone is at R

The distance QR is 6.0 cm and the time base of the oscilloscope is 20 μs div^{-1}. What are the frequency and the wavelength of the sound wave?

	frequency / kHz	wavelength / cm
A	15	6.0
B	15	12
C	20	6.0
D	20	12

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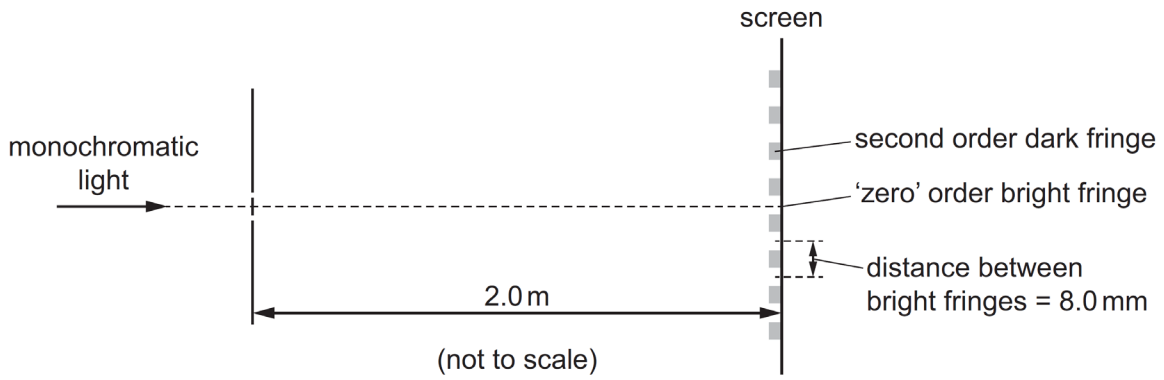
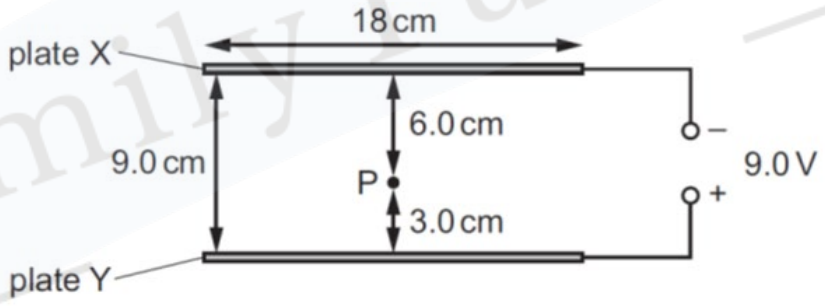
19 Monochromatic light is incident on a pair of narrow slits a distance of 0.1 mm apart. A series of bright and dark fringes are observed on a screen a distance of 2.0 m away. The distance between adjacent bright fringes is 8.0 mm.



What is the path difference between the light waves from the two slits that meet at the second order dark fringe?

A 2.0×10^{-7} m
B 4.0×10^{-7} m
C 6.0×10^{-7} m
D 8.0×10^{-7} m

20 Two parallel circular metal plates X and Y, each of diameter 18 cm, have a separation of 9.0 cm. A potential difference of 9.0 V is applied between them.



Point P is 6.0 cm from the surface of plate X and 3.0 cm from the surface of plate Y.

What is the electric field strength at P?

A 50 N C^{-1} **B** 100 N C^{-1} **C** 150 N C^{-1} **D** 300 N C^{-1}

21 The electric field strength due to a point charge at a distance r from the charge is E.

What is the electric field strength at distance $2r$ from the point charge?

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

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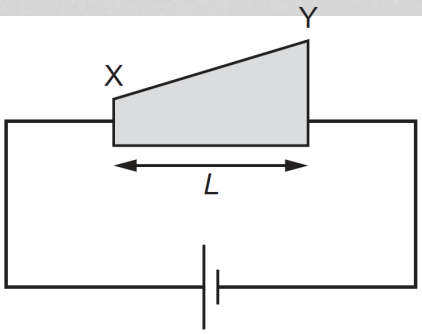
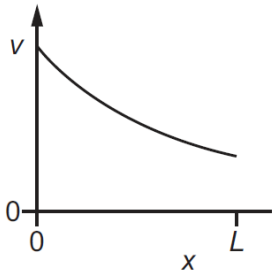
22 A wedge-shaped metal conductor of length L, varying width and uniform thickness is connected to a cell, as shown.

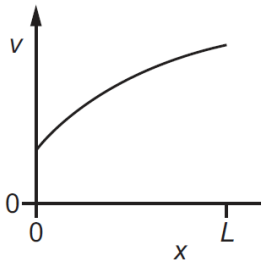


Which graph best shows how the average drift velocity v of electrons in the conductor varies with distance *x* from end X?

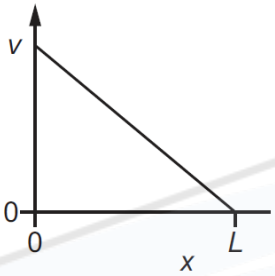
A



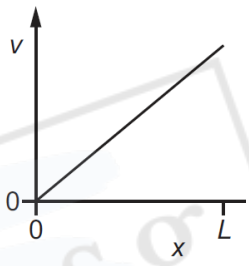
B



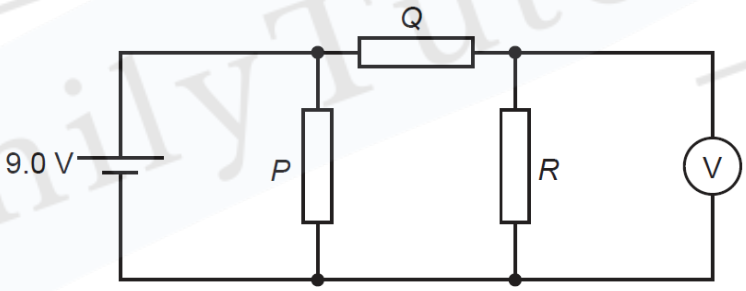
C



D



23 A 9.0 V battery with negligible internal resistance is connected into a circuit, as shown.



The resistance of the voltmeter is equal to the resistance of *R*.

The reading on the voltmeter is 3.0 V.

What is the value of the ratio $\frac{\text{resistance of the voltmeter}}{\text{resistance of Q}}$?

A $\frac{1}{2}$ **B** 1 **C** 2 **D** 4

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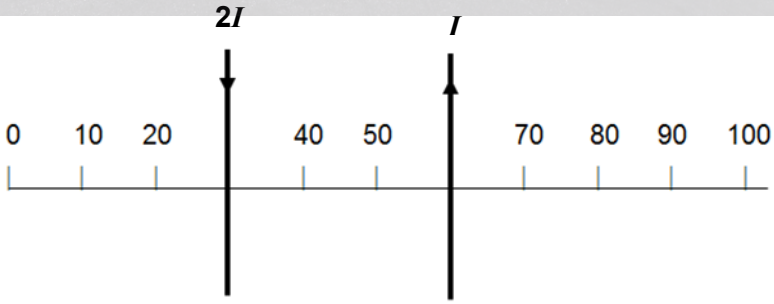
24 Two parallel, straight conductors, placed at right angles to a ruler, carry currents of $2I$ and I flowing in opposite directions.



At which point on the ruler is the resultant magnetic field the greatest?

A 20 cm mark
B 40 cm mark
C 50 cm mark
D 70 cm mark

25 A beam of electrons, travelling horizontally towards the right, passes between two horizontal charged parallel metal plates.

There is a vertical electric field between the plates. There is no deflection of the beam because of the presence of a uniform magnetic field in the region between the plates.

In which direction must this magnetic field be?

A into the paper
B out of the paper
C vertically upwards
D vertically downwards

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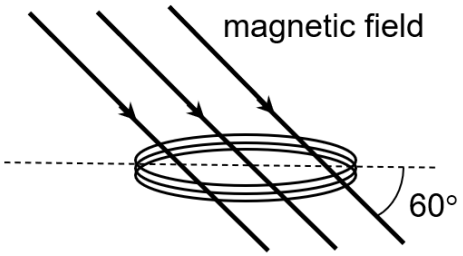
26 A magnetic field of uniform flux density 0.045 T is at an angle of 60° below the plane of horizontal coil of wire as shown.

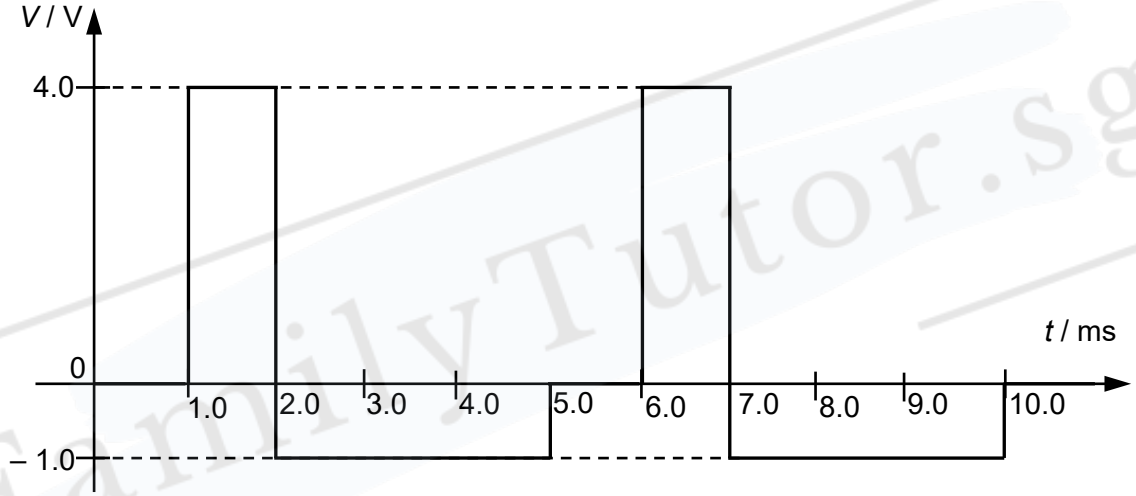


The coil of wire has 4 turns and cross sectional area of 0.30 m^2.

What is the magnitude of the change in magnetic flux linkage of the coil of wire when it is flipped over 180° about a horizontal axis?

A 0 Wb turns **B** 0.012 Wb turns **C** 0.035 Wb turns **D** 0.094 Wb turns

27 The variation with time t of the voltage V of an alternating source applied across a 2.5 Ω resistor is shown below.



What is the mean power dissipated in the resistor?

A 0.98 W **B** 1.5 W **C** 1.9 W **D** 2.4 W

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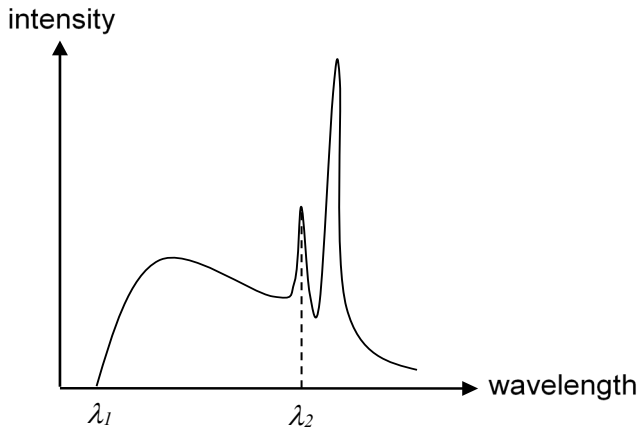
28 The graph below shows the variation of X-ray intensity with wavelength emitted from an X-ray tube.



The target metal and the accelerating voltage are varied. Which wavelengths will be affected by the changes?

	Changing the target metal	Changing the accelerating voltage
A	λ_1	λ_1
B	λ_1	λ_2
C	λ_2	λ_2
D	λ_2	λ_1

29 One nuclear reaction that can take place in a nuclear reactor may be represented by the equation

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{95}_{42}Mo + {}^{139}_{57}La + 2\,{}^{1}_{0}n + 7\,{}^{0}_{-1}e$$

Data for a nucleus and some particles are given in the table.

nucleus or particle	mass / u
$^{139}_{57}$La nucleus	138.955
$^{1}_{0}$n particle	1.00863
$^{1}_{1}$p particle	1.00728
$^{0}_{-1}$e particle	5.49×10^{-4}

What is the binding energy per nucleon of lanthanum-139 ($^{139}_{57}$La)?

A 7.84 Mev **B** 7.87 MeV **C** 19.13 MeV **D** 19.19 MeV

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30 The half-life of a certain radioactive isotope is 32 hours.

What fraction of a sample would remain after 16 hours?

A 0.25 **B** 0.29 **C** 0.5 **D** 0.71

– END OF PAPER 1 –

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PHYSICS 9749/1

Paper 1: Multiple Choice Questions **September 2023**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST
Write your name and tutorial group on this cover 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.

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30
D	C	C	D	A	B	A	B	A	B	D	C	A	A	B	C	D	B	C	B	A	A	B	B	A	D	B	D	A	D

Suggested Solutions

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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}

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FORMULAE

uniformly accelerated motion	s	$= ut + \frac{1}{2}at^2$
	v^2	$= u^2 + 2as$
work done on / by a gas	W	$= p\Delta V$
hydrostatic pressure	p	$= \rho gh$
gravitational potential	ϕ	$= -\frac{Gm}{r}$
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	$= R_1 + R_2 + ...$
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	$= x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	$= \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	$= \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	$= \mu_o nI$
radioactive decay	x	$= x_0 \exp(-\lambda t)$
decay constant	λ	$= \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

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1 A man of mass 75.2 kg uses a set of weighing scales to measure his mass three times. He obtains the following readings.

	mass / kg
reading 1	80.2
reading 2	80.1
reading 2	80.2

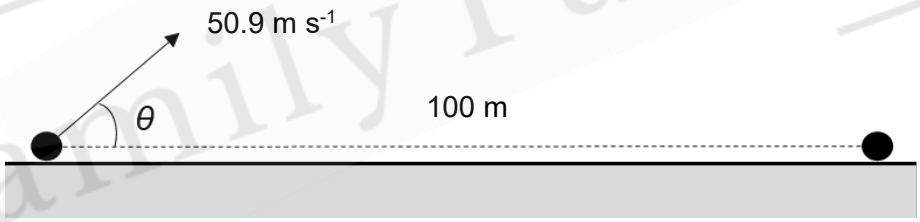
Which statement describes the precision and accuracy of the weighing scales?

A	not precise to ± 0.1 kg and accurate to ± 0.1 kg
B	not precise to ± 0.1 kg and not accurate to ± 0.1 kg
C	precise to ± 0.1 kg and accurate to ± 0.1 kg
D	precise to ± 0.1 kg and not accurate to ± 0.1 kg

Answer: D

Since the weighing scale's reading is bout 5 kg away from the man's true mass, the scale reading is not accurate. However, repeated readings are close to one another with 0.1 kg deviation. Hence the readings are precise.

2 An object is launched with a speed of 50.9 m s^{-1} at an angle θ above the horizontal, as shown.



The ground is level. The object lands on the ground 100 m from its initial launch position.

What is the value of the angle θ?

You may need to make use of the double angle formula: $\sin(2\theta) = 2\sin\theta\cos\theta$

A	2.8°	**B**	5.5°	**C**	11°	**D**	79°

Solution: C

In the horizontal direction:
$50.9\,t\cos\theta = 100$

In the vertical direction (taking upwards as positive):
$0 = 50.9\,t\sin\theta - (0.5)(9.81)t^2 = 50.9\sin\theta - \frac{1}{2}(9.81)t$
$50.9\sin\theta = (0.5)(9.81)t$

$$t = \frac{50.9\sin\theta}{(0.5)(9.81)}$$

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	Substituting into the previous equation: $100 = \frac{50.9^2 \sin\theta\cos\theta}{(0.5)(9.81)} = \frac{50.9^2(0.5)(\sin 2\theta)}{(0.5)(9.81)}$ $2\theta = 22^\circ$ $\theta = 11^\circ$

3	Two spheres with different masses are initially moving towards each other with the same speed. The two spheres collide elastically. Which of the following statements is **true**?	
	A	The two spheres can be at rest at the same time because they were initially moving in opposite directions.
	B	The two spheres can be at rest at the same time because momentum is always conserved in an elastic collision.
	C	The two spheres cannot be at rest at the same time at any point in time because the total momentum of the system is not zero.
	D	The two spheres cannot be at rest at the same time at any point in time because energy is always conserved in an elastic collision.
	Solution: C Since the two spheres do not have the same momentum (since their momentum are unequal in magnitudes), the total momentum of the system is not zero, and hence they cannot be at rest at the same time.	

4	A rower is sitting on a boat in the middle of a calm lake. Which of the following forces forms a Newton's third law pair with the upthrust acting on the boat?	
	A	The weight of the boat alone.
	B	The weight of the rower alone.
	C	The combined weight of the boat and the rower.
	D	The force of the boat on the lake's water to displace some of the lake's water.
	Solution: D The action-reaction pair to the upthrust (which is exerted by the water on the boat) is the downwards force exerted by the boat on the water when it displaced some of the lake's water.	

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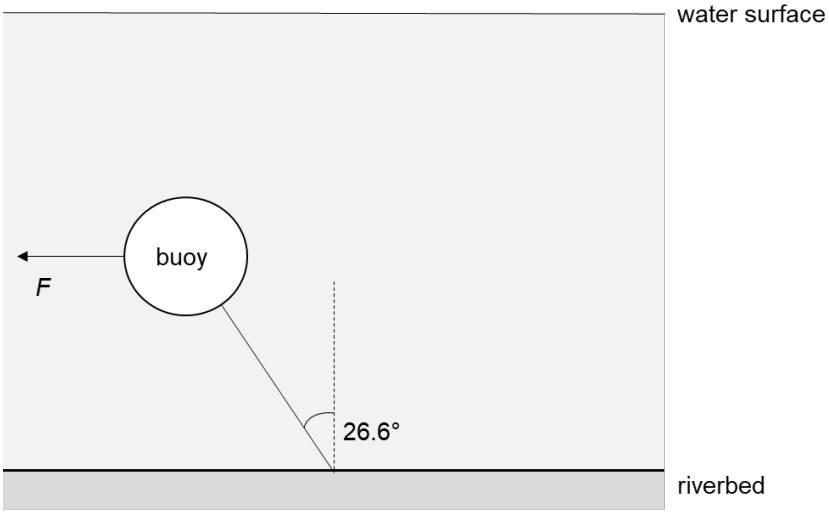
5 A fully submerged buoy is tethered by a rope to a riverbed. The current of the river exerts a constant horizontal force of *F* on the buoy causing the rope to make an angle of 26.6° to the vertical, as shown. The buoy is in equilibrium.



The buoy has a volume of 0.500 m^3 and a density of 390 kg m^{-3}.

The river water has a density of 1000 kg m^{-3}.

What is the force *F* exerted by the river current on the buoy *F*?

A	1500 N	**B**	3830 N	**C**	6000 N	**D**	9810 N

Solution: A

The vertical forces on the buoy are the vertical component of tension, upwards upthrust and the downwards weight.

The net force in the vertical direction is:

$$F_y = U - W$$
$$= V\rho_w g - mg$$
$$= V\rho_w g - V\rho_b g$$
$$= Vg(\rho_w - \rho_b)$$
$$= (0.500)(9.81)(1000 - 390)$$
$$= 3000\text{N}$$

The tangent of the angle that the rope makes with the vertical can be expressed as the ratio of the magnitude of the resultant horizontal force acting on the buoy to the resultant vertical force:

$$\tan 26.6 = \frac{F_x}{F_y}$$

$$0.5 = \frac{F_x}{3000}$$

$$F_x = 1500\text{N}$$

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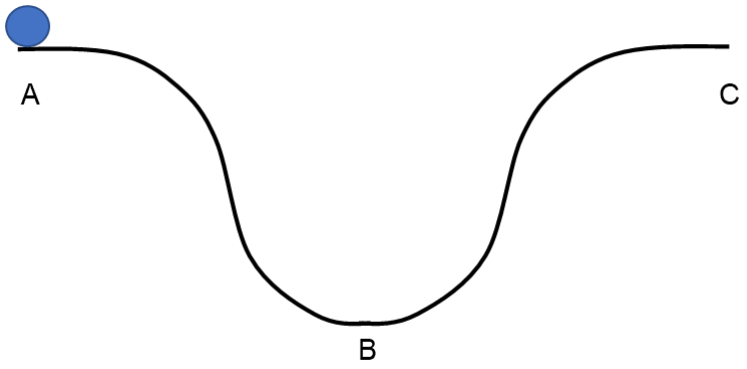
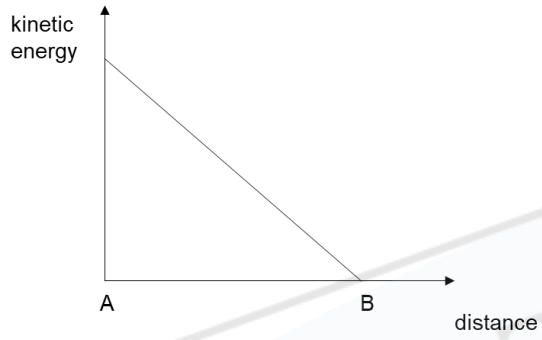
6 An object moves along a frictionless track from A to C, through B, which is the lowest point of the motion.

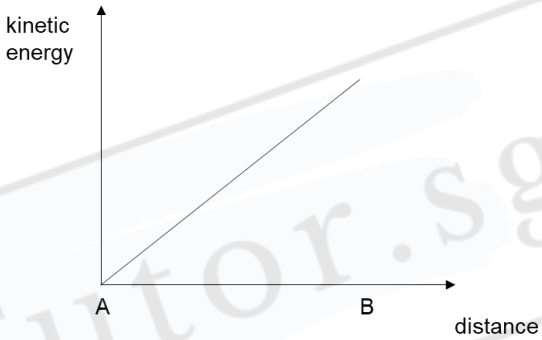


Which graph shows how the kinetic energy of the object varies with the vertical distance from A?

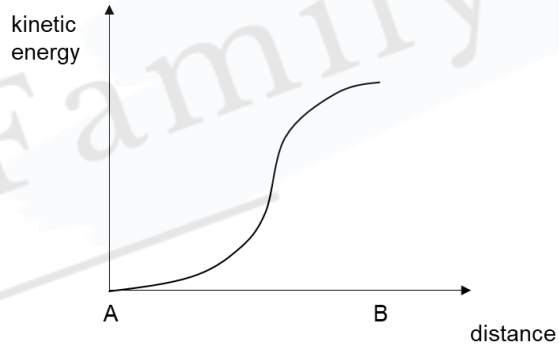
A



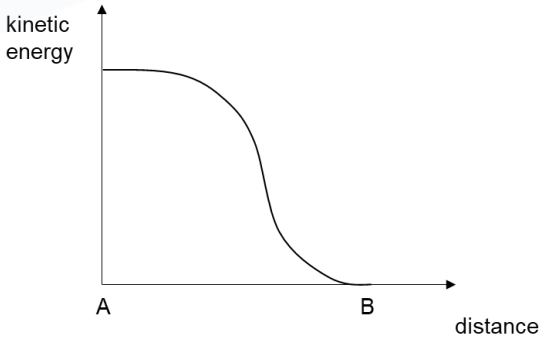
B



C



D



Solution: B

The gravitational potential energy will decrease linearly with the vertical distance from A since the change in GPE = $mg\Delta h$

The kinetic energy will increase at the same linear rate, and therefore, the answer is B.

[Turn over

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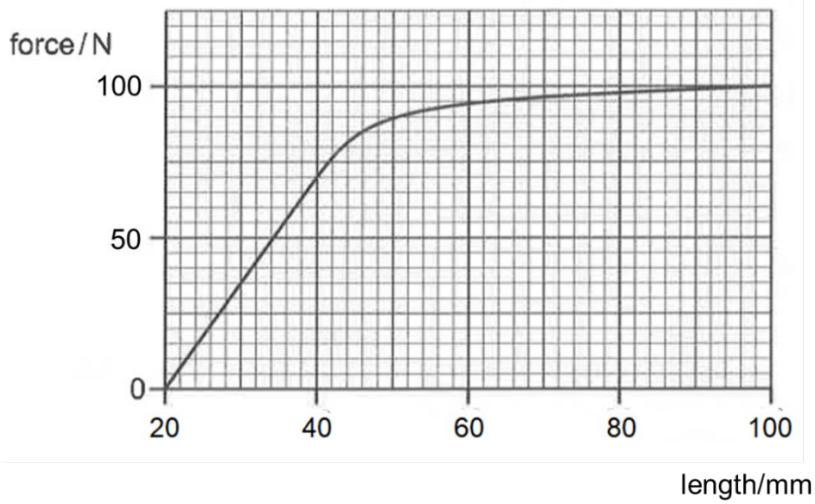
7 A rubber strip is stretched by a force. The graph of the applied force against its length is shown.



What is the work done in stretching the strip to the first point where it no longer obeys Hooke's Law?

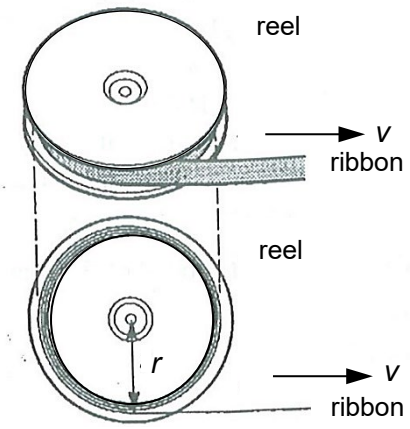
A	0.70 J	**B**	6.3 J	**C**	700 J	**D**	6300 J

Solution: A

The limit of proportionality is when the strip no longer obeys Hooke's Law. This occurs at 40mm of length (20 mm of extension).

Work done
= area under the graph up to 40mm
= ½ (0.0020 m)(70N)
=0.70 J

8 A ribbon, wound around a reel, is pulled and rotates about its centre. The ribbon leaves the reel at a constant *v* and at a variable distance *r* from the centre of the reel as shown.



What is the relationship between the angular velocity of the reel and the variable distance *r* from the centre of the reel?

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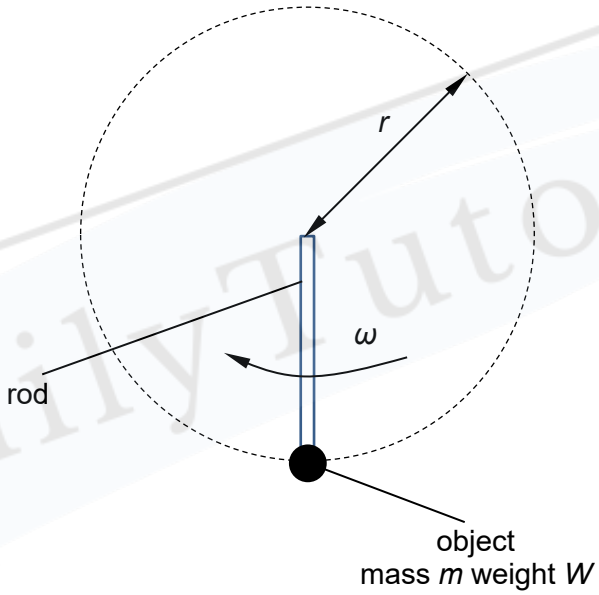
	A	Angular velocity is proportional to $\frac{1}{r^2}$.
	B	Angular velocity is proportional to $\frac{1}{r}$.
	C	Angular velocity is proportional to *r*.
	D	Angular velocity does not depend on *r*.

Answer: B

$v = r\omega \quad \Rightarrow \quad \omega = \frac{v}{r}$ where ω is the angular velocity.

Since *v* is constant, angular velocity ω is proportional to $\frac{1}{r}$.

9 An object of mass *m* and weight *W* is fixed to one end of a light rod which rotates in a vertical circle of radius *r*. The object has an angular velocity when it is vertically below the centre of the circle



What is the tension in the rod acting upwards on the object when the object is vertically below the centre of the circle?

A	$W + mr\omega^2$	**B**	$W - mr\omega^2$	**C**	$mr\omega^2 - W$	**D**	$mr\omega^2$

Answer: A

T – tension in the rod

At the bottom of the circular path, $(T - W)$ provides the centripetal force.

$(T - W) = mr\omega^2 \quad \Rightarrow \quad T = W + mr\omega^2$

[Turn over

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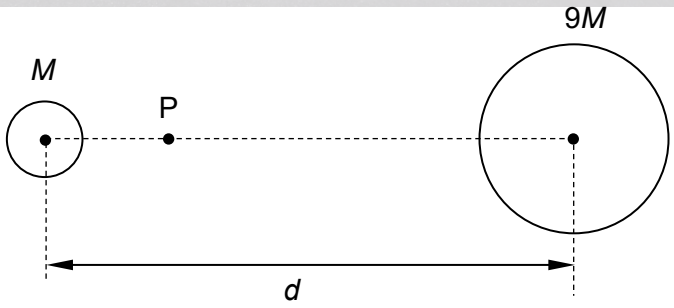
10 Two isolated stars, of mass M and $9M$, are separated in space by a distance d between the centres of the stars.

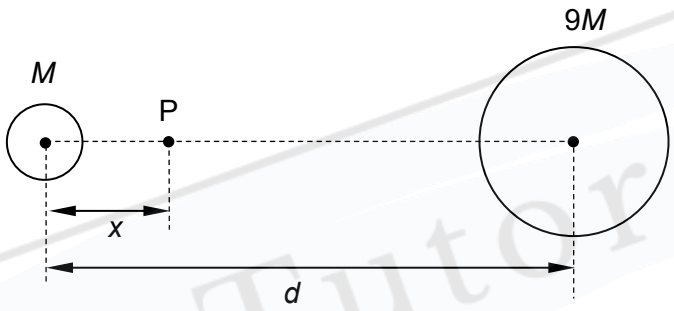


Point P is a point, between the centres of the stars, where the gravitational field strength is zero.

What is the gravitational potential at P?

A	$-\frac{10GM^2}{d}$	**B**	$-\frac{16GM}{d}$	**C**	$-\frac{20GM^2}{d}$	**D**	$-\frac{32GM}{d}$

Answer: B



x – distance from the centre of star mass M.

At P, where gravitational field strength is zero,

$$\frac{GM}{x^2} = \frac{G(9M)}{(d-x)^2}$$

$$(d-x)^2 = 9x^2$$

$$d - x = 3x$$

$$x = \frac{1}{4}d$$

Gravitational potential at P = $-\frac{GM}{\frac{1}{4}d} - \frac{G(9M)}{\frac{3}{4}d} = -\frac{GM}{d}\left(4 + \frac{4}{3}\times 9\right) = -\frac{16GM}{d}$

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11 The International Space Station (ISS) orbits the Earth with uniform speed, above the Earth's atmosphere, at a constant height 420 km above the Earth's surface.

What statement about the ISS is correct?

A	There is no gravitational force on the ISS.
B	The resultant force on the ISS is in the direction it is moving.
C	The ISS is not accelerating.
D	The acceleration of the ISS is less than 9.81 m s^{-2}.

Answer: D

The gravitational force provides the centripetal force for the ISS to move in circular motion and the direction of the centripetal force is towards the centre of the Earth. Option A and B are incorrect.

The acceleration is equal to the magnitude of the gravitational field strength $\left(\frac{GM_{Earth}}{r^2}\right)$.

Since the acceleration on the Earth's surface is 9.81 m s^{-1} and the ISS is above the Earth's surface, its acceleration will be less than 9.81 m s^{-1}. Option D.

12 A weather balloon, initially stationary on the ground, contains an ideal gas with an internal energy of 500 J. The balloon is then launched into the air, reaching a certain altitude Y where the potential energy of the gas has increased by 100 J and its kinetic energy is 250 J.

Assuming the balloon is tied tightly and there is no heat transfer or work done on the ideal gas, what is the internal energy of the gas when the balloon is at that altitude Y?

A	150 J	**B**	350 J	**C**	500 J	**D**	850 J

Answer: C

Given Q = 0 and W = 0, thus $\Delta U = 0$.
No change in internal energy → internal energy remains at the initial value of 500 J.

Recall also that internal energy of an ideal gas is associated with the kinetic energy due to the random motion of the molecules, and independent of the bulk changes in KE and PE of the system as a whole.

13 A sealed container is filled with an ideal gas which is initially at a temperature of 50 °C. The root-mean-square (r.m.s.) speed of the gas molecules at this temperature is measured to be 400 m s^{-1}.

If the temperature of the gas is increased to 100 °C, what is now the r.m.s speed of the gas molecules?

A	430 m s^{-1}	**B**	460 m s^{-1}	**C**	570 m s^{-1}	**D**	800 m s^{-1}

Answer: A

$$\frac{1}{2}m(c^2) = \frac{3}{2}kT$$

$$c_{rms} \propto \sqrt{T}$$

$$\frac{c_{rms,new}}{400} = \sqrt{\frac{100+273.15}{50+273.15}} = 1.07$$

$$c_{rms,new} = 430\ m\ s^{-1}$$

[Turn over

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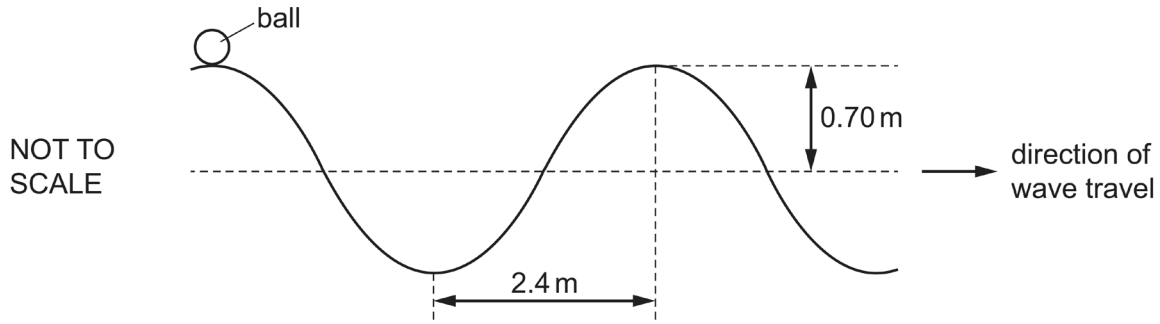
14	Which of the following is **not** an example of resonance?	
	A	A flag flaps at a larger amplitude when blown by a stronger wind.
	B	A glass sheet shattering when exposed to certain frequencies of sound.
	C	A bottle filled with water producing a loud sound when air is blown over its mouth.
	D	A washing machine strongly vibrating when the drum rotates at a certain speed.
	Solution: A A flag fluttering with a larger amplitude only shows that the amplitude of an oscillation increases when the magnitude of the force increases, and is not specifically an example of resonance. The rest are examples of objects vibrating strongly at a certain frequency when subjected to a periodic external force of the same frequency.	

15	When a spring-mass system is displaced by an initial displacement X and released, it moves in a simple harmonic motion with a maximum momentum of p. The same spring-mass system is now displaced by an initial displacement of $0.5X$. What is the new maximum momentum of its motion, in terms of p?							
	A	$0.25p$	**B**	$0.5p$	**C**	$2p$	**D**	$4p$
	Solution: B The maximum velocity is given by $v = \omega x_0$ where ω is the angular frequency and x_0 is the amplitude of the oscillation, which, in this case, is the initial displacement X. Also, since $p = mv$ Then, $p \propto v \propto X$ So, when the displacement is halved, the maximum momentum is halved as well.							

16	A transverse water wave is moving along the surface of some water. This causes a ball to move vertically without moving horizontally as it floats upon the surface. At one instant, the ball is at the position shown.  The wave has a frequency of 0.20 Hz and an amplitude of 0.70 m. The distance between a trough and an adjacent peak is 2.4 m. What is the distance travelled by the ball in a time of 20 s?

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	A	5.6 m	**B**	9.6 m	**C**	11.2 m	**D**	19.2 m

Answer: C

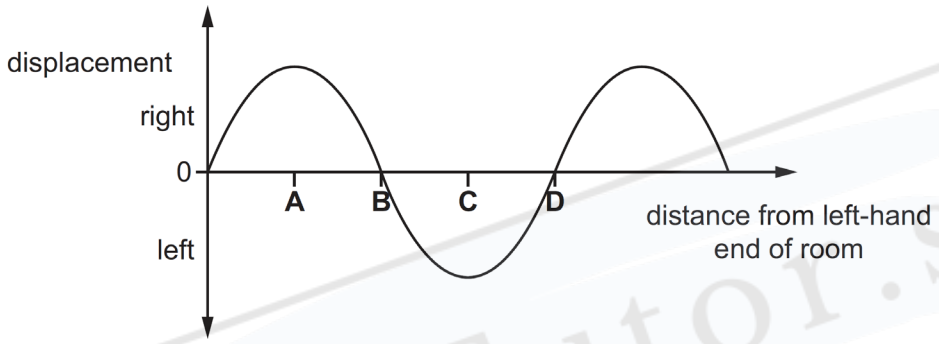
Period of the wave = $\frac{1}{f}$ = 5 s

In 20 s, the ball would have oscillated by $\frac{20}{5}$ = 4 cycles

It would have moved a total distance of 4 x (0.7 x 4) = 11.2 m

Students who found the speed of the wave using fλ, and then take speed x time = dist would end up getting 19.2 m (D).

17 A sound wave travels from left to right across a room. The variation with distance across the room of the displacement of the air molecules at one instant is shown. At which distance will the air pressure be lowest?



Answer: D

The air molecule at A & the air molecules next to it are being displaced to the right at that instant in time.
Similarly, the air molecule at position C and the air molecules next to it are being displaced to the left at that instant in time.

The air molecule at B is not displaced but the air molecules next to it are being displaced towards it and the air pressure will be the highest there.

The air molecule at D is not displaced and the air molecules next to it are being displaced AWAY from it so the air pressure will be the lowest there.

[Turn over

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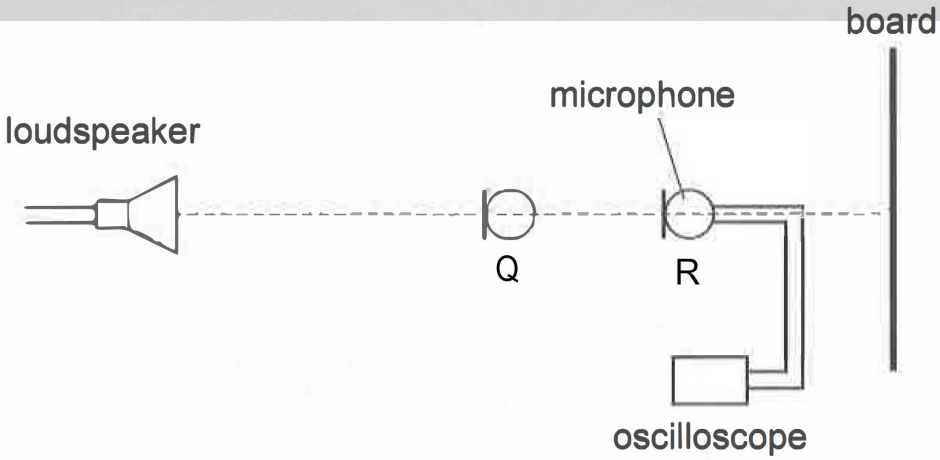
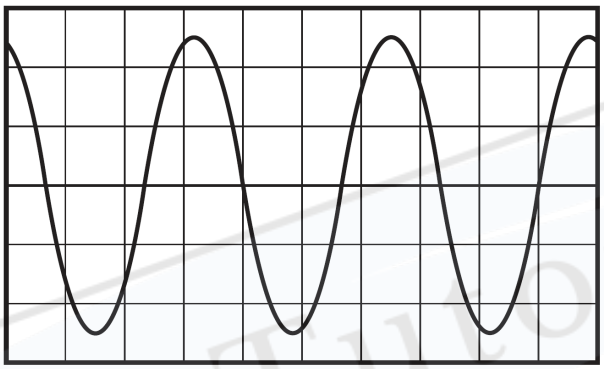
18 Stationary sound waves are investigated using the apparatus shown.



Q and R are adjacent positions of the microphone that give maximum amplitude on the oscilloscope, as shown.



oscilloscope screen when microphone is at R

The distance QR is 6.0 cm and the time base of the oscilloscope is 20 μs div^{-1}. What are the frequency and the wavelength of the sound wave?

	frequency / kHz	wavelength / cm	
A	15	6.0	
B	15	12	
C	20	6.0	
D	20	12	

Answer: B

Distance between two antinodes = $\frac{\lambda}{2}$ = 6.0 cm
Wavelength = 6.0 x 2 = 12 cm

1.5 T as seen from the oscilloscope = $5 \times 20 \times 10^{-6}$
$T = \frac{5 \times 20 \times 10^{-6}}{1.5}$
Frequency = $\frac{1}{T} = \frac{1.5}{5 \times 20 \times 10^{-6}}$ = 15 000 Hz = 15 kHz

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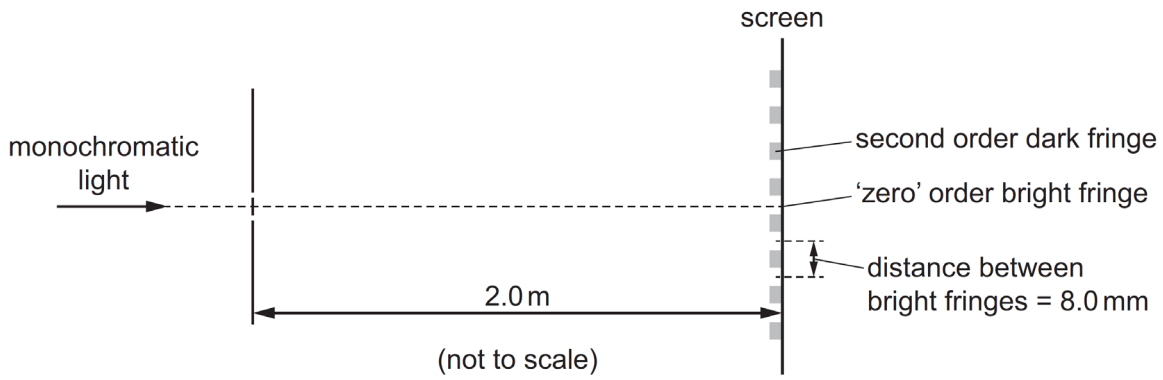
19 Monochromatic light is incident on a pair of narrow slits a distance of 0.1 mm apart. A series of bright and dark fringes are observed on a screen a distance of 2.0 m away. The distance between adjacent bright fringes is 8.0 mm.



What is the path difference between the light waves from the two slits that meet at the second order dark fringe?

	A	2.0×10^{-7} m
	B	4.0×10^{-7} m
	C	6.0×10^{-7} m
	D	8.0×10^{-7} m

Answer: C

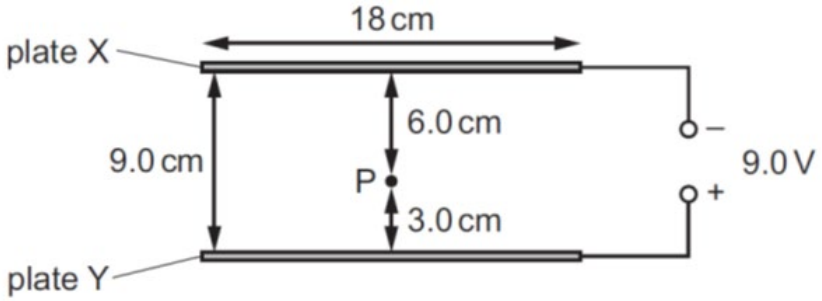
Double slit equation,

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

$$\lambda = \frac{xa}{D} = \frac{8\times10^{-3} \times 0.1\times10^{-3}}{2} = 4\times10^{-7}$$

At the n = 2 dark fringe, the path difference travelled by the light waves are 1.5 λ
Path difference = $1.5\lambda = 6 \times 10^{-7}$ m

20 Two parallel circular metal plates X and Y, each of diameter 18 cm, have a separation of 9.0 cm. A potential difference of 9.0 V is applied between them.



Point P is 6.0 cm from the surface of plate X and 3.0 cm from the surface of plate Y.

What is the electric field strength at P?

	A	50 N C^{-1}	**B**	100 N C^{-1}	**C**	150 N C^{-1}	**D**	300 N C^{-1}

[Turn over

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Answer: B

$E = V/d = 9.0 / 0.09 = 100\ N\ C^{-1}$

---

21 The electric field strength due to a point charge at a distance r from the charge is E.

What is the electric field strength at distance $2r$ from the point charge?

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

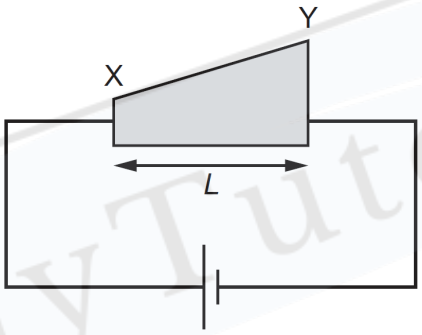
Answer: A

$$E \propto \frac{1}{r^2},\ so\ \frac{E}{E'} = \frac{r'^2}{r^2} \rightarrow \frac{E}{E'} = \frac{4r^2}{r^2}$$

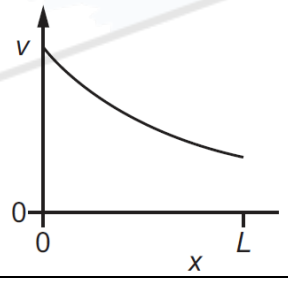
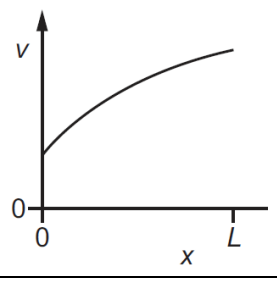
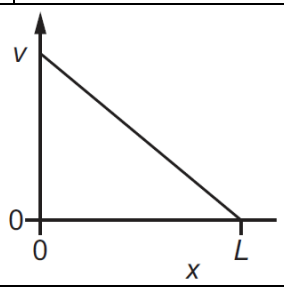
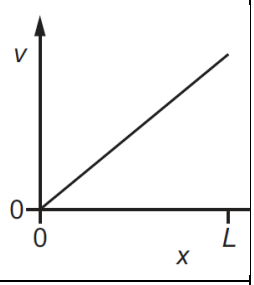
Hence $E' = \frac{E}{4}$

---

22 A wedge-shaped metal conductor of length L, varying width and uniform thickness is connected to a cell, as shown.



Which graph best shows how the average drift velocity v of electrons in the conductor varies with distance x from end X?

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

Answer: A

From $I = nAv_dq$

$I = nAv_dq$

$v_d = \frac{I}{nAq}$

The cross-sectional area of the metal conductor increases from X to Y but the current must remain constant. So the drift speed v_d of the electrons must decrease as they move from X

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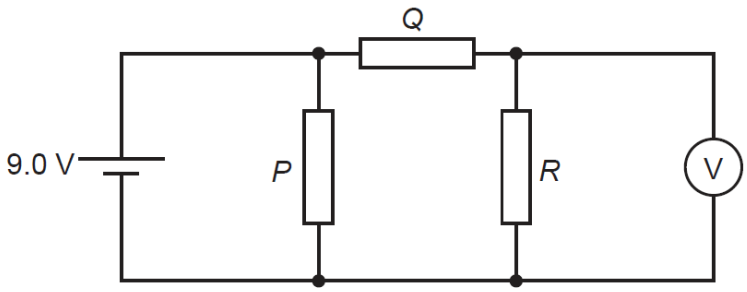
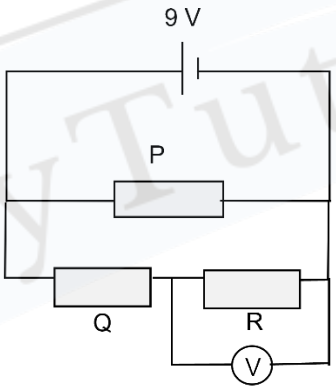
	to Y, eliminating graphs B and D. Graph C can also be rejected, as this graph implies that the electrons stop at Y.

23	A 9.0 V battery with negligible internal resistance is connected into a circuit, as shown.  The resistance of the voltmeter is equal to the resistance of *R*. The reading on the voltmeter is 3.0 V. What is the value of the ratio $\frac{\text{resistance of the voltmeter}}{\text{resistance of Q}}$?

A	$\frac{1}{2}$	**B**	1	**C**	2	**D**	4

Answer: B

Redrawing the circuit,



Resistor *Q* and *R* are in series and have a pd of 9 V across them.
Voltmeter and resistor *R* are in parallel, the potential difference across both is also 3 V.
Potential difference across Resistor *Q* is 9-3 = 6 V
Resistance of voltmeter cannot be ignored.
Let resistance of voltmeter be *R*
Effective resistance of voltmeter and resistor *R* (as they are in parallel and have the same resistance) = $\frac{R}{2}$

By potential divider approach,

$$\frac{\text{effective resistance of the voltmeter \& resistor } R}{\text{resistor } Q} = \frac{\text{pd across voltmeter \& resistor } R}{\text{pd across resistor } Q}$$

$$\frac{\frac{R}{2}}{Q} = \frac{3}{6}$$

$$\frac{R}{Q} = 1$$

[Turn over

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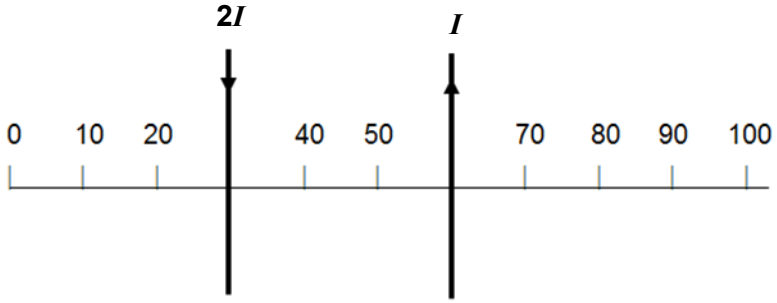
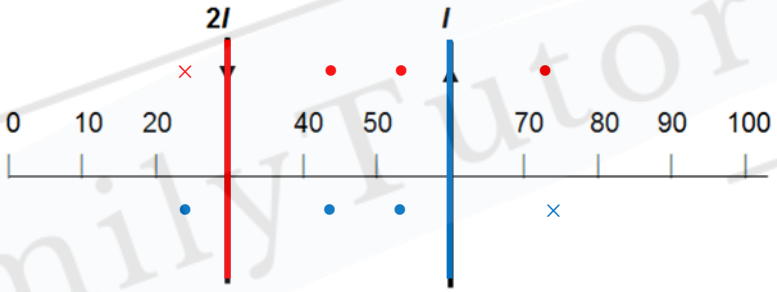
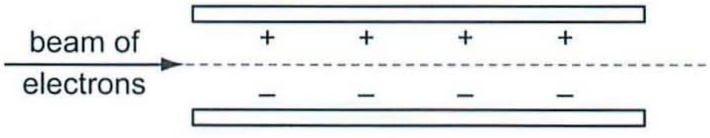
	* If students pick A, they have ignored the resistance of the voltmeter.

24	Two parallel, straight conductors, placed at right angles to a ruler, carry currents of $2I$ and I flowing in opposite directions.  At which point on the ruler is the resultant magnetic field the greatest?	
	A	20 cm mark
	B	40 cm mark
	C	50 cm mark
	D	70 cm mark
	Answer: B Using the RHGR, the magnetic field due to the individual wires are indicated on the diagram.  $B_{40cm} = \frac{\mu_0(2I)}{2\pi(0.1)} + \frac{\mu_0(I)}{2\pi(0.2)} = 12.5\frac{\mu_0 I}{\pi}$ $B_{50cm} = \frac{\mu_0(2I)}{2\pi(0.2)} + \frac{\mu_0(I)}{2\pi(0.1)} = 10\frac{\mu_0 I}{\pi}$	

25	A beam of electrons, travelling horizontally towards the right, passes between two horizontal charged parallel metal plates.  There is a vertical electric field between the plates. There is no deflection of the beam because of the presence of a uniform magnetic field in the region between the plates. In which direction must this magnetic field be?	
	A	into the paper
	B	out of the paper

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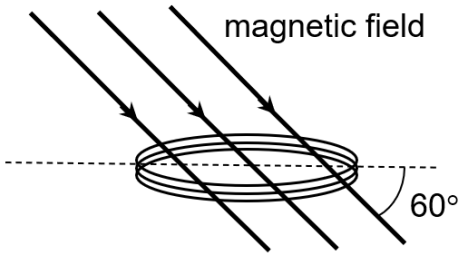
	C	vertically upwards
	D	vertically downwards

Answer: A
The electric force on the electrons due to the electric field is upwards.
Hence the magnetic force must be downwards in order for the beam not to be deflected.
Using FLHR, current is towards the left, field must be into the paper.

26 A magnetic field of uniform flux density 0.045 T is at an angle of 60° below the plane of horizontal coil of wire as shown.



The coil of wire has 4 turns and cross sectional area of 0.30 m^2.

What is the magnitude of the change in magnetic flux linkage of the coil of wire when it is flipped over 180° about a horizontal axis?

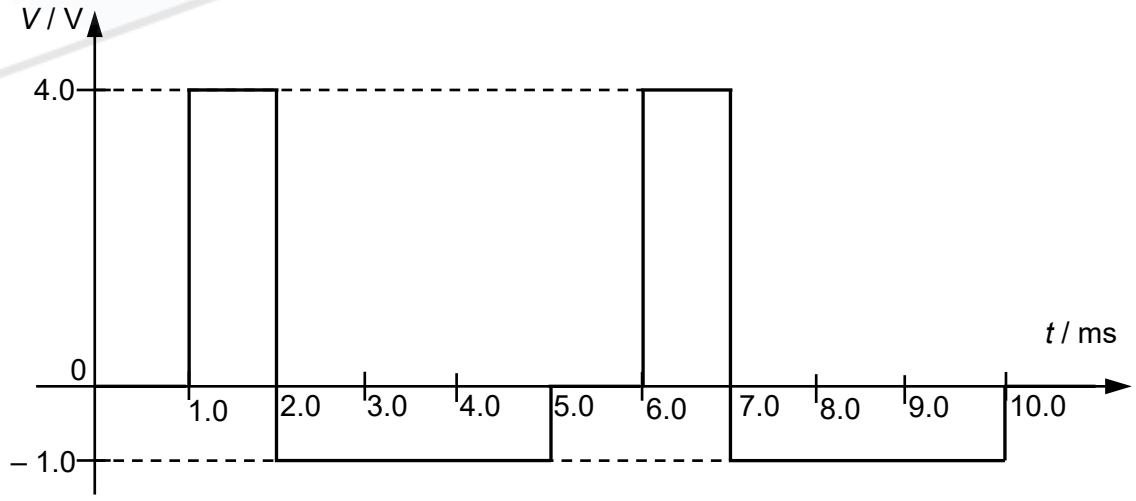
A 0 Wb turns	**B** 0.012 Wb turns	**C** 0.035 Wb turns	**D** 0.094 Wb turns

Answer: D

Taking downwards as positive,

$\Delta\phi = \phi_f - \phi_i$
= NA (B sin 60 - (-Bsin60))
= 4 x 0.3 x [0.045 sin60 - (-0.045 sin60)]
= 0.094 Wb turns

27 The variation with time *t* of the voltage *V* of an alternating source applied across a 2.5 Ω resistor is shown below.



What is the mean power dissipated in the resistor?

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	A 0.98 W	**B** 1.5 W	**C** 1.9 W	**D** 2.4 W

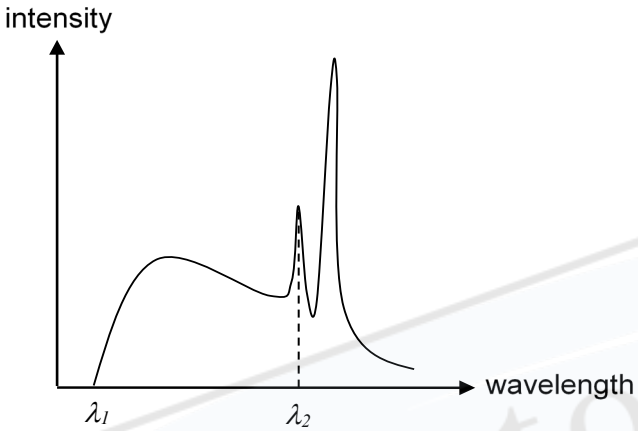
Answer: B

To find r.m.s. value of V, we need to square the graph and find the average value of V^2 then find square root.

$V_{r.m.s.} = \sqrt{\frac{(4^2 \times 1) + (1 \times 3)}{5}} = \sqrt{(3.8)}$

Power dissipated = $V_{r.m.s.}^2 / R = 3.8 / 2.5 = 1.5$ W

28 The graph below shows the variation of X-ray intensity with wavelength emitted from an X-ray tube.



The target metal and the accelerating voltage are varied. Which wavelengths will be affected by the changes?

	Changing the target metal	Changing the accelerating voltage	
A	λ_1	λ_1	
B	λ_1	λ_2	
C	λ_2	λ_2	
D	λ_2	λ_1	

Answer: D

The minimum wavelength, λ_1, is affected by the potential difference which accelerates the electron and causes it to gain KE. The electron loses all its KE in the form of an X ray photon with minimum wavelength through a single head-on collision with the target atom.

λ_2 is located at one of the peaks. Changing the target metal will affect the characteristic wavelength of the peaks which is *dependent* on the target material. Since each element has a unique set of electron energy levels, the energy differences between these levels are also characteristic of the material.

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29 One nuclear reaction that can take place in a nuclear reactor may be represented by the equation

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{95}_{42}Mo + {}^{139}_{57}La + 2\,{}^{1}_{0}n + 7\,{}^{0}_{-1}e$$

Data for a nucleus and some particles are given in the table.

nucleus or particle	mass / u
$^{139}_{57}$La nucleus	138.955
$^{1}_{0}$n particle	1.00863
$^{1}_{1}$p particle	1.00728
$^{0}_{-1}$e particle	5.49×10^{-4}

What is the binding energy per nucleon of lanthanum-139 ($^{139}_{57}$La)?

A	7.84 Mev	**B**	7.87 MeV	**C**	19.13 MeV	**D**	19.19 MeV

Answer: A

Given the nuclear mass and not atomic mass,

Δm = (82 x 1.00863u) + (57 x 1.00728u) – 138.955u = 1.16762u

Energy = Δmc^2 = (1.16762 x 1.66 x 10^{-27}) x (3.00 x 10^{8})^2

$$= 1.74442428 \times 10^{-10}\ \text{J} = \frac{1.74442428 \times 10^{-10}}{1.6 \times 10^{-13}}\ \text{MeV} = 1090.265\ \text{MeV}$$

$$\text{Energy per nucleon} = \frac{1090.265}{139} = 7.84\ \text{MeV}$$

30 The half-life of a certain radioactive isotope is 32 hours.

What fraction of a sample would remain after 16 hours?

A	0.25	**B**	0.29	**C**	0.5	**D**	0.71

Answer: D

Using $x = x_0\left(\frac{1}{2}\right)^n$

Since 16 hours is 0.5 half-life,

$$x = x_0\left(\frac{1}{2}\right)^{0.5} = 0.7071x_0 = 0.71x_0$$

– END OF PAPER 1 –

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CLASS	**2T**

PHYSICS
Paper 2: Structured Questions

9749/2
August 2023
2 hours

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

READ THESE INSTRUCTIONS FIRST
Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, 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.

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FOR EXAMINER'S USE	
Q1	/ 10
Q2	/ 10
Q3	/ 8
Q4	/ 10
Q5	/ 14
Q6	/ 9
Q7	/ 19
PAPER 2	/ 80

This document consists of **22** printed pages.

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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}

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FORMULAE

uniformly accelerated motion	s	$= ut + \frac{1}{2}at^2$
	v^2	$= u^2 + 2as$
work done on / by a gas	W	$= p\Delta V$
hydrostatic pressure	p	$= \rho gh$
gravitational potential	ϕ	$= -\frac{Gm}{r}$
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	$= R_1 + R_2 + ...$
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	$= x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	$= \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	$= \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	$= \mu_o nI$
radioactive decay	x	$= x_0 \exp(-\lambda t)$
decay constant	λ	$= \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 (a) A swimmer is swimming at a constant speed in a pool. Drag forces due to the water oppose the motion of the swimmer.

Explain why the swimmer travels at constant speed.

……..

……..

……..

…….……[2]

(b) The power output P of a swimmer used to overcome the drag forces travelling when at speed v is given by

$$P=\frac{1}{2}C_D\rho A v^3$$

where C_D is the drag coefficient, ρ is the density of water and A is the frontal area of the swimmer.

In an experiment to measure the C_D for freestyle, the data for a particular swimmer is collected. The data is shown in Table 1.1.

Table 1.1

quantity	magnitude	uncertainty
P/ W	294	± 2
ρ/ kg m^{-3}	1000	± 1
A/ m^2	0.20	± 0.01
v/ m s^{-1}	1.4	± 0.1

Determine the C_D of the swimmer, with its actual uncertainty. Give your answer to an appropriate number of significant figures.

C_D = …….. ± ……..…… [4]

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(c) **(i)** Derive, from the definition of power, an expression of the drag force F experienced by the swimmer in terms of the velocity v.

[2]

(ii) Hence or otherwise, calculate the work done by the swimmer to overcome the drag force when he swims a distance of 50 m at a constant speed of 1.4 m s^{-1}.

work done = ... J [2]

[Total: 10]

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[Turn over

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2 **(a)** Fig. 2.1 shows a mass initially travelling at right angles to the Earth's uniform gravitational field.

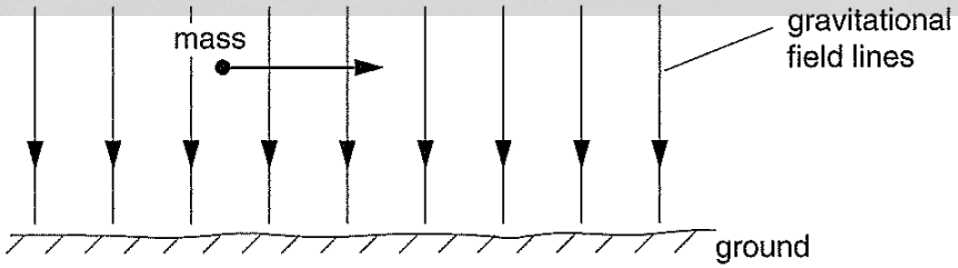

Fig. 2.1

Describe the subsequent motion of the mass.

.....

..... [1]

(b) Fig. 2.2 shows an electron initially travelling parallel to a uniform electric field.

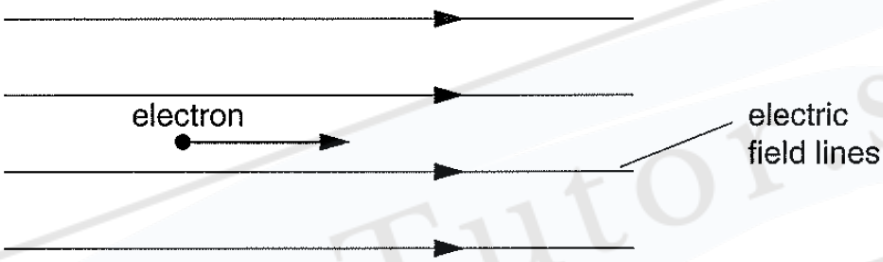

Fig. 2.2

Describe the subsequent motion of the electron.

.....

.....

.....[2]

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(c) Fig. 2.3 shows a long molecule placed in a uniform electric field.

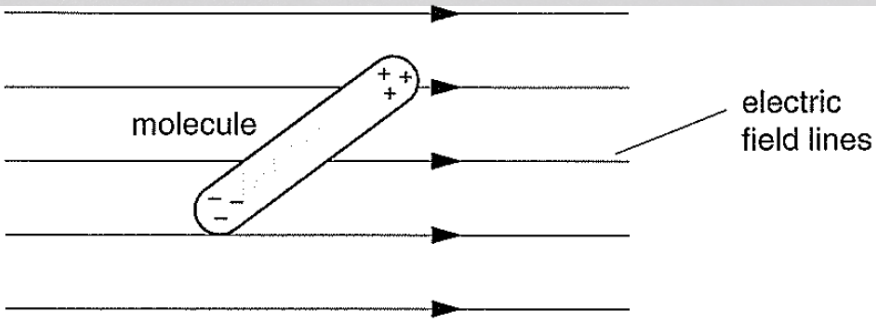

Fig. 2.3

The ends of the molecule have equal but opposite charges. Describe and explain the initial motion of the molecule in the electric field.

……

……

……

…… [2]

(d) Fig. 2.4 shows a sphere of weight 1.6×10^{-2} N with an electric charge of +2.0 μC. It is released from rest, in vacuum, between two parallel, vertical metal plates. The separation of the plates is 0.10 m. One plate has a potential of +80 V and the other plate has a potential of -80 V.

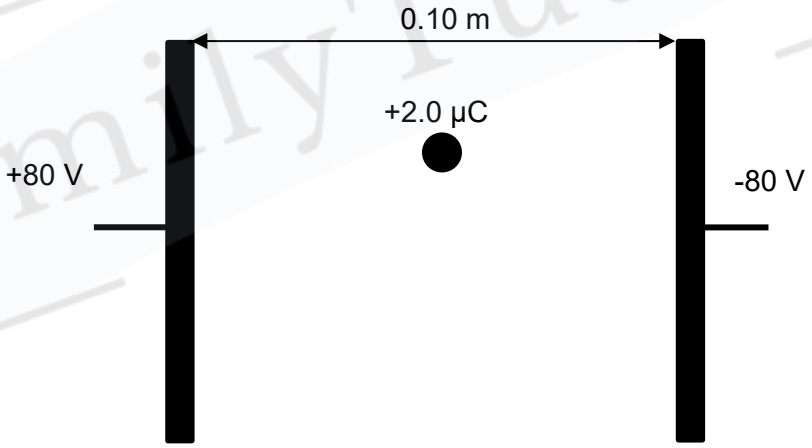

Fig. 2.4

(i) Determine the electric force experienced by the sphere.

force = …… N [2]

[Turn over

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(ii) On Fig. 2.4, sketch the path taken by the sphere after it is released. [1]

(e) The variations with separation of the gravitational potential energy U_G and of the electric potential energy U_E between two protons are shown in Fig. 2.5.

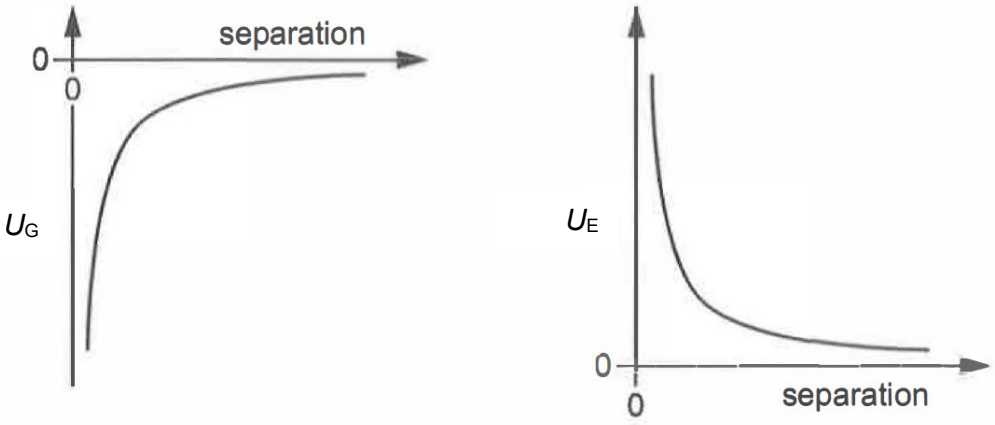

Fig. 2.5

Explain why the gravitational potential energy and the electric potential energy have opposite signs.

……

……

……

…… [2]

[Total: 10]

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3 A cantilever spar cable-stayed bridge is a unique yet functional variation of the traditional cable suspension bridge.

In one such model bridge, a bridge beam is supported by a cable. The cable connected at an angle of 30° to a non-uniform cantilever spar of length *L* slanted at an angle of 50° from the ground with a base at P, as shown in Fig. 3.1.

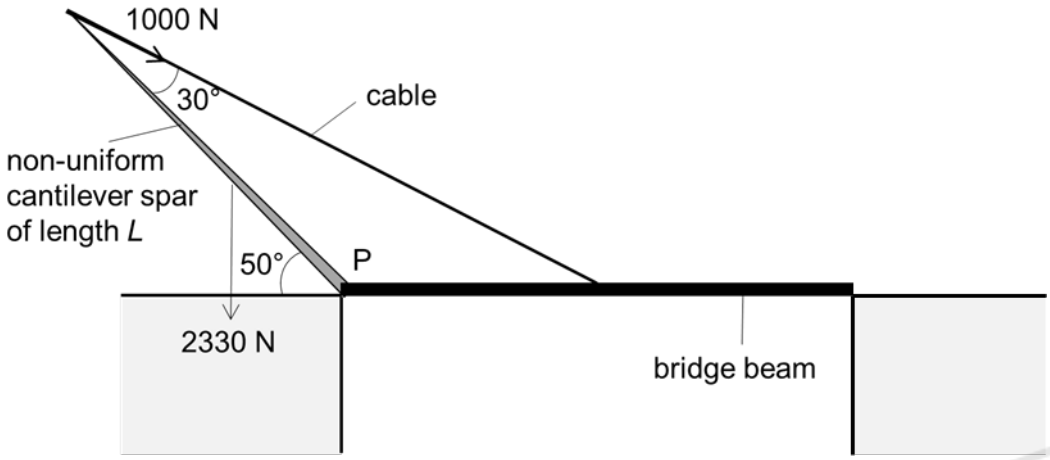

Fig 3.1 (not to scale)

The tension in the cable is 1000 N and the weight of the cantilever spar is 2330 N.

(a) By taking moments about P, show that the centre of mass of the cantilever spar is located at a distance of 0.33*L* from P.

[3]

(b) Calculate the magnitude of the force acting on the cantilever spar at P.

magnitude of force at P = ... N [3]

[Turn over

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(c) The traditional cable-stayed bridge design is shown in Fig 3.2

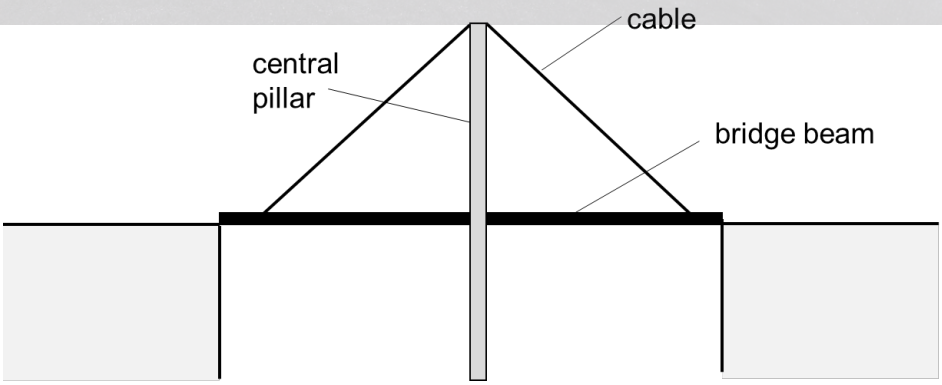

Fig 3.2

Suggest, with a reason, one advantage a cantilever spar cable-stayed bridge may have over a traditional cable-stayed bridge design.

……

……

……

……[2]

[Total: 8]

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4 (a) A battery of electromotive force (e.m.f.) 9.0 V and internal resistance *r* is connected to two resistors S and T, as shown in Fig. 4.1.

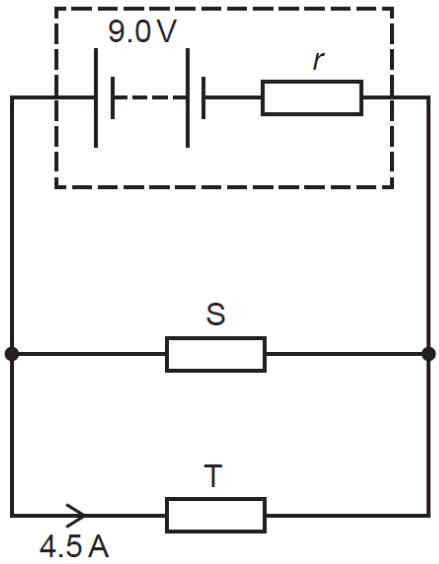

Fig 4.1

A total charge of 650 C moves through resistor S in a time interval of 540 s. During this time resistor S dissipates 4800 J of energy. The current in resistor T is 4.5 A. Assume that the e.m.f. of the battery remains constant.

Calculate:

(i) the current in resistor S

current = ...A [1]

(ii) the internal resistance *r* of the battery.

r = ... Ω [3]

[Turn over

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(b) A sinusoidal alternating voltage has a root-mean-square (r.m.s.) potential difference (p.d.) of 4.2 V and a frequency of 50 Hz.

(i) By reference to heating effect, explain what is meant by the root-mean-square (r.m.s.) value of an alternating current.

……..

……..

…….[1]

(ii) The alternating voltage is applied across a resistor of resistance 760 Ω.

Determine the maximum power dissipated by the resistor.

maximum power dissipated = …….. mW [2]

(iii) On Fig. 4.2, sketch the variation with time *t* of the power *P* transferred in the resistor. Include on your graph a time equal to two periods of the alternating potential difference.

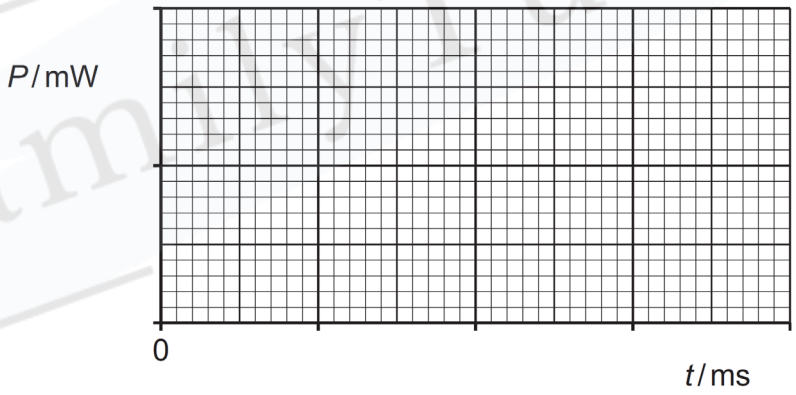

Fig. 4.2

[3]

[Total: 10]

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

.....

.....

.....[2]

(b) Two coils, P and S, are wound on an iron core, as shown in Fig. 5.1.

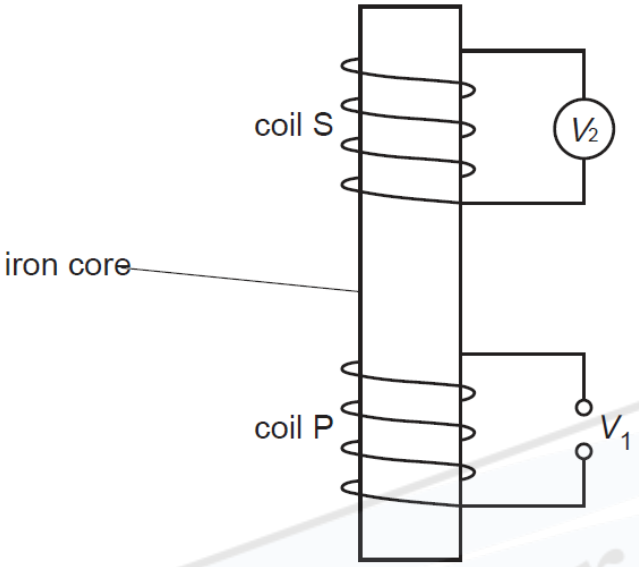

Fig. 5.1

Coil P is connected to a potential difference (p.d.) V_1 that gives rise to a magnetic field in the iron core.

Fig. 5.2 shows the variation with time t of the magnetic flux density B in the iron core.

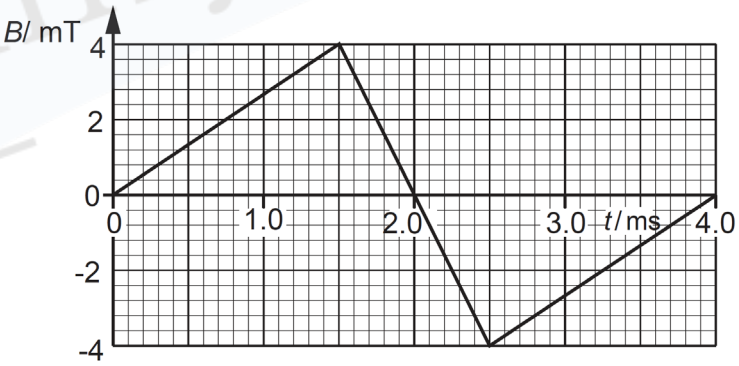

Fig. 5.2

[Turn over

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Coil S contains 250 turns of wire. Each turn of wire has a diameter of 2.5 cm. A voltmeter measures the electromotive force (e.m.f.) V_2 that is induced across coil S.

Use data from Fig. 5.2 to determine the maximum electromotive force (e.m.f.) induced in coil S.

e.m.f. = ... V [3]

(c) On Fig. 5.3, sketch the variation with t of V_2 between t = 0 and t = 4.0 ms.

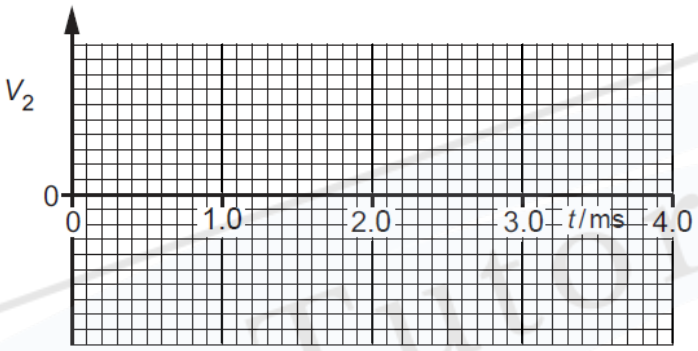

Fig. 5.3

[4]

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(d) Coil S in **(b)** is now replaced with a copper ring that rests loosely on top of coil P. The supply to coil P is replaced with a cell and a switch that is initially open, as shown in Fig. 5.4.

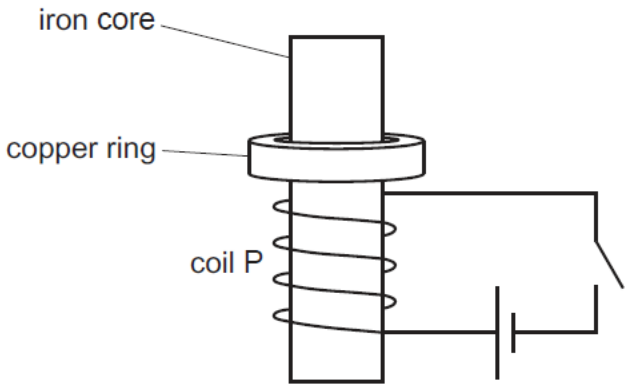

Fig. 5.4

(i) The switch is now closed. As it is closed, the copper ring is observed to move vertically upwards on the iron core.

Explain why this happens.

……

……

……

……[4]

(ii) Suggest, with a reason, what would be the effect on the ring of repeating the procedure in **(d)(i)** with the terminals of the cell reversed.

……

……[1]

[Total: 14]

[Turn over

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6 **(a)** State how a line emission spectrum may be explained on the basis of the existence of discrete electron energy levels in atoms.

……

……

……

……

……[3]

(b) The lowest six discrete energy levels for a hydrogen atom are shown in Fig. 6.1. The diagram is drawn to scale and the ground state is at -13.6 eV.

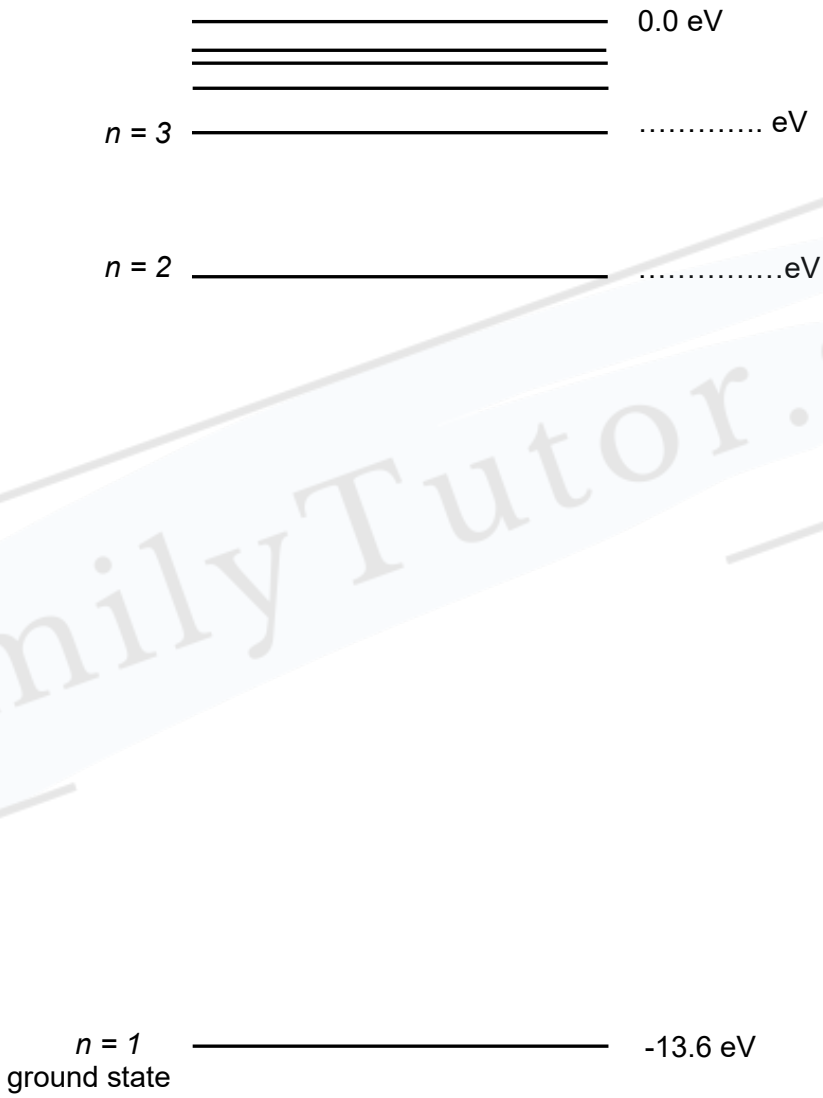

Fig. 6.1

(i) On Fig. 6.1, label the values for energy at energy levels $n = 2$ and $n = 3$. [1]

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(ii) Calculate the wavelength of the light emitted when an electron falls from $n = 3$ energy level to the $n = 2$ energy level.

wavelength = …….. m [3]

(iii) Electromagnetic radiation is emitted when an electron falls to the ground state from any of the other energy levels. State the region of the electromagnetic spectrum in which the radiation lies.

electromagnetic radiation is ……. [1]

(iv) Describe one way by which an electron in gaseous hydrogen can be raised from a lower energy level to a higher energy level.

.....

..... [1]

[Total: 9]

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

Beginning in 1934, the Italian physicist Enrico Fermi began bombarding elements with neutrons instead of protons, theorizing that Chadwick's uncharged particles could pass into the nucleus without resistance. Like other scientists at the time, Fermi paid little attention to the possibility that matter might disappear during bombardment and result in the release of huge amounts of energy in accordance with Einstein's formula, $E = mc^2$, which stated that mass and energy were equivalent. Fermi and his colleagues bombarded sixty-three stable elements and produced thirty-seven new radioactive ones. They also found that carbon and hydrogen proved useful as moderators in slowing the bombarding neutrons and that slow neutrons produced the best results since neutrons moving more slowly remained in the vicinity of the nucleus longer and were therefore more likely to be captured.

One element Fermi bombarded with slow neutrons was uranium, the heaviest of the known elements. Scientists disagreed over what Fermi had produced in this transmutation. Some thought that the resulting substances were new "transuranic" elements, while others noted that the chemical properties of the substances resembled those of lighter elements. Fermi was himself uncertain. For the next several years, attempts to identify these substances dominated the research agenda in the international scientific community, with the answer coming out of Nazi Germany just before Christmas 1938.

The radiochemists Otto Hahn and Fritz Strassmann were bombarding elements with neutrons in their Berlin laboratory when they made an unexpected discovery. They found that while the nuclei of most elements changed somewhat during neutron bombardment, uranium nuclei changed greatly and broke into two roughly equal pieces. They split and became not the new transuranic elements that some thought Fermi had discovered but radioactive barium isotopes (barium has the atomic number 56) and fragments of the uranium itself. The substances Fermi had created in his experiments, that is, did more than resemble lighter elements; they were lighter elements. Importantly, the products of the Hahn-Strassmann experiment weighed less than that of the original uranium nucleus, and herein lay the primary significance of their findings. For it followed from Einstein's equation that the loss of mass resulting from the splitting process must have been converted into energy in the form of kinetic energy that could in turn be converted into heat.

Calculations made by Hahn's former colleague, Lise Meitner, a refugee from Nazism then staying in Sweden, and her nephew, Otto Frisch, led to the conclusion that so much energy had been released that a previously undiscovered kind of process was at work. Frisch, borrowing the term for cell division in biology - binary fission - named the process fission. For his part, Fermi had produced fission in 1934 but had not recognized it.

The large amount of energy released in a nuclear fission reaction, together with the emission of more than one neutron, has made it possible for neutron-induced fission to be used as a source of useful energy. When a neutron is captured by a Uranium-235 nucleus, it causes the nucleus to fission. On average, 2.5 neutrons are emitted in these fission reactions. This is illustrated in Fig. 7.1.

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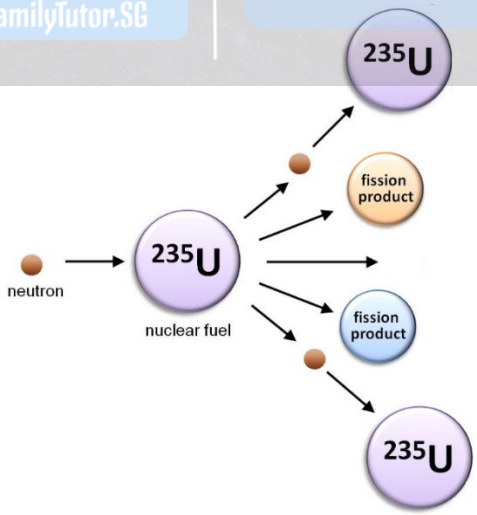

Fig. 7.1

When the conditions are suitable, a chain reaction can occur. If this chain reaction is not controlled, an explosion is likely to occur. However, if the chain reaction is controlled, as in a nuclear reactor, a source of continuous power may be created.

(a) **(i)** Explain what is meant by neutron-induced fission.

……

…… [1]

(ii) Explain what is meant by chain reaction.

……

…… [1]

(iii) Suggest why, in an uncontrolled chain reaction where all neutrons are captured by Uranium-235 nuclei, the majority of the energy is released during the final stages of the fission of a sample of the uranium.

……

……

…… [2]

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(b) The induced fission reaction of Uranium-235 may be represented by a nuclear equation of the form

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{a}_{b}\mathrm{P} + {}^{c}_{d}\mathrm{Q} + (2 \text{ or } 3)\,{}^{1}_{0}\mathrm{n} + 198\mathrm{MeV}$$

The fission products P and Q have approximately equal masses. However, when any two nuclei are fissioned, the fission products may not be the same. If a large sample of Uranium- 235 is fissioned, many different fission products will be produced. The percentage amount of each fission product in the fissioned material is referred to as the percentage yield.

The variation with nucleon number of the percentage yield of different fission products is referred to as a 'fission yield curve' and is illustrated in Fig. 7.3.

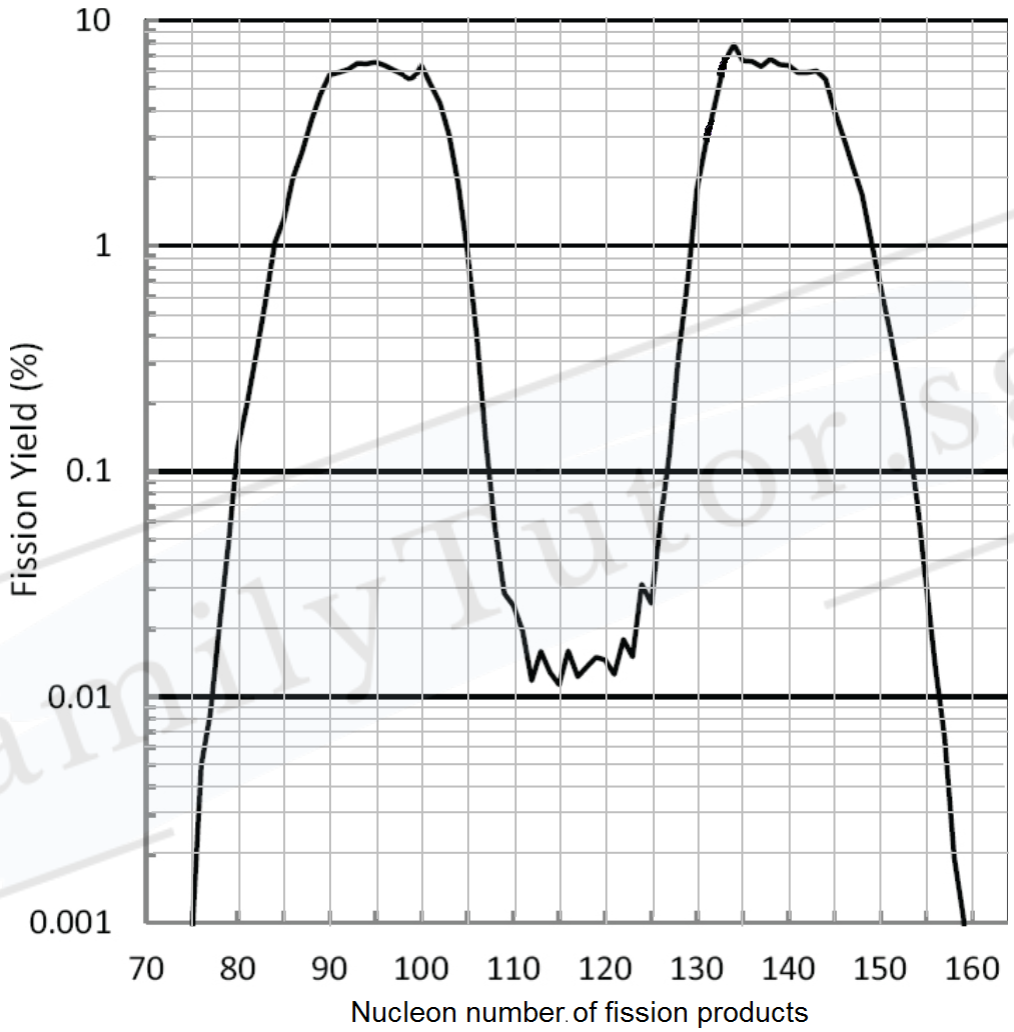

Fig. 7.3

(i) State the proton number of the other fission product for the fission of one uranium if one of the products is $^{89}_{36}\mathrm{Kr}$.

proton number = ... [1]

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(ii) Suggest why the percentage yield is shown on a logarithmic scale.

……

…… [1]

(iii) Show that the percentage yield of Molybdenum-99 ($^{99}_{42}Mo$) is about 400 times more than those fission products having approximately equal masses.

[2]

(c) The energy released during one fission reaction of a uranium nuclei occurs partly as kinetic energy of the fission products (167 MeV) and of the neutrons (5 MeV).

(i) Suggest one other mechanism by which energy is released in the fission reaction.

…… [1]

(ii) In a nuclear power station, 25% of the energy of the fission products is converted into electrical energy.

Calculate, for the fission of a mass of 1.0 kg of Uranium-235,

1. the number of nuclei in 1.0 kg of Uranium-235,

number of nuclei = …… [2]

2. the electrical energy generated,

energy = ……J [3]

[Turn over

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3. the average power output, in megawatts, of the power station if the uranium is fissioned in a time of 24 hours.

power = ……MW [2]

(d) The fission products are usually radioactive and give rise to a series of radioactive decay products. Each decay product has its own half-life. Two such fission products with their decay products and half-lives are shown below.

$$^{99}_{42}\text{Mo} \xrightarrow{67\text{ hours}} {}^{99}_{43}\text{Tc} \xrightarrow{2 \times 10^5\text{ years}} {}^{99}_{44}\text{Ru (stable solid)}$$

$$^{140}_{54}\text{Xe} \xrightarrow{16\text{ seconds}} {}^{140}_{55}\text{Cs} \xrightarrow{1.1\text{ minutes}} {}^{140}_{56}\text{Ba} \xrightarrow{13\text{ days}} {}^{140}_{57}\text{La} \xrightarrow{40\text{ hours}} {}^{140}_{58}\text{Ce (stable solid)}$$

Consider equal amounts of these two products.

Suggest why there are very different problems for the storage of this nuclear waste.

……...

……...

……..……..

…….……. [3]

[Total: 19]

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Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
CLASS	**2T**

PHYSICS
Paper 2: Structured Questions

9749/2
August 2023
2 hours

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

READ THESE INSTRUCTIONS FIRST
Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, 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.

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Suggested Solutions

FOR EXAMINER'S USE	
Q1	/ 10
Q2	/ 10
Q3	/ 8
Q4	/ 10
Q5	/ 14
Q6	/ 9
Q7	/ 19
PAPER 2	/ 80

This document consists of **27** printed pages and **1** blank page.

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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}

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FORMULAE

uniformly accelerated motion	s	$= ut + \frac{1}{2}at^2$
	v^2	$= u^2 + 2as$
work done on / by a gas	W	$= p\Delta V$
hydrostatic pressure	p	$= \rho gh$
gravitational potential	ϕ	$= -\frac{Gm}{r}$
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	$= R_1 + R_2 + ...$
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	$= x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	$= \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	$= \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	$= \mu_o nI$
radioactive decay	x	$= x_0 \exp(-\lambda t)$
decay constant	λ	$= \frac{\ln 2}{t_{\frac{1}{2}}}$

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Answer **all** questions from this paper.

1 (a) A swimmer is swimming at a constant speed in a pool. Drag forces due to the water oppose the motion of the swimmer.

Explain why the swimmer travels at constant speed.

……

……

……

……..……..[2]

Solution:

The swimmer experiences a forward force from the water (thrust) which is equal and opposite to the drag force so that the net force is zero. 1

According to Newton's first law of motion, since there is no net force the swimmer will travel at a constant speed. 1

(b) The power output P of a swimmer used to overcome the drag forces travelling when at speed v is given by

$$P=\frac{1}{2}C_D\rho A v^3$$

where C_D is the drag coefficient, ρ is the density of water and A is the frontal area of the swimmer.

In an experiment to measure the C_D for freestyle, the data for a particular swimmer is collected. The data is shown in Table 1.1.

Table 1.1

quantity	magnitude	uncertainty
P/W	294	±2
ρ/kg m^{-3}	1000	±1
A/m^2	0.20	±0.01
v/m s^{-1}	1.4	±0.1

Determine the C_D of the swimmer, with its actual uncertainty. Give your answer to an appropriate number of significant figures.

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C_D = …… ± …… [4]

Solution:

$$C_D = \frac{2P}{\rho A v^3} = \frac{2(294)}{1000(0.20)(1.4)^3}$$

$C_D = 1.07$ 1

$$\frac{\Delta C_D}{C_D} = \frac{\Delta P}{P} + \frac{\Delta \rho}{\rho} + \frac{\Delta A}{A} + 3\frac{\Delta v}{v} = \frac{2}{294} + \frac{1}{1000} + \frac{0.01}{0.20} + 3\frac{0.1}{1.4}$$

$\frac{\Delta C_D}{C_D} = 0.272$ 1

$\Delta C_D = 0.272 \times 1.07 \approx 0.3$ 1

$C_D = 1.1 \pm 0.3$ 1

(c) **(i)** Derive, from the definition of power, an expression of the drag force F experienced by the swimmer in terms of the velocity v. [2]

Solution:

Since $P = \frac{W}{t} = \frac{Fs}{t} = Fv$ 1

$$F = \frac{P}{v} = \frac{\frac{1}{2} C_D \rho A v^3}{v}$$

$$F = \frac{1}{2} C_D \rho A v^2$$ 1

(ii) Hence or otherwise, calculate the work done by the swimmer to overcome the drag force when he swims a distance of 50 m at a constant speed of 1.4 m s^{-1}.

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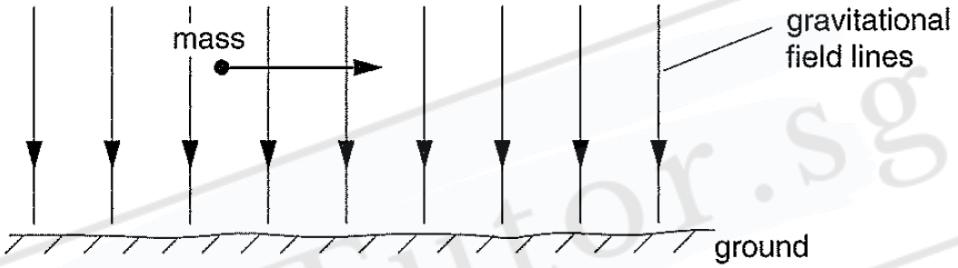
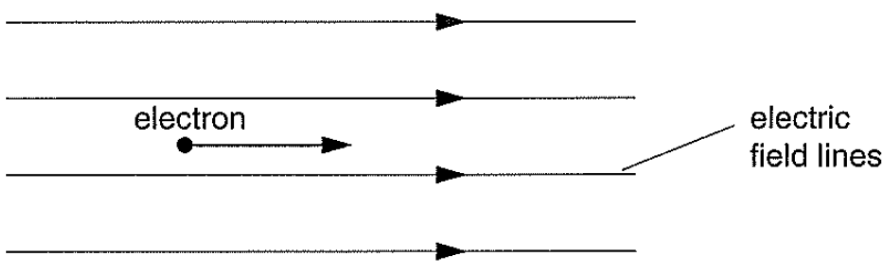
			work done = ... J	[2]
			Solution: $W = Fs = \frac{1}{2} C_D \rho A v^2 s = \frac{1}{2}(1.07)(1000)(0.20)(1.4)^2(50)$ W = 10500 J	1 1

2	**(a)**	Fig. 2.1 shows a mass initially travelling at right angles to the Earth's uniform gravitational field.  **Fig. 2.1** Describe the subsequent motion of the mass.	
		..... [1]	
		Solution: Mass will follow a parabolic path towards the ground	1
	(b)	Fig. 2.2 shows an electron initially travelling parallel to a uniform electric field.  **Fig. 2.2** Describe the subsequent motion of the electron.	

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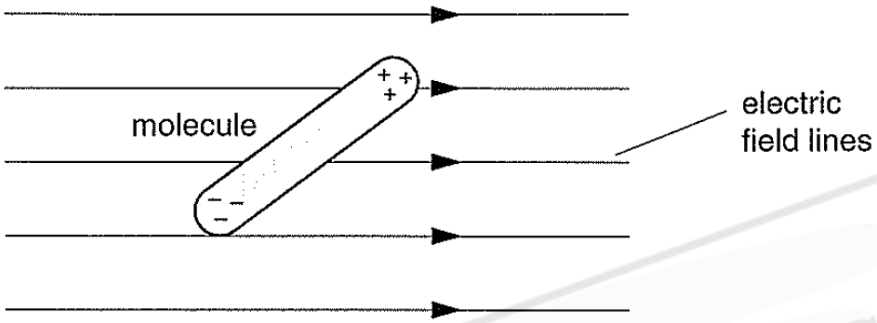
		…… …… ……[2]	
		Solution: Electron will slow down to a stop and then accelerate to the left	 1 1
	(c)	Fig. 2.3 shows a long molecule placed in a uniform electric field.  **Fig. 2.3** The ends of the molecule have equal but opposite charges. Describe and explain the initial motion of the molecule in the electric field.	
		…… …… …… …… [2]	
		Solution: Forces acting on ends of the molecule are equal and opposite or they form a couple This causes the molecule to rotate clockwise about its centre of mass	 1 1
	(d)	Fig. 2.4 shows a sphere of weight 1.6×10^{-2} N with an electric charge of +2.0 μC. It is released from rest, in vacuum, between two parallel, vertical metal plates. The separation of the plates is 0.10 m. One plate has a potential of +80 V and the other plate has a potential of -80 V. 0.10 m	

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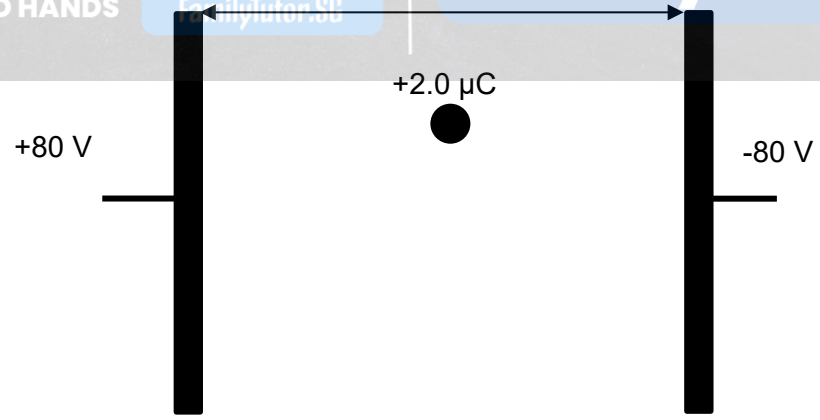


Fig. 2.4

(i) Determine the electric force experienced by the sphere.

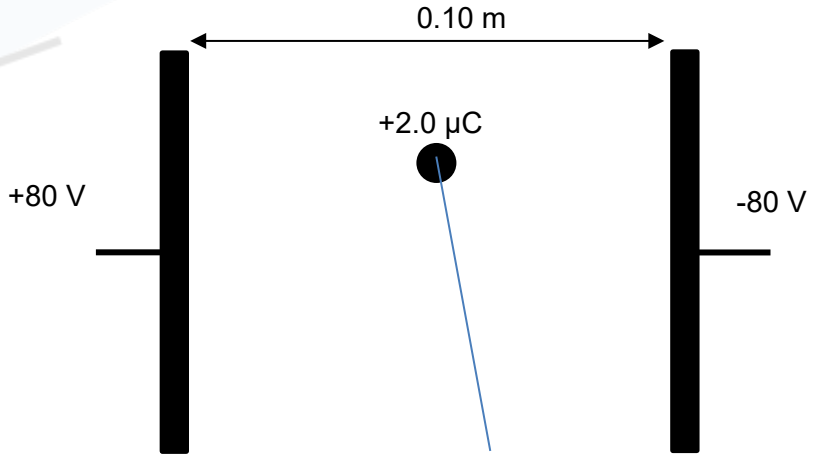
force = ... N [2]

Solution:

$F_E = qV/d$
$= 2 \times 10^{-6} \times 160 / 0.10$ 1
$= 3.2 \times 10^{-3}$ N 1

(ii) On Fig. 2.4, sketch the path taken by the sphere after it is released. [1]

Solution:



Straight line pointing downward slightly to right (less than 20 degrees from vertical) 1

(e) The variations with separation of the gravitational potential energy U_G and of the electric potential energy U_E between two protons are shown in Fig. 2.5.

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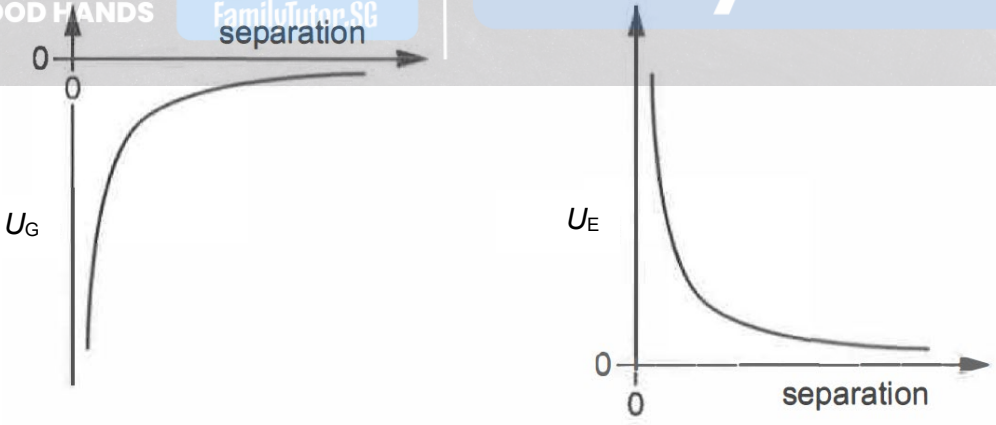

Fig. 2.5

Explain why the gravitational potential energy and the electric potential energy have opposite signs.

.....

.....

.....

..... [2]

Solution:

The gravitational force acting between the protons are attractive whereas the electric force acting between the protons are repulsive, 1

so

the work done by an external agent to bring a proton from infinity to the point is negative. 1

the work done by an external agent to bring a proton from infinity to the point is positive.

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3 A cantilever spar cable-stayed bridge is a unique yet functional variation of the traditional cable suspension bridge.

In one such model bridge, a bridge beam is supported by a cable. The cable connected at an angle of 30° to a non-uniform cantilever spar of length L slanted at an angle of 50° from the ground with a base at P, as shown in Fig. 3.1.

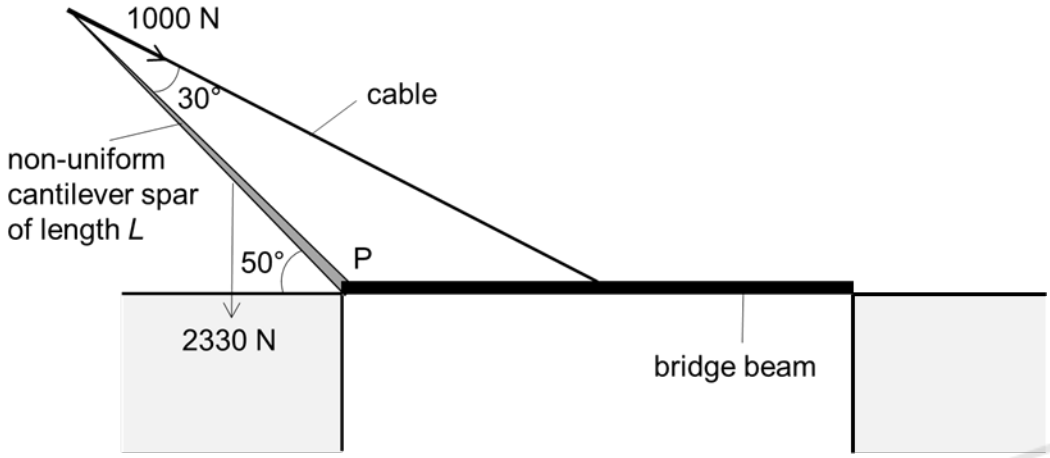

Fig 3.1 (not to scale)

The tension in the cable is 1000 N and the weight of the cantilever spar is 2330 N.

(a) By taking moments about P, show that the centre of mass of the cantilever spar is located at a distance of $0.33L$ from P. [3]

Solution:

Taking moments about P:

Let d be the distance of the centre of mass from P

Moment due to the tension = Moment due to the weight

$T \times L\sin(30) = W \times d\cos(50)$ 1

$1000 \times 0.5L = 2330 \times 0.643d$ 1

$d = 0.33L$ (shown) 1

(b) Calculate the magnitude of the force acting on the cantilever spar at P.

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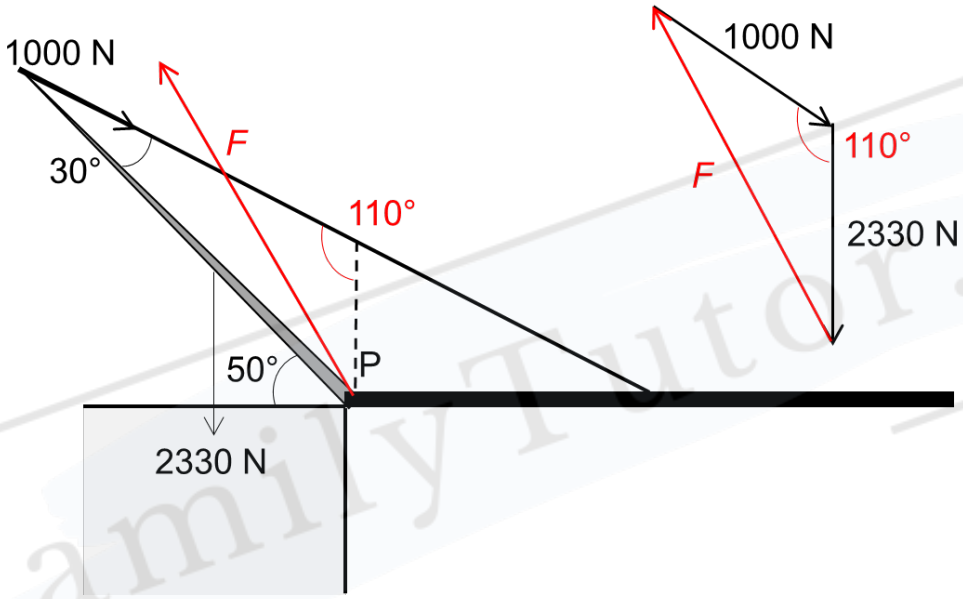
magnitude of force at P = ... N [3]

Solution:

Since the forces are in equilibrium, the three forces must form a closed vector triangle.

1



To solve for F, use the cosine rule:

$F^2 = 1000^2 + 2330^2 - 2(1000)(2330)\cos 110$ 1

$F = 2830$ N 1

(c) The traditional cable-stayed bridge design is shown in Fig 3.2

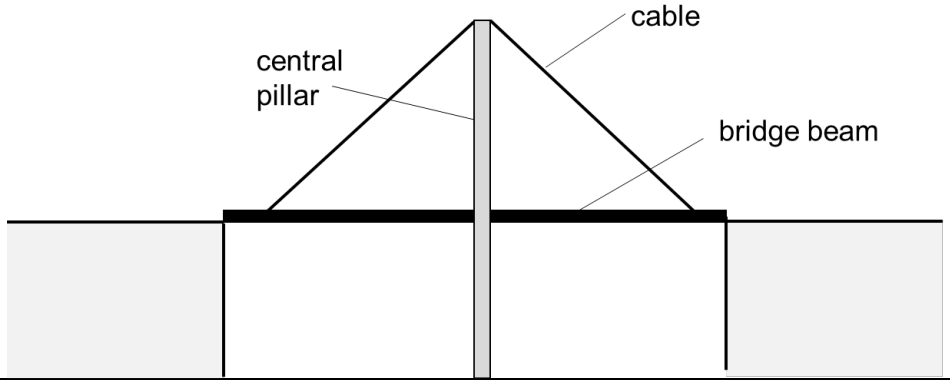


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Fig 3.2

Suggest, with a reason, one advantage a cantilever spar cable-stayed bridge may have over a traditional cable-stayed bridge design.

……

……

……

……[2]

Solution:

the cantilever spar requires fewer cables to support a bridge — 1
since there is no need to support spans on either side of the central pillar — 1

OR

wider space of vessels to pass through under the bridge — 1
since there is no central pillar — 1

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4 **(a)** A battery of electromotive force (e.m.f.) 9.0 V and internal resistance *r* is connected to two resistors S and T, as shown in Fig. 4.1.

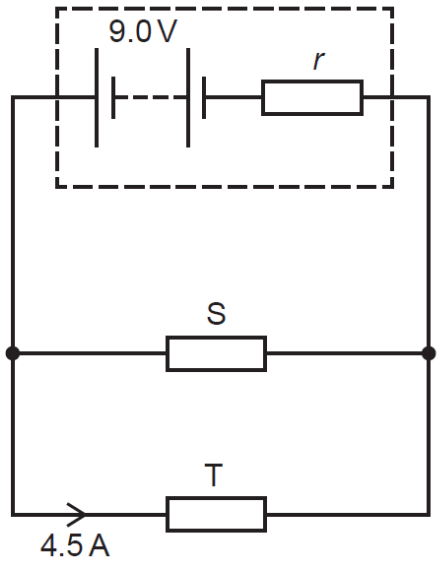

Fig 4.1

A total charge of 650 C moves through resistor S in a time interval of 540 s. During this time resistor S dissipates 4800 J of energy. The current in resistor T is 4.5 A. Assume that the e.m.f. of the battery remains constant.

Calculate:

(i) the current in resistor S

current = ...A [1]

Solution:

$I = \frac{Q}{t} = \frac{650}{540} = 1.2$ A

1

(ii) the internal resistance *r* of the battery.

r = ... Ω [3]

Solution:

$V = \frac{W}{Q} = \frac{4800}{650} = 7.38$ V or use $V = \frac{P}{I}$ and $P = \frac{W}{t}$

1

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			Find $I_{tot} = 1.2 + 4.5 = 5.7\ A$	1
			Terminal p.d. $V = E - I_{tot} r$ $= 9 - 5.7\ r$ $7.38 = 9 - (1.2 + 4.5)\ r$ $r = 0.28\ \Omega$	1
	(b)	A sinusoidal alternating voltage has a root-mean-square (r.m.s.) potential difference (p.d.) of 4.2 V and a frequency of 50 Hz.		
		(i)	By reference to heating effect, explain what is meant by the root-mean-square (r.m.s.) value of an alternating current.	
			…… …… ……[1]	
			Solution: the value of steady direct current that dissipates energy at the same rate as the alternating current in a given resistance.	1
		(ii)	The alternating voltage is applied across a resistor of resistance 760 Ω. Determine the maximum power dissipated by the resistor.	
			maximum power dissipated = …… mW	[2]
			Solution: From $V_{rms} = \frac{V_o}{\sqrt{2}}$ $V_o = 4.2\,x\sqrt{2} = 5.94V$ $P_{max} = \frac{V_o^2}{R} = \frac{5.94^2}{760}$ $= 46\,mW$	1 1
		(iii)	On Fig. 4.2, sketch the variation with time t of the power P transferred in the resistor. Include on your graph a time equal to two periods of the alternating potential difference.	

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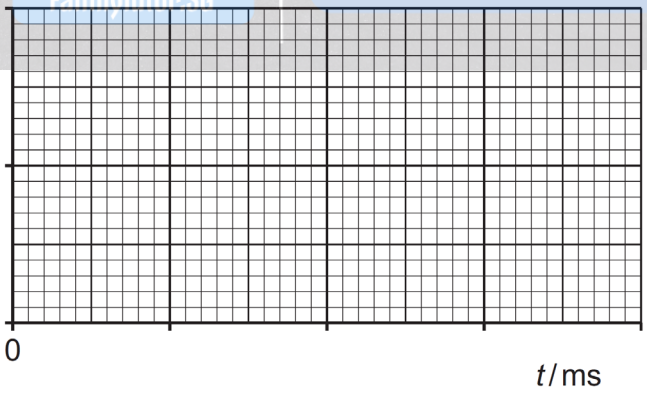
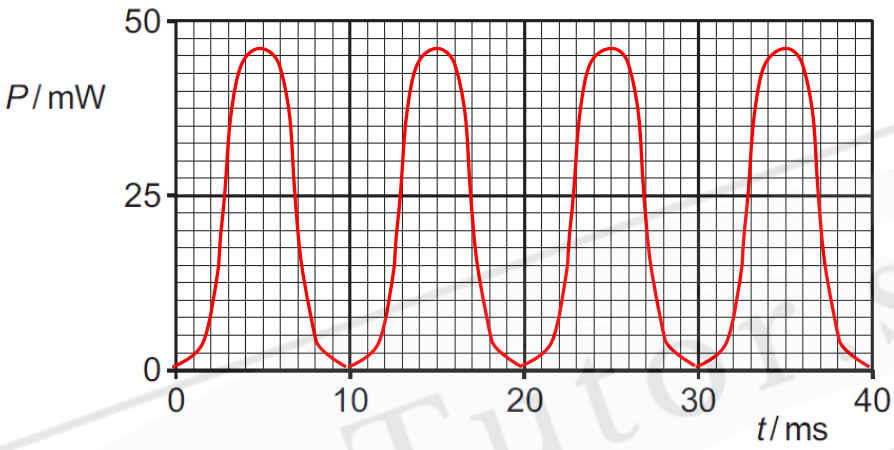


Fig. 4.2

[3]

Solution:



1
1
1

5	**(a)**	State Faraday's law of electromagnetic induction. ....[2]	
		Solution: The magnitude of the electromotive force (e.m.f.) induced in a conductor is directly proportional to the rate of change of magnetic flux linkage of the conductor.	1 1
	(b)	Two coils, P and S, are wound on an iron core, as shown in Fig. 5.1.	

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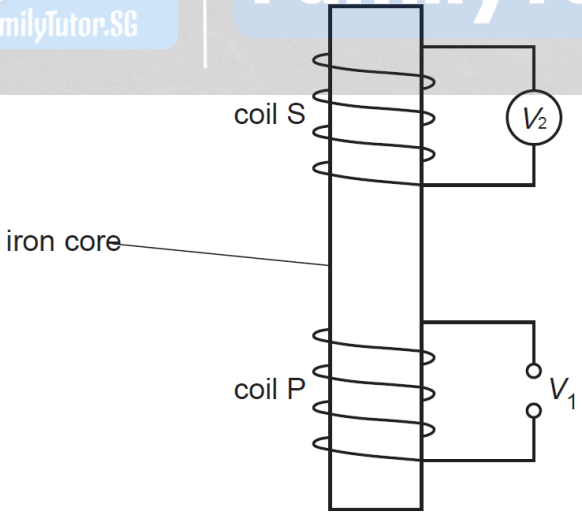

Fig. 5.1

Coil P is connected to a potential difference (p.d.) V_1 that gives rise to a magnetic field in the iron core.

Fig. 5.2 shows the variation with time t of the magnetic flux density B in the iron core.

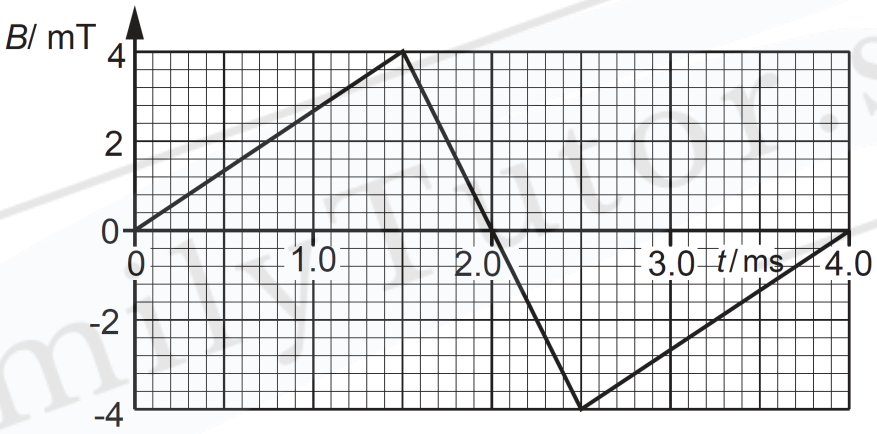

Fig. 5.2

Coil S contains 250 turns of wire. Each turn of wire has a diameter of 2.5 cm. A voltmeter measures the electromotive force (e.m.f.) V_2 that is induced across coil S.

Use data from Fig. 5.2 to determine the maximum electromotive force (e.m.f.) induced in coil S.

e.m.f. = ... V [3]

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Solution:

Max gradient of the B-t graph

$$= \frac{dB}{dt} = \frac{(4-(-4))x10^{-3}}{(2.5-1.5)x10^{-3}} = 8 \text{ T s}^{-1}$$ 1

Maximum induced e.m.f. in coil S

$$= |E| = \frac{dNBA}{dt} = NA\frac{dB}{dt}$$

$$= N x \pi x \left(\frac{D}{2}\right)^2 x \frac{dB}{dt}_{max}$$ 1

$$= 250 x \pi x \left(\frac{2.5x10^{-2}}{2}\right)^2 x 8$$

= 0.982 V 1

(c) On Fig. 5.3, sketch the variation with t of V_2 between t = 0 and t = 4.0 ms.

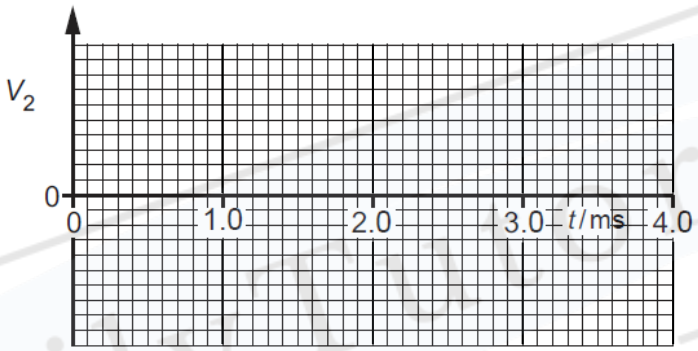

Fig. 5.3

[4]

Solution:

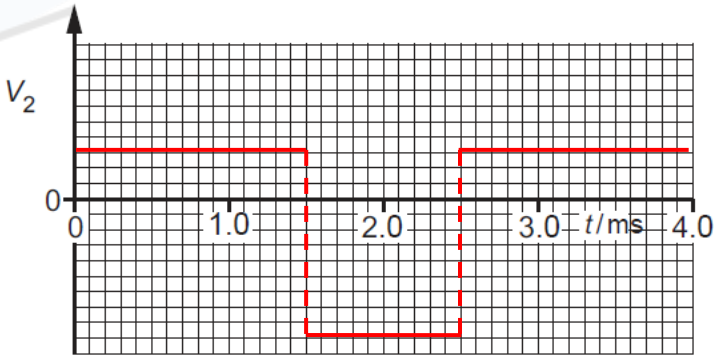

Fig. 5.3

V_2 stepped, all at non-zero values, between t = 0 and t = 0.40 s (horizontal line for all 3 segments) – *Marker: not time based* 1

*V*2 shown with same non-zero magnitude up to t = 0.15 s and after t = 0.25 s but with a different magnitude between these times (Marker: either a hill or valley) 1

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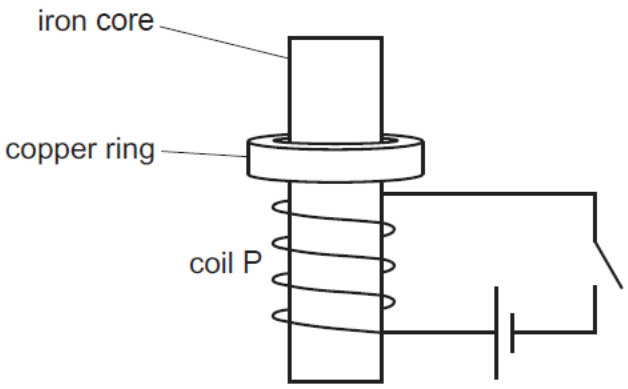
			V_2 shown with a magnitude between t = 0.15 s and t = 0.25 s that is three times the magnitude before t = 0.15 s and after t = 0.25 s	1
			V_2 shown with same sign up to t = 0.15 s and after t = 0.25 s, and opposite sign in between	1
	(d)		Coil S in **(b)** is now replaced with a copper ring that rests loosely on top of coil P. The supply to coil P is replaced with a cell and a switch that is initially open, as shown in Fig. 5.4.  **Fig. 5.4**	
		(i)	The switch is now closed. As it is closed, the copper ring is observed to move vertically upwards on the iron core. Explain why this happens.	
			…… …… …… ……[4]	
			Solution: Increasing/ changing current in coil P causes increasing/ changing magnetic flux density in coil iron core links the magnetic flux density/ field from coil P to the ring Increasing/changing (magnetic) flux linkage experienced by the ring causes induced e.m.f. in ring by Faraday's law and this causes a current in ring (closed circuit) (magnetic) field due to (induced) current in ring interacts with (coil's) field to oppose the change to cause an upwards force (on ring) according to Lenz's law.	1 1 1 1
		(ii)	Suggest, with a reason, what would be the effect on the ring of repeating the procedure in **(d)(i)** with the terminals of the cell reversed.	
			…… ……	[1]

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			Solution: Both magnetic fields reverse direction so ring still moves up or current (in ring) and (coil's) field both reverse so ring still moves up or when terminals are reverse, there will still be a changing flux experienced by the ring so ring still moves up.	1

6	**(a)**	State how a line emission spectrum may be explained on the basis of the existence of discrete electron energy levels in atoms.	
		……... ……... ……... ……... ……[3]	
		Solution: A line emission spectrum shows that only certain values of wavelengths (or frequencies) of photons are emitted when gas atoms de-excite. Photons emitted have energies equal to the differences between the pairs of electron energy levels involved in the de-excitation. The fact that only certain wavelengths are seen implies that only photons of certain energies are emitted, which in turn implies that electrons inside an atom can only possess certain discrete values of energies (called the electron energy levels).	1 1 1

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(b) The lowest six discrete energy levels for a hydrogen atom are shown in Fig. 6.1. The diagram is drawn to scale and the ground state is at -13.6 eV.

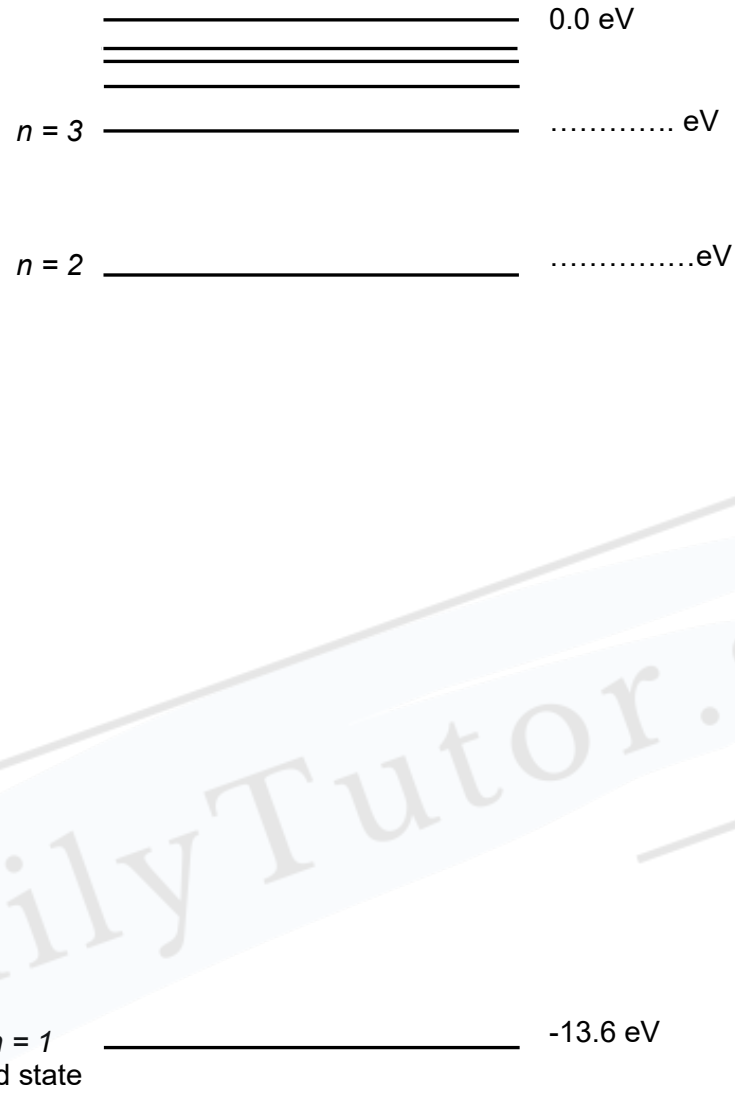

Fig. 6.1

(i) On Fig. 6.1, label the values for energy at energy levels $n = 2$ and $n = 3$. [1]

Solution:

Use ruler to measure

n = 2 is - 3.4 eV 1
n = 3 is -1.5 eV 1

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		(ii)	Calculate the wavelength of the light emitted when an electron falls from n = 3 energy level to the n = 2 energy level.	
			wavelength = …….. m	[3]
			Solution: Energy of photon = (-1.5 – (-3.4)) eV $\frac{hc}{\lambda}$ = (-1.5 – (-3.4)) (1.6 x 10^{-19}) $\frac{6.63 x 10^{-34} x 3 x 10^{8}}{\lambda}$ = (-1.5 – (-3.4)) (1.6 x 10^{-19}) λ = 6.54 x 10^{-7} m (For info: visible region)	1 1 1
		(iii)	Electromagnetic radiation is emitted when an electron falls to the ground state from any of the other energy levels. State the region of the electromagnetic spectrum in which the radiation lies.	
			electromagnetic radiation is ……	[1]
			Solution: From (b)(ii), energy of photons emitted when electrons fall to n = 2 state lie in the visible region. For greater difference in energy levels (eg. n = 2 to n = 1, photons emitted when electrons fall to n=1 state lie in the ultraviolet region.	 1
		(iv)	Describe one way by which an electron in gaseous hydrogen can be raised from a lower energy level to a higher energy level.	
			…… ……	[1]
			Solution: By thermal excitation by heating up the hydrogen gas. (electrons of high energy) OR By applying high voltage across the gas using a voltage discharge tube/ cathode ray tube OR Shine white light on the gas (use photons of all wavelengths)/ expose to sunlight	 1 1 1

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

Beginning in 1934, the Italian physicist Enrico Fermi began bombarding elements with neutrons instead of protons, theorizing that Chadwick's uncharged particles could pass into the nucleus without resistance. Like other scientists at the time, Fermi paid little attention to the possibility that matter might disappear during bombardment and result in the release of huge amounts of energy in accordance with Einstein's formula, $E = mc^2$, which stated that mass and energy were equivalent. Fermi and his colleagues bombarded sixty-three stable elements and produced thirty-seven new radioactive ones. They also found that carbon and hydrogen proved useful as moderators in slowing the bombarding neutrons and that slow neutrons produced the best results since neutrons moving more slowly remained in the vicinity of the nucleus longer and were therefore more likely to be captured.

One element Fermi bombarded with slow neutrons was uranium, the heaviest of the known elements. Scientists disagreed over what Fermi had produced in this transmutation. Some thought that the resulting substances were new "transuranic" elements, while others noted that the chemical properties of the substances resembled those of lighter elements. Fermi was himself uncertain. For the next several years, attempts to identify these substances dominated the research agenda in the international scientific community, with the answer coming out of Nazi Germany just before Christmas 1938.

The radiochemists Otto Hahn and Fritz Strassmann were bombarding elements with neutrons in their Berlin laboratory when they made an unexpected discovery. They found that while the nuclei of most elements changed somewhat during neutron bombardment, uranium nuclei changed greatly and broke into two roughly equal pieces. They split and became not the new transuranic elements that some thought Fermi had discovered but radioactive barium isotopes (barium has the atomic number 56) and fragments of the uranium itself. The substances Fermi had created in his experiments, that is, did more than resemble lighter elements; they were lighter elements. Importantly, the products of the Hahn-Strassmann experiment weighed less than that of the original uranium nucleus, and herein lay the primary significance of their findings. For it followed from Einstein's equation that the loss of mass resulting from the splitting process must have been converted into energy in the form of kinetic energy that could in turn be converted into heat.

Calculations made by Hahn's former colleague, Lise Meitner, a refugee from Nazism then staying in Sweden, and her nephew, Otto Frisch, led to the conclusion that so much energy had been released that a previously undiscovered kind of process was at work. Frisch, borrowing the term for cell division in biology - binary fission - named the process fission. For his part, Fermi had produced fission in 1934 but had not recognized it.

The large amount of energy released in a nuclear fission reaction, together with the emission of more than one neutron, has made it possible for neutron-induced fission to be used as a source of useful energy. When a neutron is captured by a Uranium-235 nucleus, it causes the nucleus to fission. On average, 2.5 neutrons are emitted in these fission reactions. This is illustrated in Fig. 7.1.

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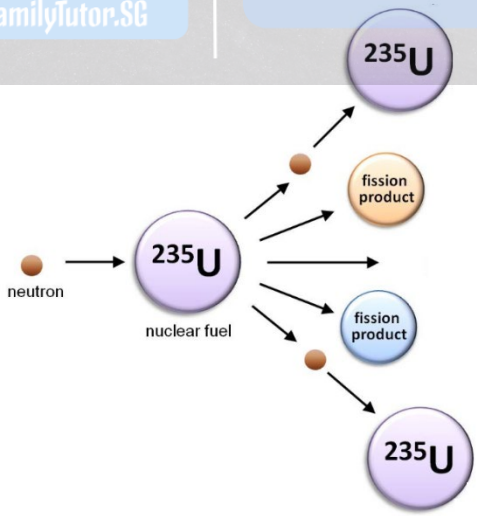

Fig. 7.1

When the conditions are suitable, a chain reaction can occur. If this chain reaction is not controlled, an explosion is likely to occur. However, if the chain reaction is controlled, as in a nuclear reactor, a source of continuous power may be created.

(a) **(i)** Explain what is meant by neutron-induced fission.

……

…… [1]

Solution:
splitting up of a (large) nucleus / nuclide after absorbing a neutron 1

(ii) Explain what is meant by chain reaction.

……

…… [1]

Solution:
(neutrons) one of the products prompt further fission or neutrons collide with further nuclei 1

(iii) Suggest why, in an uncontrolled chain reaction where all neutrons are captured by Uranium-235 nuclei, the majority of the energy is released during the final stages of the fission of a sample of the uranium.

……

……

…… [2]

Solution:
The number of neutrons emitted will be very large as the stages proceed 1
and hence leading to a very large number of reactions 1

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(b) The induced fission reaction of Uranium-235 may be represented by a nuclear equation of the form

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{a}_{b}\mathrm{P} + {}^{c}_{d}\mathrm{Q} + (2 \text{ or } 3)\,{}^{1}_{0}\mathrm{n} + 198\mathrm{MeV}$$

The fission products P and Q have approximately equal masses. However, when any two nuclei are fissioned, the fission products may not be the same. If a large sample of Uranium-235 is fissioned, many different fission products will be produced. The percentage amount of each fission product in the fissioned material is referred to as the percentage yield.

The variation with nucleon number of the percentage yield of different fission products is referred to as a 'fission yield curve' and is illustrated in Fig. 7.3.

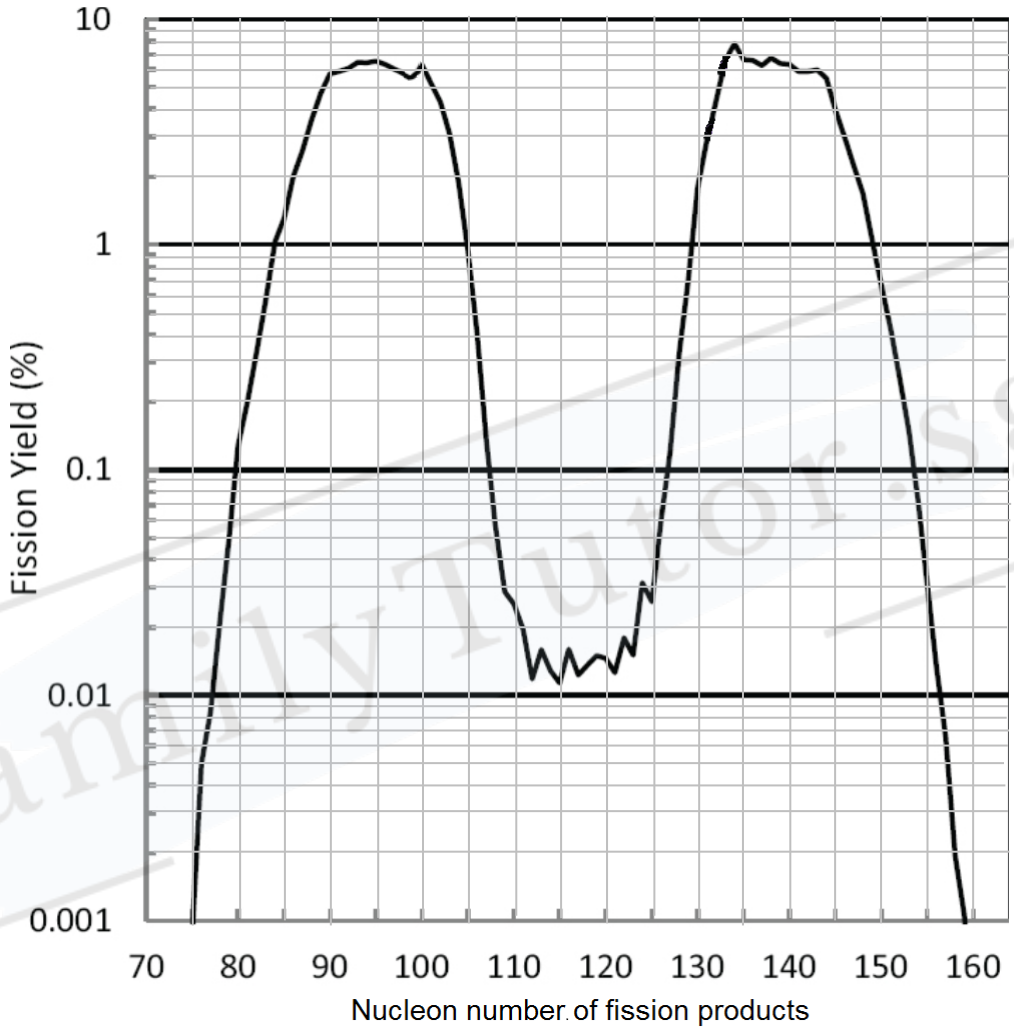

Fig. 7.3

(i) State the proton number of the other fission product for the fission of one uranium if one of the products is $^{89}_{36}\mathrm{Kr}$.

proton number = ... [1]

Solution:
92 – 36 = 56 1

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		(ii)	Suggest why the percentage yield is shown on a logarithmic scale. …… …… [1]	
			Solution: The range of percentage yield varies over a wide range of magnitude and hence in order to show the variation of the values in a single graph, a logarithmic scale is used.	1
		(iii)	Show that the percentage yield of Molybdenum-99 ($^{99}_{42}Mo$) is about 400 times more than those fission products having approximately equal masses. [2]	
			Solution: Percentage yield of having 99 = 6 % Percentage yield of masses equal = 1.5 x 10^{-2} % Both values to get 1 mark each Therefore, the ratio = 6/(1.5 x 10^{-2}) = 400	1 1
	(c)	The energy released during one fission reaction of a uranium nuclei occurs partly as kinetic energy of the fission products (167 MeV) and of the neutrons (5 MeV).		
		(i)	Suggest one other mechanism by which energy is released in the fission reaction. …… [1]	
			Solution: Gamma photon	1
		(ii)	In a nuclear power station, 25% of the energy of the fission products is converted into electrical energy. Calculate, for the fission of a mass of 1.0 kg of Uranium-235,	
			1. the number of nuclei in 1.0 kg of Uranium-235, number of nuclei = …… [2]	
			Solution: 1.00kg / 235 u = 1.00 kg / 235 x (1.66 x 10^{-27} kg) =2.56 x 10^{24}	1 1

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2. the electrical energy generated,

energy = ……J [3]

Solution:
Energy of fission products = $2.5634 \times 10^{24} \times 167 \times 10^{6} \times 1.6 \times 10^{-19}$ 1
Electrical energy = $0.25 \times 2.5634 \times 10^{24} \times 167 \times 10^{6} \times 1.6 \times 10^{-19}$ 1
$= 1.71 \times 10^{13}$ J 1

3. the average power output, in megawatts, of the power station if the uranium is fissioned in a time of 24 hours.

power = ……MW [2]

Solution:
Power = energy / time
$= 1.7124 \times 10^{13} / (24 \times 60 \times 60)$ 1
$= 1.98 \times 10^{8}$ W 1

(d) The fission products are usually radioactive and give rise to a series of radioactive decay products. Each decay product has its own half-life. Two such fission products with their decay products and half-lives are shown below.

$$^{99}_{42}\text{Mo} \xrightarrow{67\text{ hours}} {}^{99}_{43}\text{Tc} \xrightarrow{2 \times 10^{5}\text{ years}} {}^{99}_{44}\text{Ru}\ \text{(stable solid)}$$

$$^{140}_{54}\text{Xe} \xrightarrow{16\text{ seconds}} {}^{140}_{55}\text{Cs} \xrightarrow{1.1\text{ minutes}} {}^{140}_{56}\text{Ba} \xrightarrow{13\text{ days}} {}^{140}_{57}\text{La} \xrightarrow{40\text{ hours}} {}^{140}_{58}\text{Ce}\ \text{(stable solid)}$$

Consider equal amounts of these two products.

Suggest why there are very different problems for the storage of this nuclear waste.

……

……

……

…… [3]

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		Solution: $^{99}_{42}Mo$ and its decay products have a very long half life. This means that the storage of $^{99}_{42}Mo$ will have to be in a lead container and put away for a very long time. (Max 2 marks for the next 3 points) On the other hand, $^{140}_{54}Xe$ has a very short half life and many decay products. For the same amount of these fission products, $^{140}_{54}Xe$ having many more fission products imply a greater safety concern for 2 reasons: 1. the total activity of $^{140}_{54}Xe$ and its daughter products is much higher than $^{99}_{42}Mo$. 2. with a short half-life, it means the decay constant is much greater, using $A=\lambda N$, the activity from $^{140}_{54}Xe$ is much higher. The much higher activity implies that $^{140}_{54}Xe$ is very hazardous immediately after it is produced, and must be handled with great care.	1 1 1 1

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Catholic Junior College

JC2 Preliminary Examinations

Higher 2

CANDIDATE NAME	
CLASS	**2T**

PHYSICS

Paper 3: Longer Structured Questions

9749/3
September 2023
2 hours

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.

Section A
Answer **all** questions.

Section B
Answer one question only.
Write on the cover page the question number attempted in Section B.

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

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	/ 8
Q4	/ 14
Q5	/ 8
Q6	/ 11
Q7	/ 3
SECTION B	
	/ 20
TOTAL	/80

This document consists of **26** printed pages and **0** blank page.

[Turn over

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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}

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FORMULAE

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$	
	$v^2 = u^2 + 2as$	
work done on / by a gas	$W = p\Delta V$	
hydrostatic pressure	$p = \rho gh$	
gravitational potential	$\phi = -\frac{Gm}{r}$	
temperature	$T / K = T / ^\circ C + 273.15$	
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	$R = R_1 + R_2 + ...$	
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$	
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$	
alternating current / voltage	$x = x_0 \sin \omega t$	
magnetic flux density due to a long straight wire	$B = \frac{\mu_o I}{2\pi d}$	
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o NI}{2r}$	
magnetic flux density due to a long solenoid	$B = \mu_o nI$	
radioactive decay	$x = x_0 \exp(-\lambda t)$	
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$	

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Section A

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

1 A ball of mass 10 g is dropped from a height and falls through air. The variation with time t of the speed of the ball v is shown in Fig. 1.1

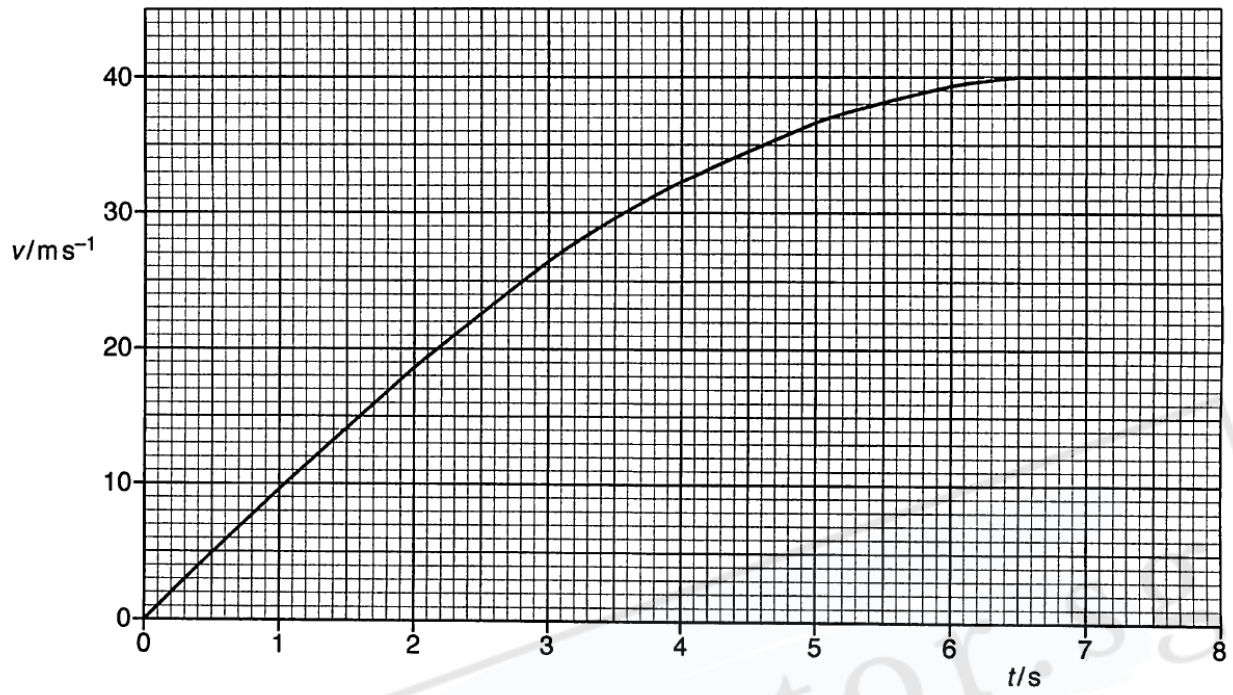

Fig 1.1

(a) **(i)** Use Fig 1.1. to determine the acceleration of the ball at time t = 0. Show your construction on Fig 1.1.

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

(ii) By reference to your answer in **(a)(i)**, suggest the difference, if any, between your answer and the acceleration of free fall.

.....

.....

.....

..... [2]

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(b) Calculate the maximum resistive force acting on the ball.

force = ... N [1]

(c) On Fig 1.1, draw another curve to show the variation with time *t* of the speed of the ball *v* if the ball was dropped in a more viscous medium. [2]

[Total: 8]

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2 A binary star consists of two stars A and B. The two stars may be considered to be isolated in space. The centres of the two stars are separated by a constant distance, as illustrated in Fig. 2.1.

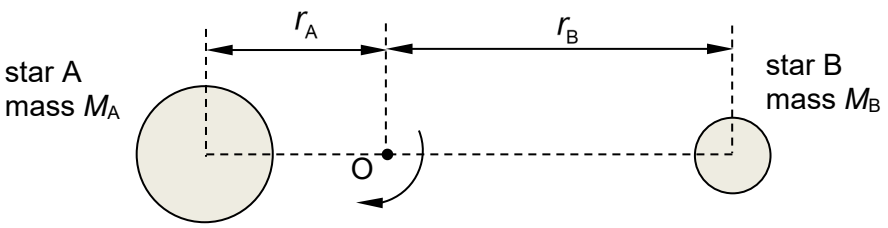

Fig. 2.1

Star A of mass M_A has a larger mass than star B of mass M_B such that $M_A = 4M_B$.

The stars are in circular orbits about each other such that the centre of their orbits is at a fixed point O. The radius of orbit of star A and star B are r_A and r_B respectively.

The period of each orbit is T.

(a) Explain why the two stars must always be directly opposite as they move in the circular orbit.

.....

.....

.....

..... [2]

(b) Show that $\frac{r_B}{r_A} = 4$. Explain your working.

[2]

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(c) If the period T is 104 days and the separation of the centres of the stars is 1.1×10^{11} m,

(i) calculate the angular velocity of star A, and

angular velocity = ... rad s^{-1} [1]

(ii) determine the mass of each star.

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mass M_A of star A = ... kg

mass M_B of star B = ... kg [3]

[Total:8]

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3 Ice is less dense than liquid water due to the structure of the bonds between the molecules when it is in a solid state. Hence, when ice melts into water at 0°C, the density of water increases. As the liquid water increases in temperature, its density further increases to a maximum value at 4.0°C.

(a) Consider a 5.0 kg block of ice at 0°C that is melted into liquid water at the same temperature using a heat source supplying a constant power of 4180 W.

(i) The specific latent heat of fusion of ice is 3.34×10^5 J kg^{-1}.

Determine the time taken to completely melt the block of ice into liquid water at 0°C.

time = …….. s [3]

(ii) The density of ice at 0°C is 0.915 kg m^{-3} while the density of liquid water at 0°C is 0.999 kg m^{-3}.

Calculate the work done on the ice by a constant atmospheric pressure of 1.01×10^5 Pa as the ice melts completely into water at 0°C.

work done on the ice = …….. J [3]

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(b) 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 3.1 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.

Table 3.1

Process	ΔU	q	w
Ice melting into liquid water at 0°C			
Liquid water warming up from 0°C to 4°C			

[2]

[Total: 8]

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4 (a) State what is meant by *radioactive decay*.

.....

.....

.....

..... [2]

(b) A radiation detector is placed close to a radioactive source. The detector does not surround the source.

Radiation is emitted in all directions and, as a result, the activity of the source and the measured count rate are different.

Suggest two other reasons why the activity and the measured count rate may be different.

1. .....

.....

2. .....

..... [2]

(c) The variation with time *t* of the measured count rate in **(b)** is shown in Fig. 4.1.

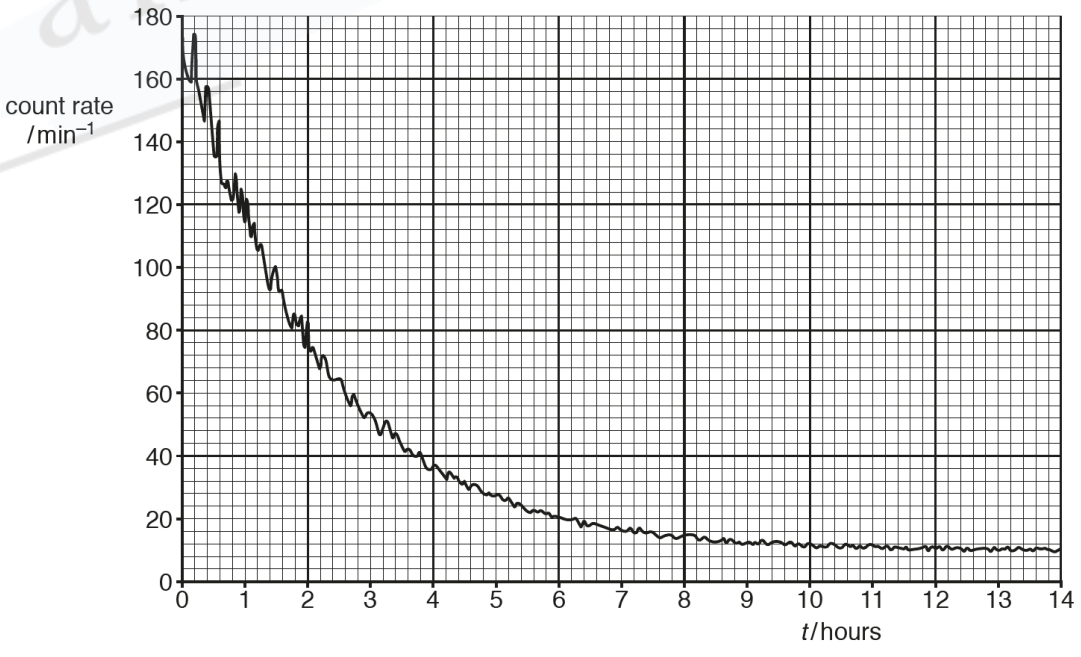

Fig. 4.1

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(i) State the feature of Fig. 4.1 that indicates the random nature of radioactive decay.

……

…… [1]

(ii) Use Fig. 4.1 to determine

1. the background count rate and,

background radiation = …… min^{-1} [1]

2. the half-life of the radioactive isotope in the source.

half-life = …… hours [4]

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(d) The readings in **(c)** were obtained at room temperature.

A second sample of this isotope is heated to a temperature of 500 °C.
The initial count rate at time t = 0 is the same as that in **(c)**.
The variation with time t of the measured count rate from the heated source is determined.

State, with a reason, whether the heating will cause a difference, if any, in

1. the half-life,

……

……

……

2. the measured count rate for any specific time.

……

……

…… [4]

[Total: 14]

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5 **(a)** Explain what is meant by *coherent* light waves.

.....

..... [1]

(b) Coherent light of wavelength 550 nm is incident normally on a double slit of slit separation 2.1 mm, as shown in Fig. 5.1. Both slits in the double slit arrangement have a width of 0.1 mm. A series of bright and dark fringes forms on a screen placed a distance of 2.4 m from the double slit. The screen is parallel to the double slit.

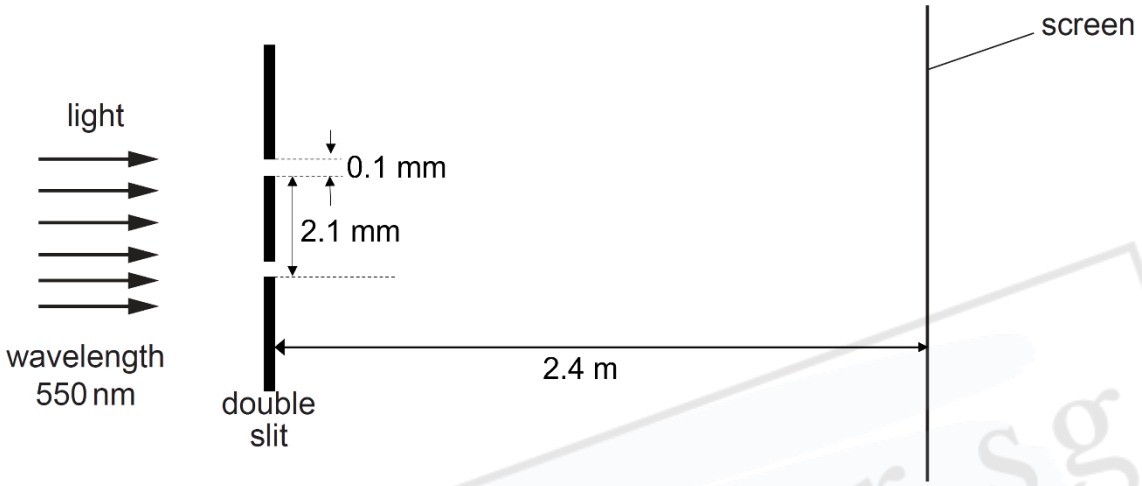

Fig. 5.1 (not to scale)

(i) Initially, one of the two slits is covered.

Calculate the width of the central fringe of the single-slit diffraction pattern seen on the screen.

Give your answer to three significant figures.

fringe width = ... m [3]

[Turn over

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(ii) Both slits are now uncovered.

Estimate, to one significant figure, the number of fringes resulting from double-slit interference that are seen within the central maximum produced by single-slit diffraction.

number = ... [3]

(iii) The light of wavelength 550 nm is replaced with monochromatic red light.

State and explain the change, if any, in the distance between the centres of adjacent double slit bright fringes.

.....

.....

..... [1]

[Total: 8]

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6 **(a)** Use the theory of the particulate nature of electromagnetic radiation to explain why there is a threshold frequency for the photoelectric effect.

.....

.....

.....

.....

.....

.....[3]

(b) An experimental setup to investigate the photoelectric effect is shown in Fig. 6.1. Electromagnetic radiation is incident on the emitter E of the photocell and the photoelectrons move towards the collector C.

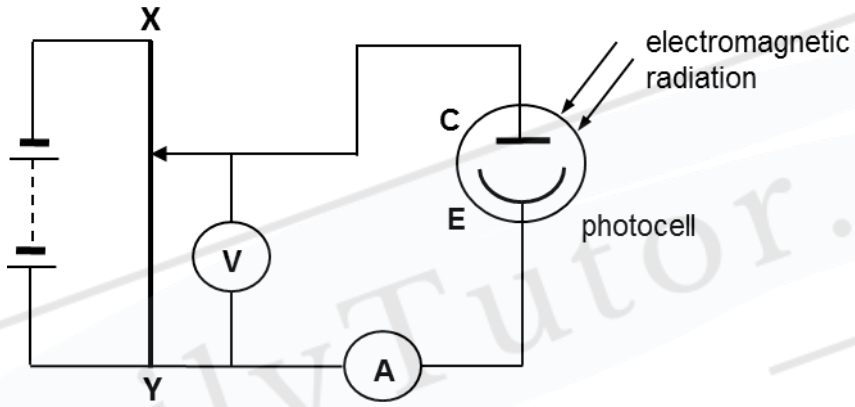

Fig. 6.1

The wavelength of the electromagnetic radiation incident on the photocell was varied. For two values of wavelength λ, the stopping potential V_S required for the ammeter reading to become zero was measured. The results are shown in Fig. 6.2.

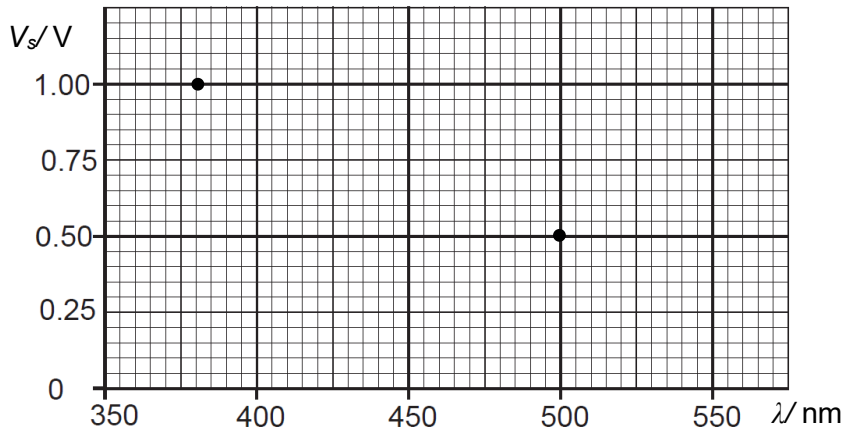

Fig. 6.2

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(i) Calculate the maximum kinetic energy of a photoelectron emitted from the metal surface by radiation of wavelength 500 nm.

maximum kinetic energy = ... J [2]

(ii) Calculate the energy of a photon of wavelength 500 nm.

energy = ... J [2]

(iii) Hence, determine

1. the work function energy of the metal surface, and

work function energy = ... J [1]

2. the maximum photon wavelength that can liberate a photoelectron.

maximum wavelength = ... nm [2]

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(iv) Suggest why it is not possible to deduce the maximum photon wavelength that can liberate a photoelectron from this metal plate directly from the data in Fig. 6.2.

.....

.....

.....[1]

[Total: 11]

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7 Fig. 7.1 shows an x-ray spectrum.

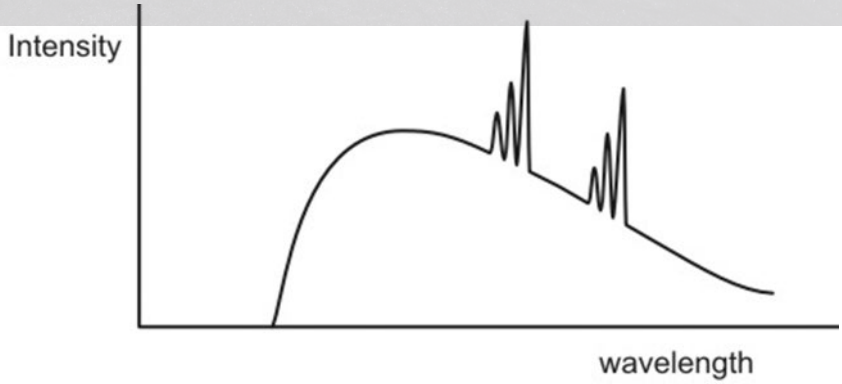

Fig. 7.1

Describe how the continuous spectrum is produced.

.....

.....

.....

.....

.....

.....

.....

.....[3]

[Total: 3]

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Section B

Answer **one** question from this section.

8 (a) Fig. 8.1 shows a diagram of an electron gun.

Electrons are emitted from a hot cathode. The electric field between the cathode and the anode accelerates the electrons through an accelerating potential difference (p.d.).

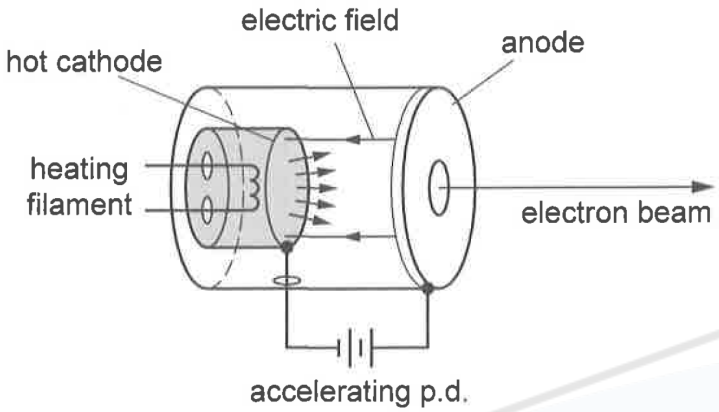

Fig. 8.1

(i) Explain what is meant by an electric field.

.....

..... [1]

(ii) Explain why the electron gun in Fig. 8.1 must be in a vacuum.

.....

.....

.....

..... [2]

[Turn over

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(iii) The kinetic energy of the electrons increases by 5.68×10^{-16} J between leaving the cathode and reaching the anode.

Calculate the accelerating p.d..

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

(iv) Suggest why the electrons reaching the anode have a range of speeds.

.....

.....

.....

..... [2]

(b) A uniform magnetic field is produced using a coil of 1500 turns of insulated wire, tightly wound on a non-magnetic tube to make a solenoid of mean radius 22 mm, as shown in Fig. 8.2. The wire itself has radius 0.86 mm and is made of a material of resistivity 1.7×10^{-8} Ω m. The coil is connected to a supply of e.m.f. 12 V and negligible internal resistance.

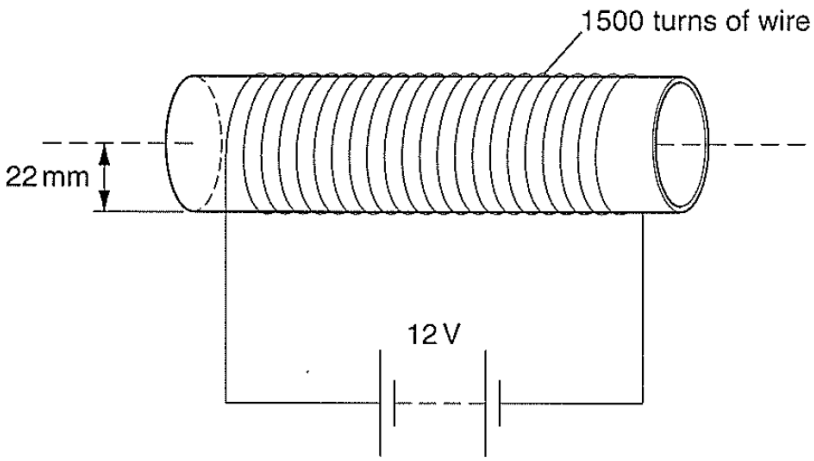

Fig. 8.2

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Calculate

(i) the total length of the 1500 turns of wire in the coil,

length = ... m [1]

(ii) the total resistance of the coil,

resistance = ... Ω [2]

(iii) the current in the coil.

current = ... A [2]

(c) The magnetic flux density in the solenoid is measured using a current balance. The current balance is a U-shaped piece of stiff wire ABCDEF pivoted at BE, as shown in Fig. 8.3.

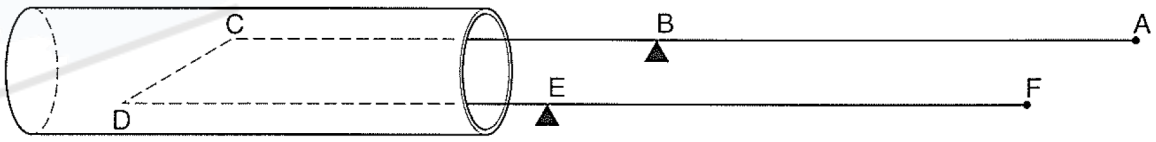

Fig. 8.3

When in use, there is a turning force on the stiff wire caused by a current in CD.

(i) Explain why the current in CD causes a turning effect.

.....

.....

..... [2]

[Turn over

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(ii) Explain why currents in CB and DE do not contribute to the turning force.

……..

…… [1]

(iii) CD has length 25 mm, CB and DE each have length 106 mm.

The stiff wire is first balanced when there is no current in it. A current of 4.9 A is then passed through CD and, in order to rebalance the stiff wire, a force of 5.7×10^{-4} N is applied at a distance of 77 mm from the pivot, as shown in Fig. 8.4. which is the side view of the balance.

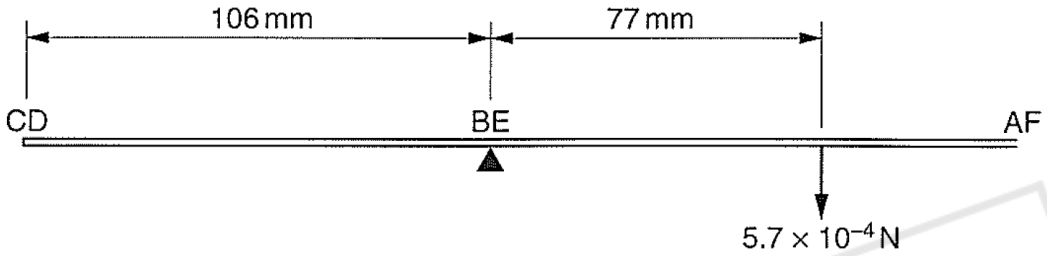

Fig. 8.4 (side view)

1. State the direction of the current in CD

direction = …….. [1]

2. Calculate the magnetic flux density in the solenoid. Give the full name of the unit for magnetic flux density.

magnetic flux density = ……

full name of unit = …….. [4]

[Total: 20]

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9 (a) State what is meant by *simple harmonic motion.*

.....

.....

.....

.....[2]

A long strip of springy steel is clamped at one end so that the strip is vertical. A mass *m* of 65 g is attached to the free end of the strip, as shown in Fig. 9.1.

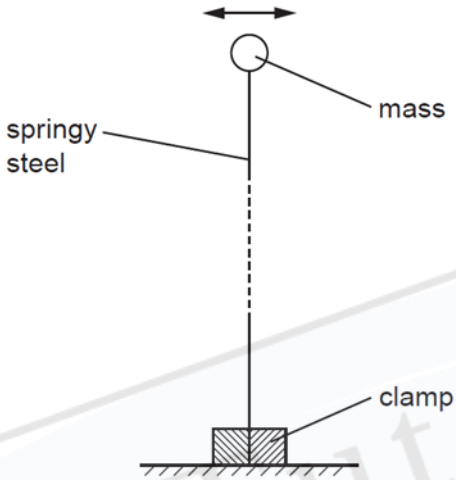

Fig. 9.1

The mass is pulled to one side and then released. The variation with time *t* of the horizontal displacement of the mass is shown in Fig. 9.2

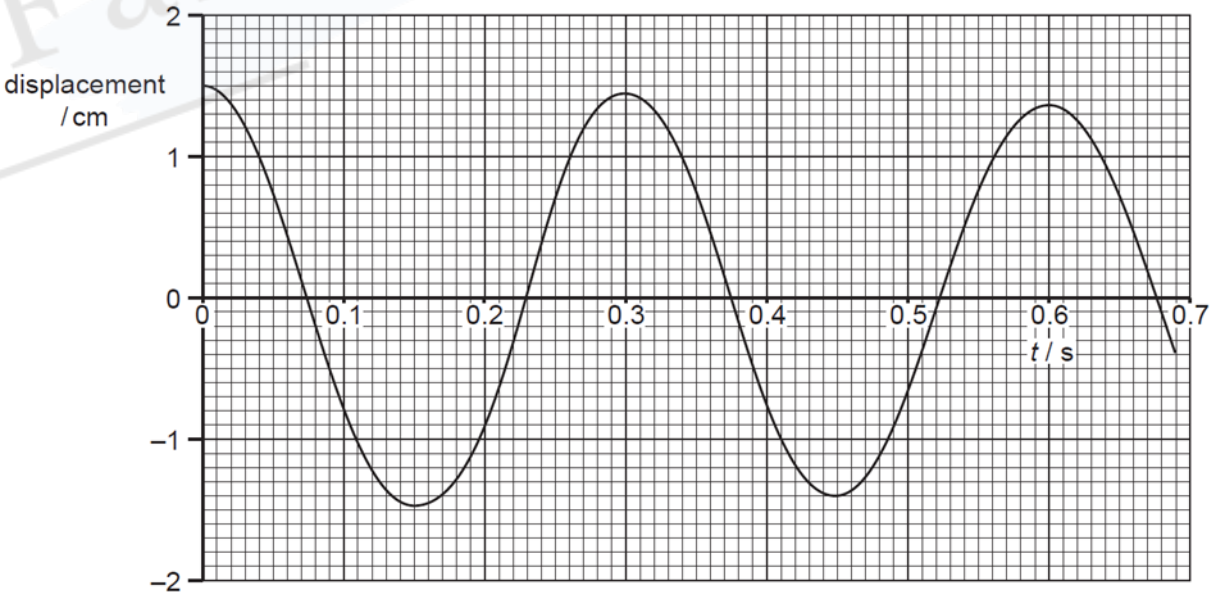

Fig. 9.2

[Turn over

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The mass undergoes damped oscillation.

(b) (i) Suggest, with a reason, whether the damping is light, critical or heavy.

……

……

…… [2]

(ii) 1. Using the data from Fig. 9.2, determine the maximum speed of the oscillation. State one time at which it is moving at maximum speed.

maximum speed =……m s^{-1}

time = …… s [2]

2. Sketch a graph showing the variation of the velocity of the mass *v* with its displacement from the equilibrium position in Fig. 9.3 for the first complete period of the oscillation.

Label the axes with an appropriate scale.

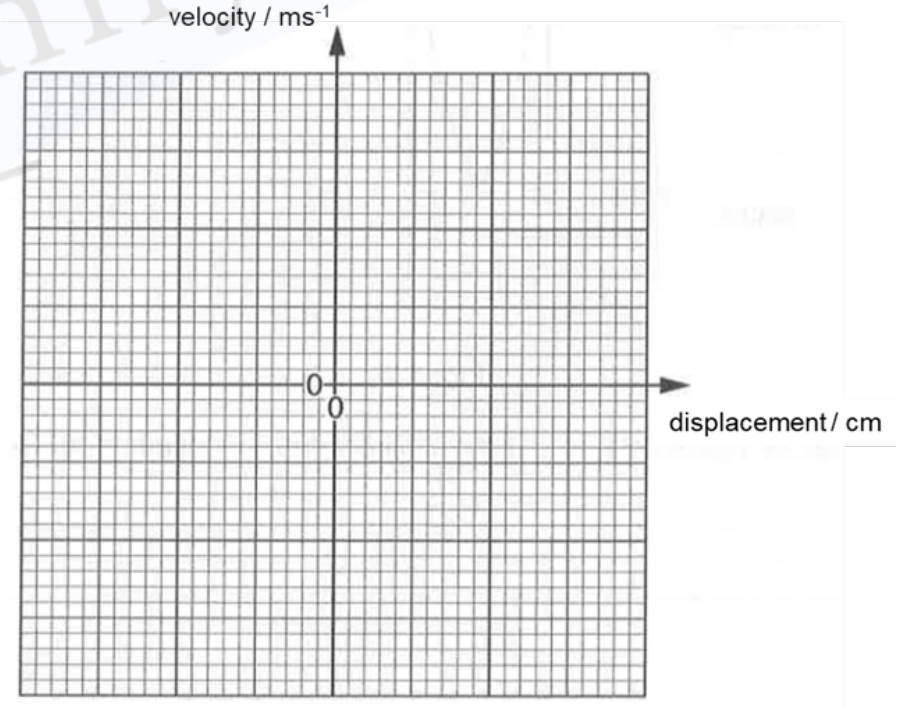

Fig. 9.3

[3]

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(iii) After eight complete oscillations of the mass, the amplitude of vibration is reduced from 1.5 cm to 1.1 cm.

1. Show that the total energy of a body oscillating in simple harmonic motion is given by

$$E_T = \frac{1}{2} m\omega^2 x_0^2$$

where ω is the angular frequency of the oscillation and x_0 is its amplitude

[3]

2. Calculate the angular frequency of the oscillations.

angular frequency = …….rad s^{-1} [2]

3. Calculate the loss of energy after eight complete oscillations.

loss of energy = …….J [2]

[Turn over

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4. Suggest with a reason, whether after another eight complete oscillations, the amplitude will be 0.7 cm.

.....

.....

..... [2]

(c) The variation of kinetic energy E_k of the mass with displacement x from its equilibrium position for the first period of oscillation is shown in Fig. 9.4.

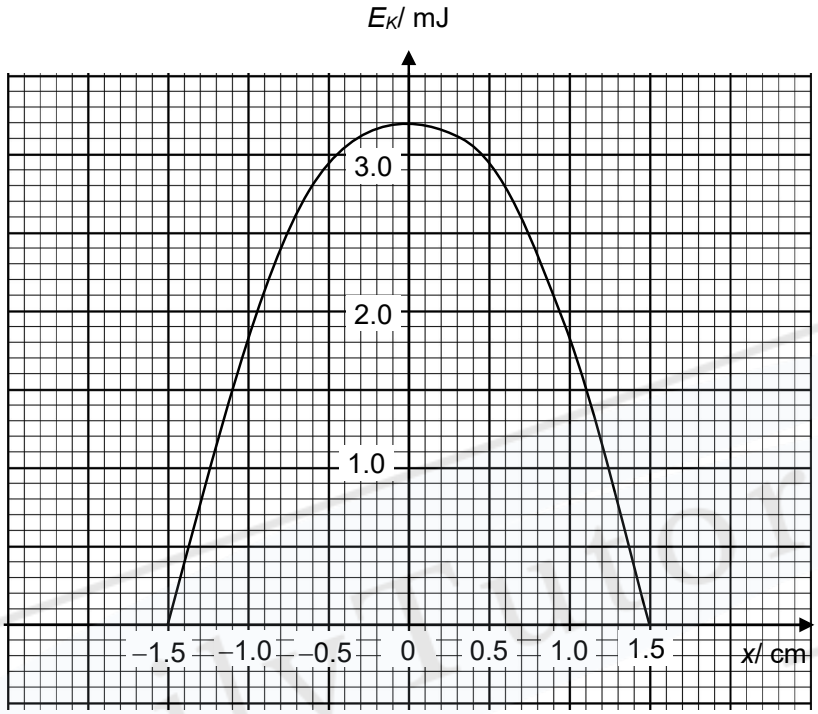

Fig. 9.4

The mass loses energy such that, after some time, its maximum kinetic energy is reduced by 1.5 mJ.

Use Fig. 9.4, without further calculation, to determine the amplitude of the oscillations. Show your construction on Fig. 9.4.

amplitude = ... cm [2]

[Total: 20]

-- END OF PAPER 3 -

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CLASS	**2T**

PHYSICS

Paper 3: Longer Structured Questions

9749/3
September 2023
2 hours

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.

Section A
Answer **all** questions.

Section B
Answer one question only.
Circle on the cover page the question number attempted in Section B.

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

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

Suggested Solutions

FOR EXAMINER'S USE	
SECTION A	
Q1	/ 8
Q2	/ 8
Q3	/ 8
Q4	/ 14
Q5	/ 8
Q6	/ 11
Q7	/ 3
SECTION B	
Q8	/ 20
Q9	/ 20
TOTAL	/80

This document consists of **33** printed pages and **0** blank page.

[Turn over

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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}

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FORMULAE

uniformly accelerated motion	s	$= ut + \frac{1}{2}at^2$
	v^2	$= u^2 + 2as$
work done on / by a gas	W	$= p\Delta V$
hydrostatic pressure	p	$= \rho gh$
gravitational potential	ϕ	$= -\frac{Gm}{r}$
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	$= R_1 + R_2 + ...$
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	$= x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	$= \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	$= \frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	$= \mu_o n I$
radioactive decay	x	$= x_0 \exp(-\lambda t)$
decay constant	λ	$= \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

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Section A

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

1 A ball of mass 10 g is dropped from a height and falls through air. The variation with time t of the speed of the ball v is shown in Fig. 1.1

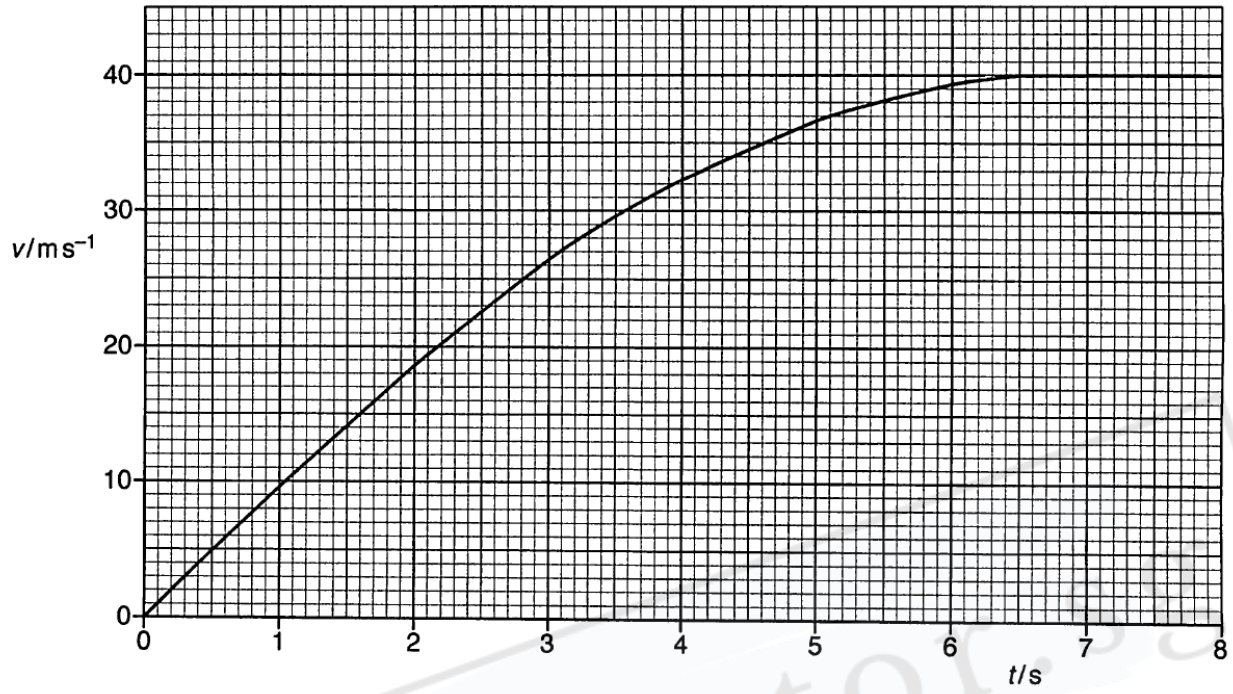

Fig 1.1

(a) (i) Use Fig 1.1. to determine the acceleration of the ball at time t = 0. Show your construction on Fig 1.1.

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

Solution:

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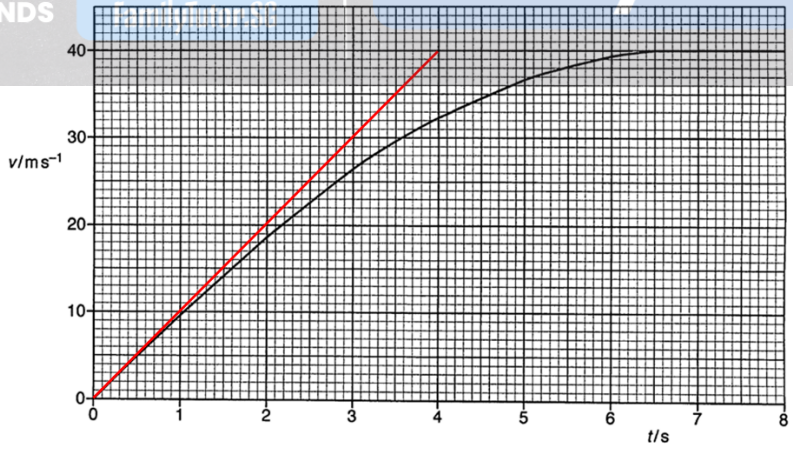

1

1
1

acceleration
= gradient of the v – t graph at t = 0
$= \frac{40-0}{4-0}$
= 10 m s^{-2}

(ii) By reference to your answer in **(a)(i)**, suggest the difference, if any, between your answer and the acceleration of free fall.

……

……

……

…… [2]

Solution:

The value obtained in **(a)(i)** is close to the value of the acceleration of the free fall. 1

At time t = 0, the velocity of the ball is (close to) 0, so no (or very little) drag force acting on it. The net force = weight, acceleration = g 1

(b) Calculate the maximum resistive force acting on the ball.

force = …… N [1]

Solution:

Maximum resistive force acts when the ball is at terminal velocity (a = 0)

At this point,
$F_{net} = mg - F_{resistive} = 0$
$F_{resistive} = mg$ = 0.01 x 9.81 = 0.0981 N 1

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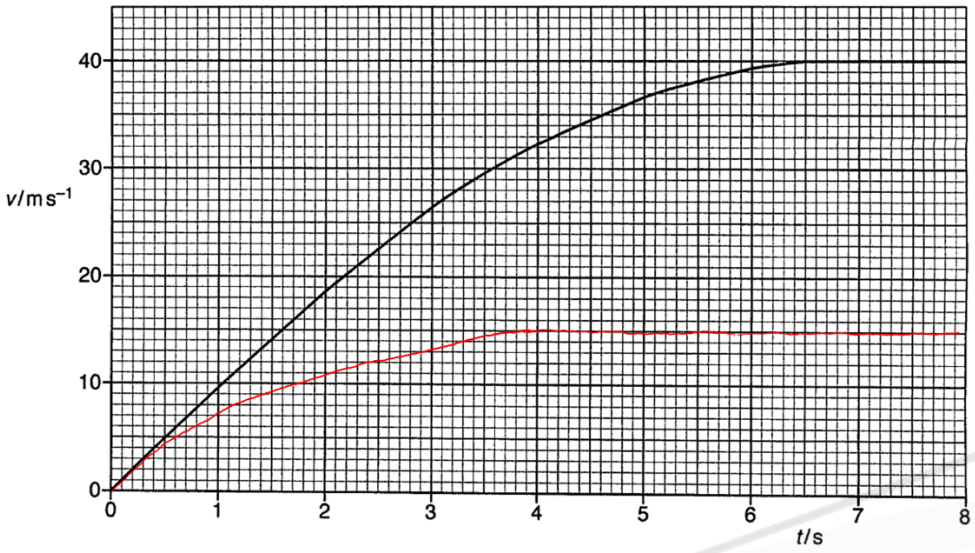
	(c)	On Fig 1.1, draw another curve to show the variation with time t of the speed of the ball v if the ball was dropped in a more viscous medium. [2] [Total: 8]	

Solution:



1 mark – rate of increase of v is lower than the original graph.
Note: mg – kv = ma, k is larger and hence acc is smaller

1 mark – object reaches terminal velocity at a lower velocity and at an earlier time.
Note: When mg = kv, terminal vel is reached or when a = 0, Hence acc = 0 is reached earlier when k is larger.

2 A binary star consists of two stars A and B. The two stars may be considered to be isolated in space. The centres of the two stars are separated by a constant distance, as illustrated in Fig. 2.1.

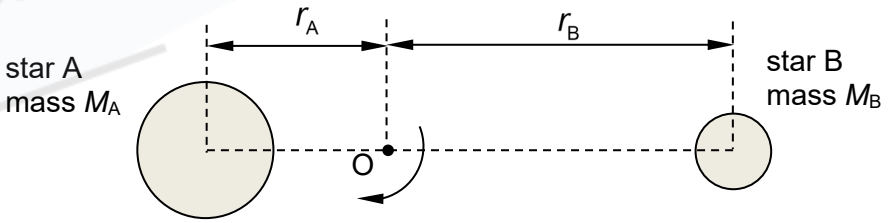


Fig. 2.1

Star A of mass M_A has a larger mass than star B of mass M_B such that $M_A = 4M_B$.

The stars are in circular orbits about each other such that the centre of their orbits is at a fixed point O. The radius of orbit of star A and star B are r_A and r_B respectively.

The period of each orbit is T.

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	(a)	Explain why the two stars must always be directly opposite as they move in the circular orbit. …… …… …… …… [2]	
		Solution: The centripetal force acting on each star is provided by the gravitational force between the two stars. The direction of the gravitational force acts along the line joining their centres of mass (which is the diameter of the circular orbit).	1 1
	(b)	Show that $\frac{r_B}{r_A} = 4$. Explain your working.	
			[2]
		Solution: The gravitational force on each star provides the centripetal force required for its respective circular motion about O. Since the stars have the same period, they have the same angular velocity ω. For star A, $\frac{GM_AM_B}{(r_A+r_B)^2} = M_Ar_A\omega^2$ ..... (1) For star B, $\frac{GM_AM_B}{(r_A+r_B)^2} = M_Br_B\omega^2$ ..... (2) --- Equating (1) and (2) OR Since the stars have the same period, they have the same angular velocity. Therefore the magnitude of centripetal force acting on each star is equal. $M_Ar_A\omega^2 = M_Br_B\omega^2$ ..... (3)	1 1

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$$\frac{r_B}{r_A} = \frac{M_A}{M_B} = \frac{4M_B}{M_B}$$

$$\frac{r_B}{r_A} = 4 \quad \text{(shown)}$$

(c) If the period T is 104 days and the separation of the centres of the stars is 1.1×10^{11} m,

(i) calculate the angular velocity of star A, and

angular velocity = ... rad s^{-1} [1]

L1 **Solution:**

angular velocity $\omega = \frac{2\pi}{T} = \frac{2\pi}{104\times24\times60\times60} = 7.0\times10^{-7}$ rad s^{-1} 1

(ii) determine the mass of each star.

mass M_A of star A = ... kg

mass M_B of star B = ... kg [3]

L2 **Solution:**

$r_A + r_B = 1.1\times10^{11}$

$r_A + 4r_A = 1.1\times10^{11}$

$r_A = 2.2\times10^{10}$ m and $r_B = 8.8\times10^{10}$ m 1

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The gravitational force on star A provides the centripetal force for its circular motion about O.

$$\frac{GM_AM_B}{(r_A+r_B)^2} = M_Ar_A\omega^2$$

$$\frac{GM_B}{(r_A+r_B)^2} = r_A\omega^2 \quad \Rightarrow \quad M_B = \frac{\omega^2 r_A (r_A+r_B)^2}{G}$$

$$M_B = \frac{(7.0\times10^{-7})^2(2.2\times10^{10})(1.1\times10^{11})^2}{(6.67\times10^{-11})}$$ 1

$$M_B = 1.96\times10^{30} = 2.0\times10^{30} \text{ kg}$$

$$M_A = 7.8 \text{ or } 8.0\times10^{30} \text{ kg}$$ 1

3 Ice is less dense than liquid water due to the structure of the bonds between the molecules when it is in a solid state. Hence, when ice melts into water at 0°C, the density of water increases. As the liquid water increases in temperature, its density further increases to a maximum value at 4.0°C.

(a) Consider a 5.0 kg block of ice at 0°C that is melted into liquid water at the same temperature using a heat source supplying a constant power of 4180 W.

(i) The specific latent heat of fusion of ice is 3.34 x 10^5 J kg^{-1}.

Determine the time taken to completely melt the block of ice into liquid water at 0°C.

time = …….. s [3]

Solution:

The heat required to melt the 5.0 kg block of ice, Q:
= mass × latent heat of fusion

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			= 5.0 kg × 3.34 x 10^5 J kg^{-1} = 1.67 x 10^6 J Time to melt the ice: = Q / P = 1.67 x 10^6 / 4180 = 400 s	
		(ii)	The density of ice at 0°C is 0.915 kg m^{-3} while the density of liquid water at 0°C is 0.999 kg m^{-3}. Calculate the work done on the ice by a constant atmospheric pressure of 1.01 x 10^5 Pa as the ice melts completely into water at 0°C. work done on the ice = …… J [3]	
			Solution: Volume of the ice, V_{ice} = mass of ice / density of ice = 5.0 / 0.915 = 5.46 m^3 Volume of the liquid water, V_{water} = mass of water / density of water = 5.0 / 0.999 = 5.01 m^3 Change in volume, ΔV = 5.01 m^3 - 5.46 m^3 = -0.45 m^3 Work done ON ice, w = - P x ΔV = - [1.01 x 10^5 * (-0.45)] = 4.55 x 10^4 J or 4.6 x 10^4 J	1 1 1
	(b)	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.		

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Use the words **positive**, **negative** and **zero** to complete Table 3.1 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.

Table 3.1

Process	ΔU	q	w
Ice melting into liquid water at 0°C			
Liquid water warming up from 0°C to 4°C			

[2]

[Total: 8]

Solution:

As the ice melts, its internal energy increases due to the energy used to increase the intermolecular separation. The source of this energy is the heat supplied to the ice and the work done on the ice by the atmospheric pressure (since the ice contracts as it melts)

As the liquid water increases in temperature, its internal energy increases. The source of this energy is the heat supplied to the water from the surroundings and the further contraction of the volume of the water (as its density continues to increase) means that the atmospheric pressure does further work on the water.

Process	ΔU	q	w
Ice melting into liquid water at 0°C	**positive**	**positive**	**positive**
Liquid water warming up from 0°C to 4°C	**positive**	**positive**	**positive**

4 **(a)** State what is meant by *radioactive decay*.

.....

.....

.....

..... [2]

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		Solution: Radioactivity (or radioactive decay) is the spontaneous and random disintegration (or decay) of an unstable nucleus into a more stable one (either unstable or become more stable) with the emission of particles (and photons i.e. alpha-particle beta-particle, gamma ray photon). (particles/ radiation – can give marks if mention partial)	1 1
	(b)	A radiation detector is placed close to a radioactive source. The detector does not surround the source. Radiation is emitted in all directions and, as a result, the activity of the source and the measured count rate are different. Suggest two other reasons why the activity and the measured count rate may be different. 1. …… …… 2. …… …… [2]	
		Solution: • emission from radioactive daughter products • self-absorption in source • absorption in air before reaching detector • detector not sensitive to all radiations • window of detector may absorb some radiation • background radiation **(not accepting a repeat mention of part of radiation is detected)** **Any of the above 2 points**	2
	(c)	The variation with time *t* of the measured count rate in **(b)** is shown in Fig. 4.1.	

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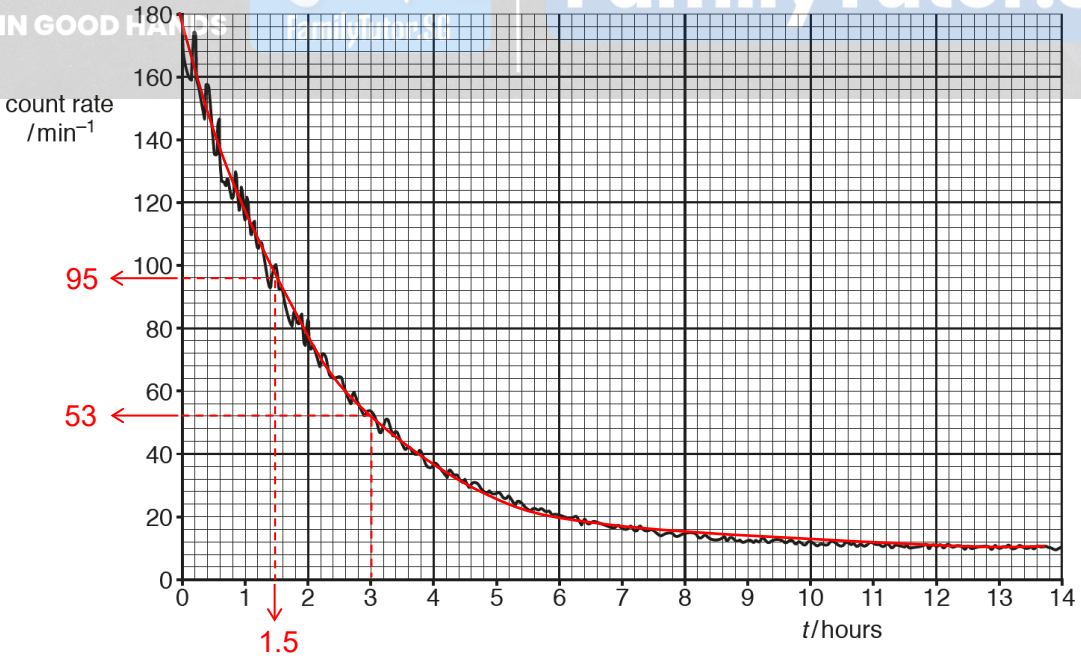

Fig. 4.1

(i) State the feature of Fig. 4.1 that indicates the random nature of radioactive decay.

.....

..... [1]

Solution:
Curve is not smooth or curve fluctuates or curve is jagged. — 1

(ii) Use Fig. 4.1 to determine

1. the background count rate and,

background radiation = ... min^{-1} [1]

Solution:
The curve is almost flat between 10 hours and 14 hours.
background radiation = 10 min^{-1} — 1

2. the half-life of the radioactive isotope in the source.

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half-life = ... hours [4]

Solution:

half-life determined at least twice — 1

Draw a curve of best fit to read off the values from the graph

First half-life

$C_0 = 180 - 10 = 170$ min^{-1}

$C_1 = \frac{C_0}{2} = \frac{170}{2} = 85$ min^{-1}

C_1 (measured) = 85 + 10 = 95 min^{-1}, from the graph, $t_{½} = 1.5$ hour

(correct method of determining half life from graph) — 1

Second half-life

$C_2 = \frac{C_1}{2} = \frac{85}{2} = 43$ min^{-1}

C_2 (measured) = 43 + 10 = 53 min^{-1}, from the graph,

$t_{½} = 3 - 1.5 = 1.5$ hour

half-life = 1.5 hours – (mark for background considerations here) — 2

(d) The readings in **(c)** were obtained at room temperature.

A second sample of this isotope is heated to a temperature of 500 °C.
The initial count rate at time t = 0 is the same as that in **(c)**.
The variation with time t of the measured count rate from the heated source is determined.

State, with a reason, whether the heating will cause a difference, if any, in

1. the half-life,

.....

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		…… **2.** the measured count rate for any specific time. …… …… …… [4] [Total: 14]
		Solution: **1.** half life : no change 1 because decay is spontaneous / independent of environment 1 **2.** count rate: likely to be <u>different</u> 1 because radioactive decay is random or cannot be predicted 1

5	**(a)**	Explain what is meant by *coherent* light waves.
		…… …… [1]
		Solution: The light waves have a constant phase difference which does not vary with time. 1
	(b)	Coherent light of wavelength 550 nm is incident normally on a double slit of slit separation 2.1 mm, as shown in Fig. 5.1. Both slits in the double slit arrangement have a width of 0.1 mm. A series of bright and dark fringes forms on a screen placed a distance of 2.4 m from the double slit. The screen is parallel to the double slit.

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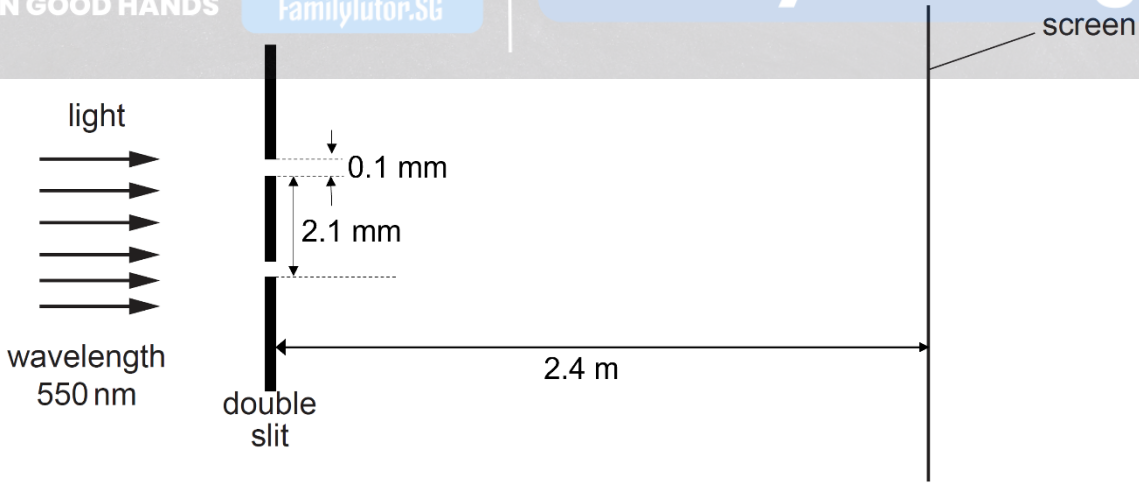

Fig. 5.1 (not to scale)

(i) Initially, one of the two slits is covered.

Calculate the width of the central fringe of the single-slit diffraction pattern seen on the screen.

Give your answer to three significant figures.

fringe width = ... m [3]

Solution:
For minima of a single slit,

$$\sin\theta_{min} = m\frac{\lambda}{b}$$

For first minima, m = 1

$\sin\theta_{min} = \frac{\lambda}{b} = \frac{550\times10^{-9}}{0.1\times10^{-3}} = 0.0055$ 1

$\tan\theta_{min} = \frac{y}{L}$

where y is half the width of the central fringe and L is the distance between the slits and the screen

Since θ_{min} is very small, we can use the approximation $\sin\theta \approx \tan\theta$ and then solve for y:

$$\sin\theta_{min} \approx \frac{y}{L}$$

$$0.0055 \approx \frac{y}{2.4}$$

y = 0.0132 m 1

Fringe width = 0.0132 x 2 = 0.0264 m (3sf) 1

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		(ii)	Both slits are now uncovered. Estimate, to one significant figure, the number of fringes resulting from double-slit interference that are seen within the central maximum produced by single-slit diffraction.	
			number = ……	[3]
			Solution: Using the double slit equation to find interference fringe separation, x $x = \frac{\lambda D}{d} = \frac{550 \times 10^{-9} \times 2.4}{2.1 \times 10^{-3}}$ $x = 6.29 \times 10^{-4}\ m$ Since these double-slit fringes sit within the width of the central single-slit diffraction fringe, number of fringes = $\frac{\text{width of central diffraction fringe}}{\text{interference fringe separation}}$ = 40 (1sf)	1 1 1
		(iii)	The light of wavelength 550 nm is replaced with monochromatic red light. State and explain the change, if any, in the distance between the centres of adjacent double slit bright fringes.	
			…… …… ……	[1]
				[Total: 8]

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			Solution: red light has longer wavelength (than 550 nm) so distance (between fringes) increases	1

6	(a)	Use the theory of the particulate nature of electromagnetic radiation to explain why there is a threshold frequency for the photoelectric effect.	
		…… …… …… …… …… ……[3]	
		Solution: In the particulate theory of light, electromagnetic radiation comprises of discrete quanta of energy, called photons. The energy *E* of each *photon* is determined by the frequency *f* of the radiation, $E=hf$, where *h* is the Planck's constant. When these photons are incident on the metal surface, they interact with the electrons in the metal on a one-to-one basis, meaning that a photon is either completely absorbed or rejected. (i.e. the energy of different photons cannot be cumulated). For an electron to be ejected from the metal surface, the electron must gain enough energy to be completely freed from the electrostatic forces of attraction of the metal cations. The minimum amount of energy required is called the *work function energy* Φ that is unique to the type of metal. The value hf must be at equal or larger than Φ. Thus there is a *minimum frequency* $f=\Phi/h$ the incoming electromagnetic radiation must be at for photoelectric emission to occur.	1 1 1
	(b)	An experimental setup to investigate the photoelectric effect is shown in Fig. 6.1. Electromagnetic radiation is incident on the emitter E of the photocell and the photoelectrons move towards the collector C.	

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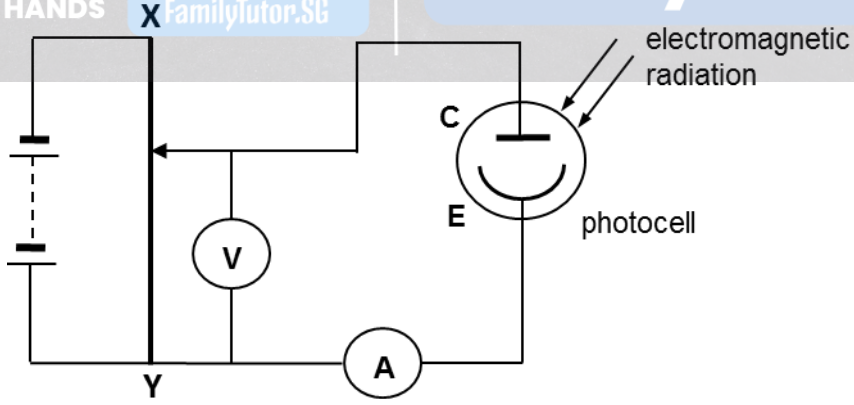

Fig. 6.1

The wavelength of the electromagnetic radiation incident on the photocell was varied. For two values of wavelength λ, the stopping potential V_S required for the ammeter reading to become zero was measured. The results are shown in Fig. 6.2.

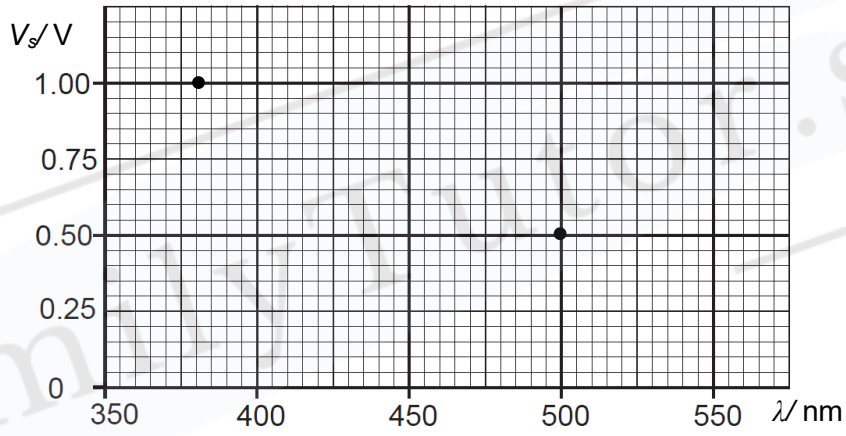

Fig. 6.2

		(i)	Calculate the maximum kinetic energy of a photoelectron emitted from the metal surface by radiation of wavelength 500 nm.	
			maximum kinetic energy = ... J	[2]
			Solution: Max KE = eV_s = 1.6 x 10^{-19} x 0.5 = 8.0 x 10^{-20} J	1 1

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		(ii)	Calculate the energy of a photon of wavelength 500 nm.		
				energy = ... J	[2]
			Solution: $E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{500 \times 10^{-9}}$ $= 3.98 \times 10^{-19}$ J		1 1
		(iii)	Hence, determine		
			1.	the work function energy of the metal surface, and	
				work function energy = ... J	[1]
				Solution: Work function energy = $E_{photon} - KE_{max}$ $= 3.98 \times 10^{-19} - 8 \times 10^{-20}$ $= 3.18 \times 10^{-19}$ J	1
			2.	the maximum photon wavelength that can liberate a photoelectron.	
				maximum wavelength = ... nm	[2]
				Solution: Work function energy = $\frac{hc}{\lambda_o}$ $\lambda_o = \frac{hc}{\phi} = \frac{6.63 \times 10^{-34} \times (3 \times 10^{8})}{3.18 \times 10^{-19}}$ $= 625$ nm	1 1

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		(iv)	Suggest why it is not possible to deduce the maximum photon wavelength that can liberate a photoelectron from this metal plate directly from the data in Fig. 6.2. ....[1] [Total: 11]	
			Solution: The graph of V_s against λ should give a curve. Since only two points are plotted on Fig 6.2, a curve cannot be drawn to find the value of λ when V_s approaches zero.	1

7 Fig. 7.1 shows an x-ray spectrum.

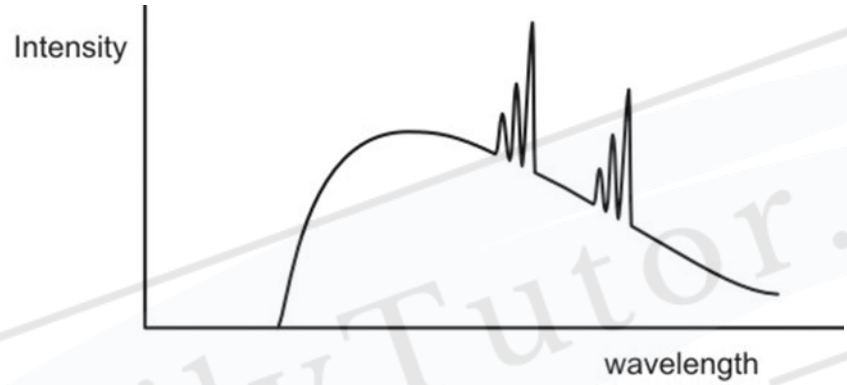

Fig. 7.1

Describe how the continuous spectrum is produced.

.....

.....

.....

.....

.....

.....

.....

.....[3]

[Total: 3]

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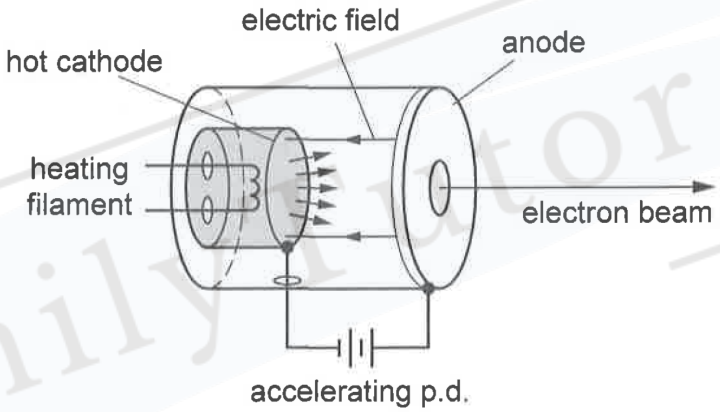
		Solution: An electron with high speed/ KE interacts with the nucleus of a target metal and accelerates/decelerates. As electron is a charged particle, when it undergoes a rapid deceleration, it produces an x-ray photon of energy equal to the kinetic energy lost by the incident electron via Bremsstrahlung process. If an electron has excess kinetic energy after the deceleration it goes through a series of decelerations and produces photons of a (continuous) range of wavelengths.	1 1 1

Section B

Answer **one** question from this section.

8	**(a)**	Fig. 8.1 shows a diagram of an electron gun. Electrons are emitted from a hot cathode. The electric field between the cathode and the anode accelerates the electrons through an accelerating potential difference (p.d.).  **Fig. 8.1**		
		(i)	Explain what is meant by an electric field.	
			…… ……[1]	
			Solution: Region of space where a charged body experiences an electric force	1
		(ii)	Explain why the electron gun in Fig. 8.1 must be in a vacuum.	
			……	

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			…… …… …… [2]	
			Solution: Electrons have a small mass easily deflected/ weakly ionizing/ collide with air molecules and scatter In vacuum, they can travel in a straight line and reach the anode (if not they will be deflected from their path)	 1 1
		(iii)	The kinetic energy of the electrons increases by 5.68×10^{-16} J between leaving the cathode and reaching the anode. Calculate the accelerating p.d..	
			accelerating p.d. = …… V [2]	
			Solution: W = qV $5.68 \times 10^{-16} = 1.6 \times 10^{-19} \times V$ V = 3.55 kV	 1 1
		(iv)	Suggest why the electrons reaching the anode have a range of speeds.	
			…… …… …… …… [2]	
			Solution: Thermionic emission of electrons from the filament is a random process and electrons are emitted with a range of KE from the filament.	1

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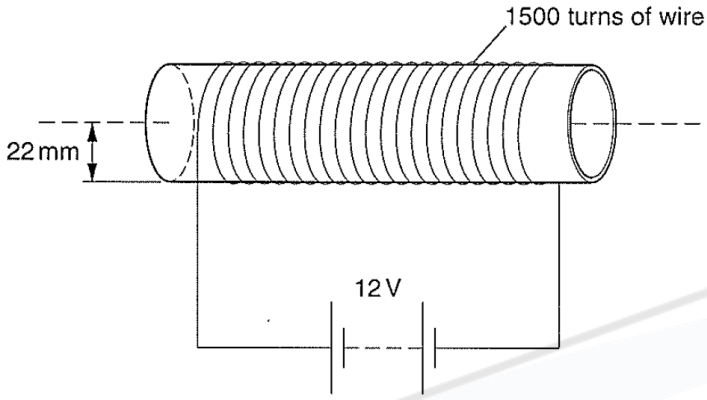
			When accelerated by the p.d., the increase in KE is the same, but since they had a range of KE when they were produced, the final KE when reaching the anode will have a range of values, hence a range of speeds.	1
	(b)	A uniform magnetic field is produced using a coil of 1500 turns of insulated wire, tightly wound on a non-magnetic tube to make a solenoid of mean radius 22 mm, as shown in Fig. 8.2. The wire itself has radius 0.86 mm and is made of a material of resistivity 1.7×10^{-8} Ω m. The coil is connected to a supply of e.m.f. 12 V and negligible internal resistance.  **Fig. 8.2** Calculate			
		(i)	the total length of the 1500 turns of wire in the coil, length = ... m [1]	
			Solution: total length of wire in the coil = $2\pi(22\text{x}10^{-3})$ (1500) = 207.3 m	1
		(ii)	the total resistance of the coil, resistance = ... Ω [2]	
			Solution: $R = \frac{\rho l}{A} = \frac{1.7\times10^{-8}\times207.3}{\pi(0.86\times10^{-3})^2}$	1
			=1.52 Ω	1

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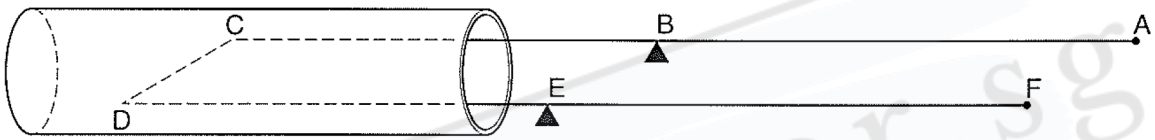
		(iii)	the current in the coil. current = ... A [2]
			Solution: I = 12 / 1.52 1 = 7.91 A 1
	(c)	The magnetic flux density in the solenoid is measured using a current balance. The current balance is a U-shaped piece of stiff wire ABCDEF pivoted at BE, as shown in Fig. 8.3.  **Fig. 8.3** When in use, there is a turning force on the stiff wire caused by a current in CD.	
		(i)	Explain why the current in CD causes a turning effect. .... [2]
			Solution: When there is a current in CD, it produces a magnetic field around the wire which interacts with the magnetic field of the solenoid. This results in a force perpendicular to both the current and the magnetic field of the solenoid. 1 This force x the perpendicular distance of wire CD from the pivot produces a moment and causes a turning effect. 1
		(ii)	Explain why currents in CB and DE do not contribute to the turning force. .... [1]

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Solution:

Currents in CB and DE are parallel to the magnetic field of the solenoid and hence no force. 1

(iii) CD has length 25 mm, CB and DE each have length 106 mm.

The stiff wire is first balanced when there is no current in it. A current of 4.9 A is then passed through CD and, in order to rebalance the stiff wire, a force of 5.7×10^{-4} N is applied at a distance of 77 mm from the pivot, as shown in Fig. 8.4. which is the side view of the balance.

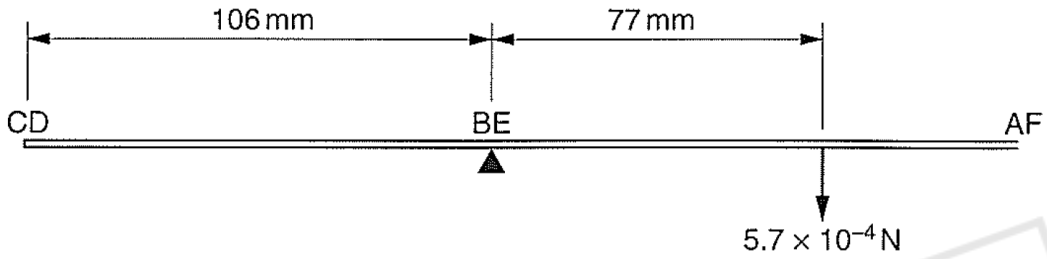

Fig. 8.4 (side view)

1. State the direction of the current in CD

direction = ... [1]

Solution: C to D 1

2. Calculate the magnetic flux density in the solenoid. Give the full name of the unit for magnetic flux density.

magnetic flux density = ...

full name of unit = ... [4]

[Total: 20]

Solution:

By POM,
$F \times 0.106 = 5.7 \times 10^{-4} \times 0.077$ 1

And $F = BIL = B(4.9)(0.025)$ 1

$B = 3.38 \times 10^{-3}$ T 1

Tesla 1

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9	(a)	State what is meant by *simple harmonic motion.* ....[2]	
		Solution: A periodic motion in which the body's acceleration is directly proportional to its displacement from its equilibrium position its acceleration is always in opposite direction to its displacement	 1 1

A long strip of springy steel is clamped at one end so that the strip is vertical. A mass *m* of 65 g is attached to the free end of the strip, as shown in Fig. 9.1.

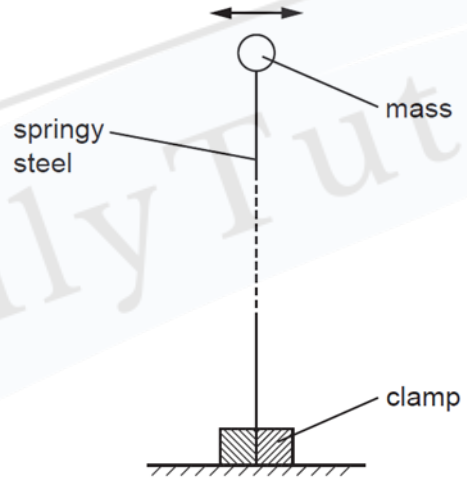

Fig. 9.1

The mass is pulled to one side and then released. The variation with time *t* of the horizontal displacement of the mass is shown in Fig. 9.2.

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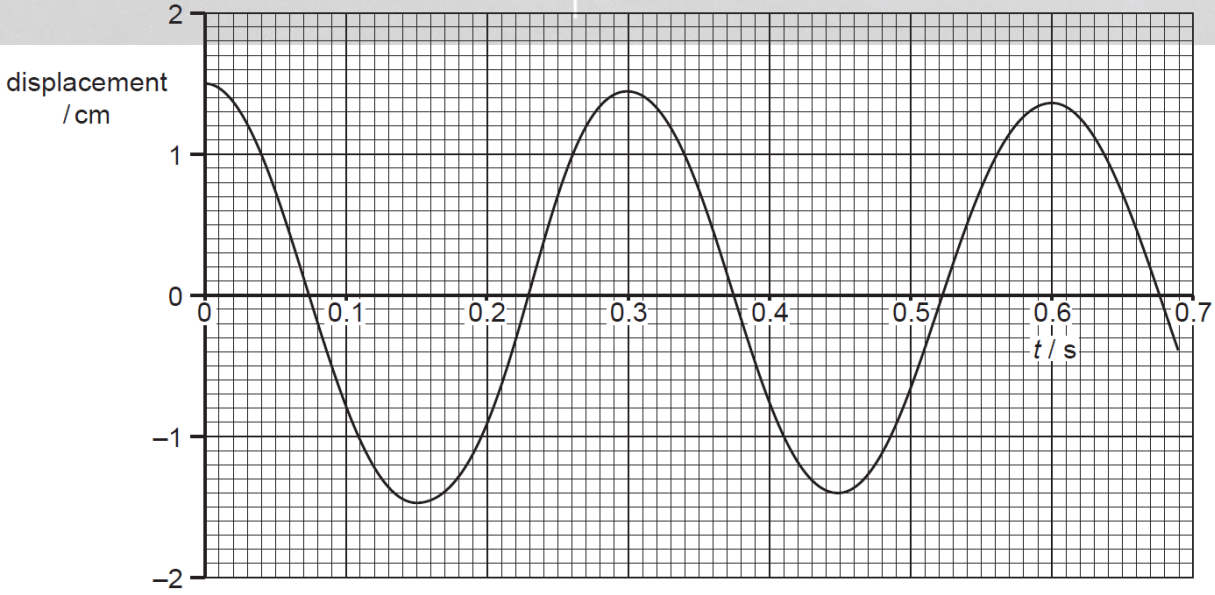

Fig. 9.2

The mass undergoes damped oscillation.

(b) **(i)** Suggest, with a reason, whether the damping is light, critical or heavy.

.....

.....

..... [2]

Solution:

The amplitude of the oscillation is decreasing gradually / oscillations continue for a long time — 1

Light damping — 1

(ii) **1.** Using the data from Fig. 9.2, determine the maximum speed of the oscillation. State one time at which it is moving at maximum speed.

maximum speed =.....m s^{-1}

time = ... s [2]

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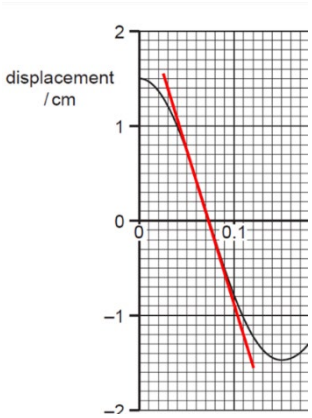
Solution:



speed
= gradient of the tangent
$= \left| \frac{(-1.2 - 1.4)}{(0.11 - 0.03)} \right|$
= 32.5 cm s^{-1} = 0.325 m s^{-1}

1

Time = 0.075 s, 0.23 s, 0.375 s, 0.52 s, 0.675 s

1

2. Sketch a graph showing the variation of the velocity of the mass *v* with its displacement from the equilibrium position in Fig. 9.3 for the first complete period of the oscillation.

Label the axes with an appropriate scale.

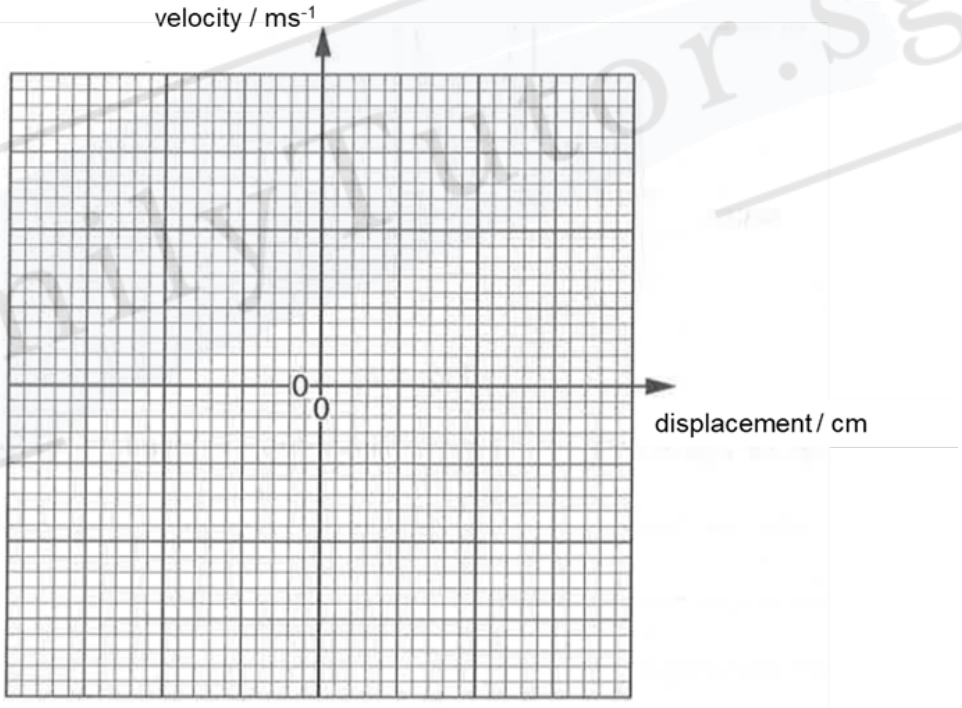


Fig. 9.3

[3]

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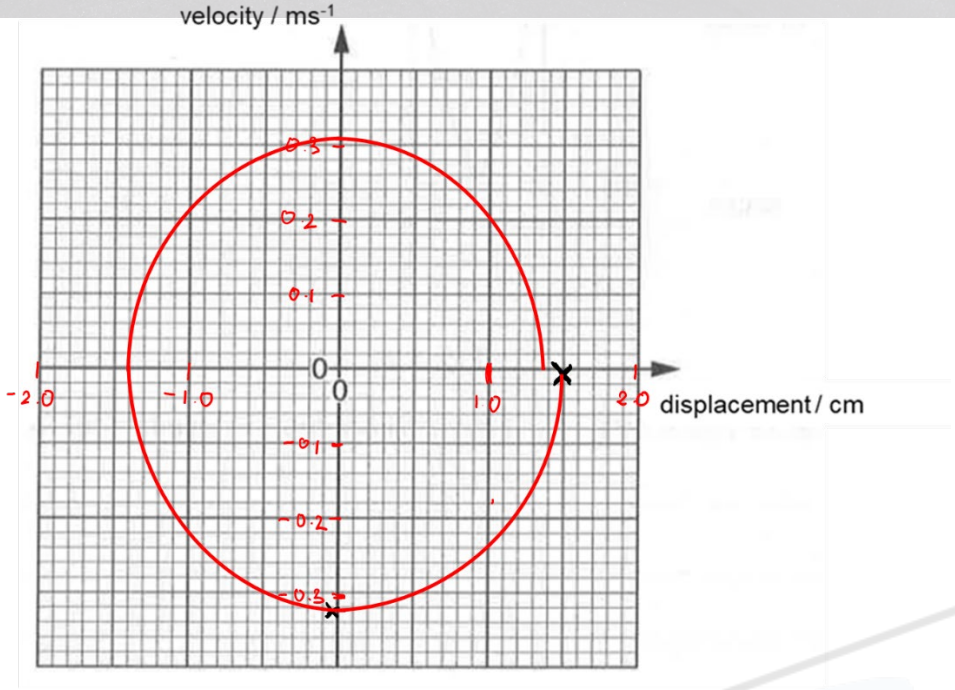
		L3		**Solution:**



1 mark – graph begins at (1.5 cm, 0)
1 mark - graph shape (clockwise, ellipse, not "closed")
1 mark – correct intercepts of axes (v and x values smaller than the previous intercept)

		(iii)	After eight complete oscillations of the mass, the amplitude of vibration is reduced from 1.5 cm to 1.1 cm.	
			1.	Show that the total energy of a body oscillating in simple harmonic motion is given by $$E_T = \frac{1}{2} m\omega^2 x_0^2$$ where ω is the angular frequency of the oscillation and x_0 is its amplitude [3]

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Solution:

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

speed is maximum when $x = 0$

$v_0 = \pm\omega\sqrt{x_0^2} = \omega x_0$ 1

The total energy of the oscillation
= maximum kinetic energy 1

$= \frac{1}{2}mv_0^2$

$= \frac{1}{2}m\omega^2 x_0^2$ 1

2. Calculate the angular frequency of the oscillations.

angular frequency = ……rad s^{-1} [2]

Solution:

$\omega = 2\pi/T$
$= 2\pi/0.3$
$= 20.9$ rad s^{-1} 1 1

3. Calculate the loss of energy after eight complete oscillations.

loss of energy = ……J [2]

Solution:

Loss of Energy
= total initial energy of oscillation – total final energy of oscillation
= ½ $m\omega^2 x_{o,initial}^2$ – ½ $m\omega^2 x_{o,final}^2$
= ½ × 0.065 × 20.9^2 ×($0.015^2 - 0.011^2$) 1
= 0.00147
= 0.0015 J 1

4. Suggest with a reason, whether after another eight complete oscillations, the amplitude will be 0.7 cm.

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.....

.....

..... [2]

Solution:

amplitude reduces exponentially / does not decrease linearly 1
so will be not be 0.7 cm 1

(c) The variation of kinetic energy E_k of the mass with displacement x from its equilibrium position for the first period of oscillation is shown in Fig. 9.4.

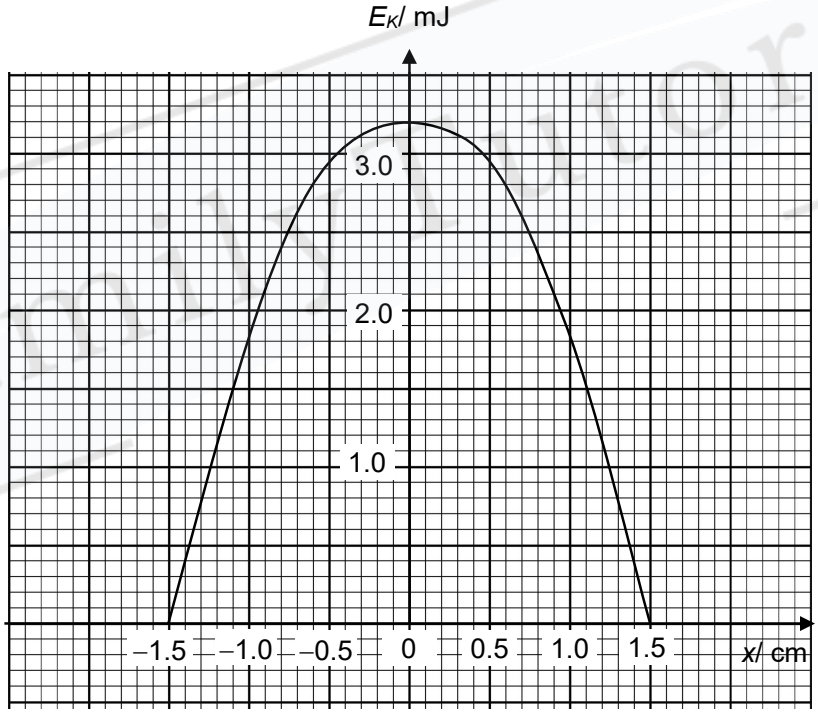

Fig. 9.4

The mass loses energy such that, after some time, its maximum kinetic energy is reduced by 1.5 mJ.

Use Fig. 9.4, without further calculation, to determine the amplitude of the oscillations. Show your construction on Fig. 9.4.

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		amplitude = ... cm [2] [Total: 20]	
		Solution: When the objects loses KE, the entire graph will be translated downwards by 1.5 mJ. The point that will now have 0 KE, or the amplitude will be the displacement at which the E was originally 1.5 mJ Construction of horizontal line at 1.5 mJ or correctly translated KE graph amplitude = 1.1 cm If shifted curve is shown with the correct 3 key points (i.e. max and the two amplitude points, 2 marks). If shifted curve is shown with only the correct max point (wrong amplitude values), 1 mark	 1 1

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PHYSICS

9749/04

Paper 4 Practical

21 Aug 2023

2 hour 30 minutes

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB or 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

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

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

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

Shift
Laboratory

For Examiner's Use	
1	**/ 15**
2	**/ 6**
3	**/ 22**
4	**/ 12**
Total	**/ 55**

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1. In this experiment, you will investigate the current in an electrical circuit.

(a) You have been provided with two metre rules A and B, each with a resistance wire attached.

Take measurements to determine the resistance per unit length of each of the wires.

The resistance per unit length of the wire attached to rule A is R_A.
The resistance per unit length of the wire attached to rule B is R_B.

R_A = ……

R_B = ……
[2]

(b) Set up the circuit as shown in Fig. 1.1.

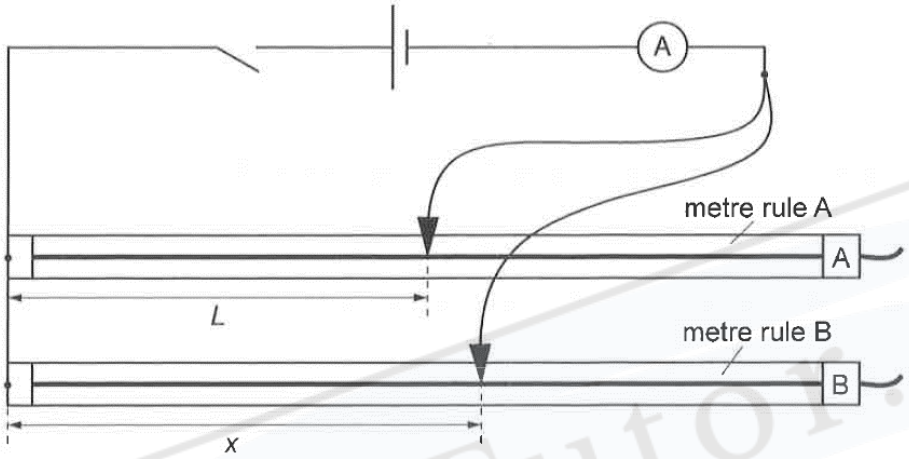

Fig. 1.1

L should be approximately half the length of the rule and *x* should be **greater** than *L*.

Close the switch.

Measure and record *L*, *x* and the ammeter reading *I*.

L = ……

x = ……

I = ……
[2]

[Turn Over

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(c) Vary *x*, obtaining a suitable range of values between 0 cm and 100 cm, and repeat **(b)**, keeping *L* constant throughout.

[3]

(d) It is suggested that I and x are related by the expression

$$I = \frac{E}{R_A L} + \frac{E}{R_B x}$$

where *E* is the electromotive force (e.m.f.) of the cell.

Plot a suitable graph to determine the value of *E*.

E = …….…….. V [7]

(e) Without taking further readings, sketch a line on your graph grid to show the results you would expect if the experiment was repeated with *x* measured on metre rule A and the same *L* in **1(b)** measured on metre rule B.

Label this line W. [1]

[Total: 15]

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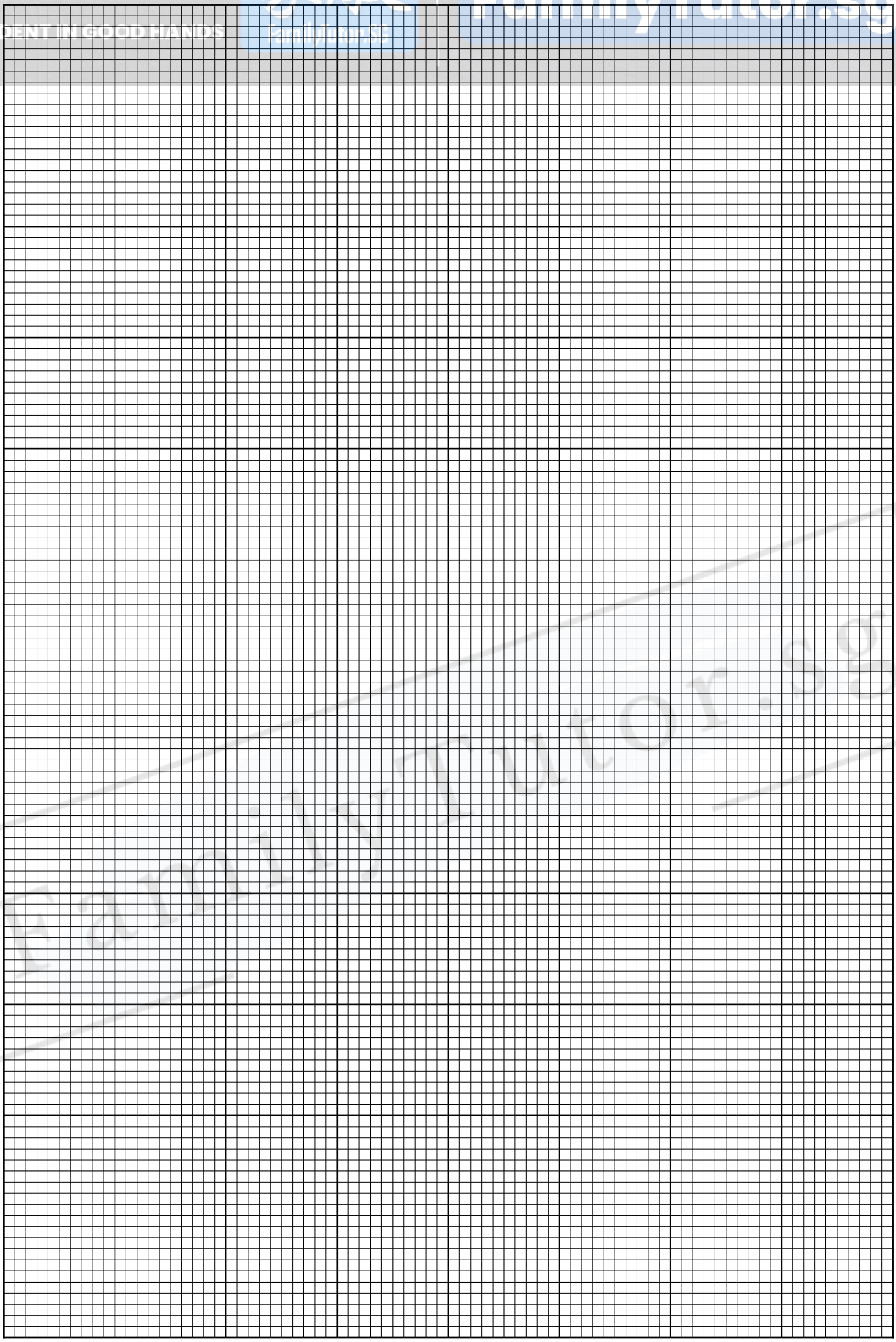

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2. In this experiment, you will investigate an oscillating system.

(a) Place the wooden strip on the pivot, as shown in Fig. 2.1.

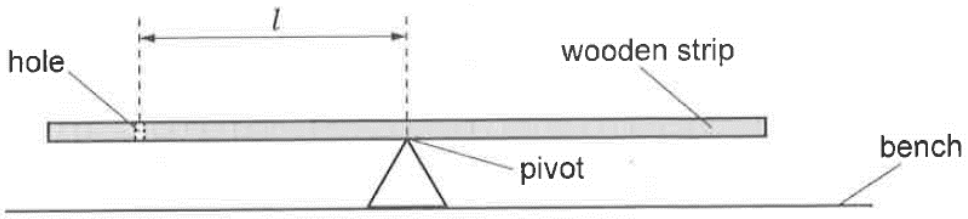

Fig. 2.1

Adjust the position of the wooden strip on the pivot until it balances. The distance between the centre of the hole in the wooden strip and the pivot is l.

Without marking on the wooden strip, measure and record l.

l = ... [1]

(b) Set up the apparatus as shown in Fig. 2.2.

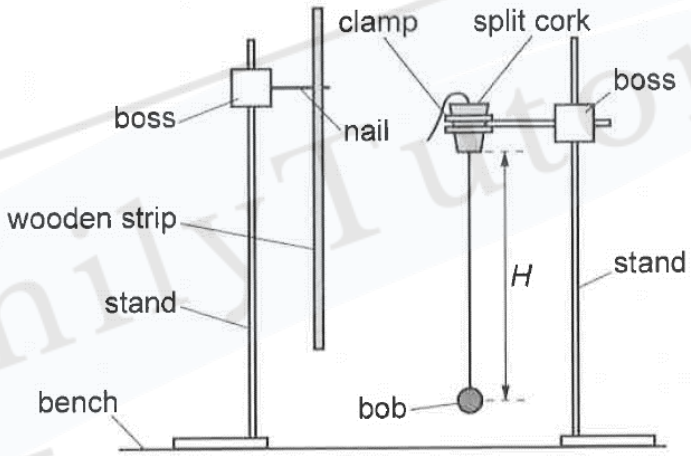

Fig. 2.2

The distance between the bottom of the split cork and the centre of the bob is H.
Adjust the string in the split cork until H is approximately 40 cm.

Displace the bob and the bottom of the wooden strip towards you through a short distance. Release the bob and the strip at the same time. The oscillations of the bob and the strip will be out of phase.

Adjust H so that the oscillations of the bob and the strip remain in phase for several cycles after release.

Measure and record H.

H = ... [1]

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(c) The quantities l and H are related by the equation

$$b = \sqrt{l(H - l)}$$

where b is a constant.

(i) Calculate b.

b = ……..…….. m [2]

(ii) If you were to repeat this experiment using a similar wooden strip with several holes at different positions along its length, describe the graph that you would plot to determine b.

……

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……..... [2]

[Total: 6]

[Turn Over

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3. In this experiment, you will investigate the stiffness of some metal wires.

A long-handled broom, as shown in Fig. 3.1, must be able to support the weight of the brush at the end without collapsing. Sometimes these brooms are used vertically to reach high places such as ceilings.

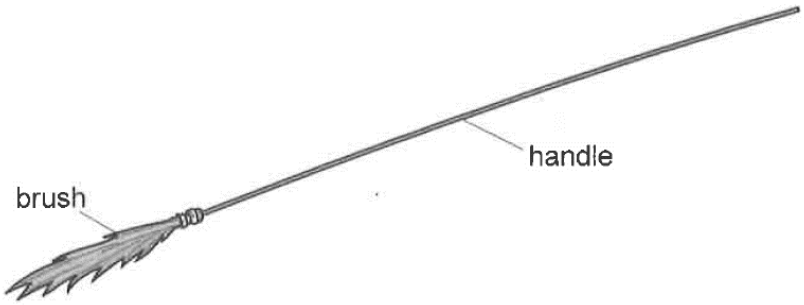

Fig. 3.1

In this experiment, you will model the broom handles using thin metal wires and investigate how the following properties of the wires affect their behaviour:

- length
- diameter
- load
- force constant.

(a) You have been provided with three wires labelled P, Q and R.

Measure and record the diameter *d* of wire P.

d = ... [1]

(b) (i) Attach the sphere of modelling clay to one end of wire P and hold the wire vertically between your thumb and first finger.
The length of wire between the centre of the sphere and the top of your thumb is *h*, as shown in Fig. 3.2.

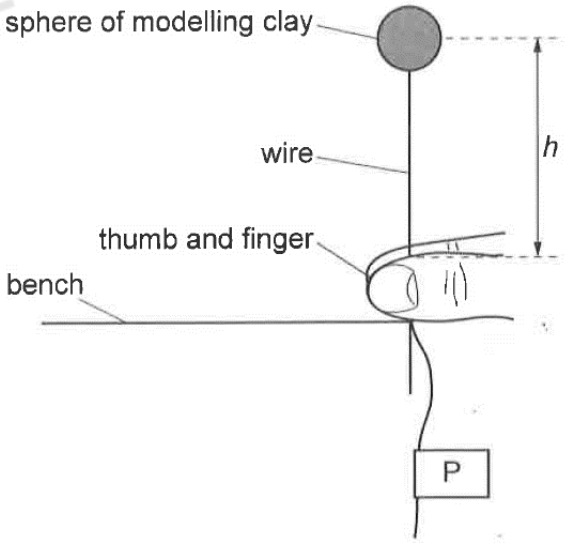

Fig. 3.2

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Increase *h* until the sphere moves down and touches the bench, as shown in Fig. 3.3.

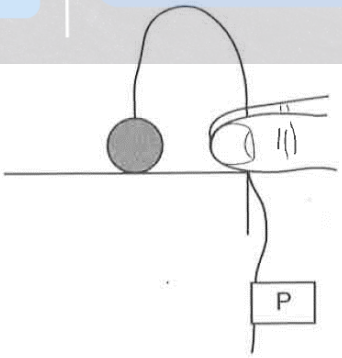

Fig. 3.3

Determine and record *h*.

h = ... [1]

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

Percentage uncertainty in *h* = ... [1]

(iii) Suggest one significant source of uncertainty in this experiment.

.....

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..... [1]

(iv) Suggest an improvement that could be made to the experiment to reduce the uncertainty identified in **(b)(iii)**.

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

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..... [1]

[Turn Over

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(c) Wire Q is made from the same material as wire P, but has a different diameter.

Repeat **(a)** and **(b)(i)** for wire Q.

d = ……

h = ……

[3]

(d) It is suggested that

$$h = c\,d^2$$

where c is a constant.

(i) Use your values from **(a)**, **(b)(i)** and **(c)** to determine two values of c.

Give your values for c to an appropriate number of significant figures.

first value for c = ……

second value for c = ……

[1]

(ii) Justify the number of significant figures given to your values for c.

……

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…… [1]

(iii) State whether the results of your experiment support the suggested relationship.
Justify your conclusion by referring to your answer in **(b)(ii)**.

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…… [1]

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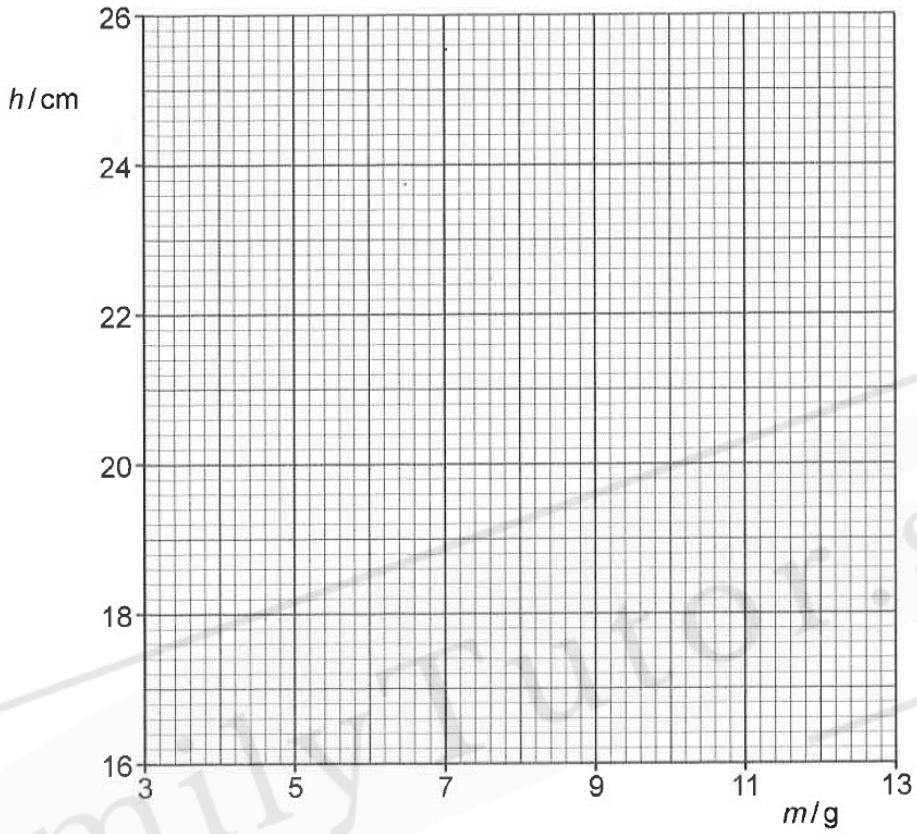
(e) In an investigation, the mass m of the sphere attached to the end of a wire was varied.

The following results for m and h were recorded.

m /g	4.4	6.1	8.1	9.9	11.8
h / cm	25.6	24.1	21.5	19.8	17.8

(i) Plot h against m on the grid and draw the straight line of best fit. [1]



(ii) Use your graph to determine the value h when no sphere is attached to the wire.

h = ……..…… cm [3]

[Turn Over

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(f) The force constant k for a wire in tension is defined as

$$k = \frac{YA}{h}$$

where Y is the stiffness of the material of the wire and the cross-sectional area A of the wire is given by $A = \frac{\pi d^2}{4}$.

Wires P and R are made from different materials but have the **same** diameter.

Table 3.1 shows the values of Y for the two wires.

Table 3.1

	Wire P	Wire R
Y / GN m^{-2}	170	120

Take measurements to determine the value of k for each material.

Tabulate your results.

[4]

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(g) The force constant *k* of wire P can be found by another method.

Plan an investigation to find *k* for a fixed length of wire P in tension using the relationship

$$F = kx$$

where *F* is the applied load and *x* is the extension of the wire.

You would be provided with several masses.

You may suggest the use of any additional apparatus commonly found in a school physics laboratory.

Your answer should include a diagram and your experimental procedure.

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[Total: 22]

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4. Fig. 4.1 shows a beaker filled with water and ice cubes all at 0° C.

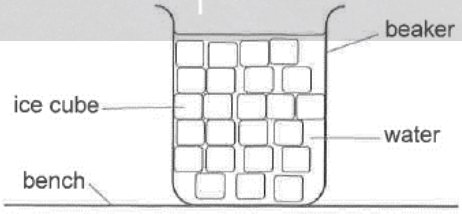

Fig. 4.1

When a constant source of heat is applied to the contents of the beaker, the ice melts.

The initial volume of each ice is the same and the number of ice cubes is n. The total mass of the contents of the beaker is m.

The time taken for the ice to melt is given by $t = k\,n^a m^b$
where k, a and b are constants.

Design an experiment to determine the values of a and b.

You are provided with trays and a freezer to produce ice cubes at 0° C.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

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

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Diagram

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[Total: 12]

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Catholic Junior College
JC2 Preliminary Examinations
Higher 2

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

PHYSICS

9749/04

Paper 4 Practical

21 Aug 2023

2 hour 30 minutes

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB or 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

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

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

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

Shift
Laboratory

For Examiner's Use	
1	/ 15
2	/ 6
3	/ 22
4	/ 12
Total	/ 55

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This paper is the 2020 A-level Paper. Please refer to the Confidential Instructions on the preparation of the apparatus

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1. In this experiment, you will investigate the current in an electrical circuit.

(a) You have been provided with two metre rules A and B, each with a resistance wire attached.

Take measurements to determine the resistance per unit length of each of the wires.

The resistance per unit length of the wire attached to rule A is R_A.
The resistance per unit length of the wire attached to rule B is R_B.

Solution:
Resistance of 100.0 cm length of wire A = 15.4 Ω
R_A = 15.4 / 100.0 = 0.154 Ω cm^{-1}

Resistance of 100.0 cm length of wire B = 26.9 Ω
R_A = 26.9 / 100.0 = 0.269 Ω cm^{-1}

R_A = ……0.154 **Ω cm^{-1}** or 15.4 **Ω m^{-1}**……..

R_B = ……0.269 **Ω cm^{-1}** or 26.9 **Ω m^{-1}**……..
[2]

(b) Set up the circuit as shown in Fig. 1.1.

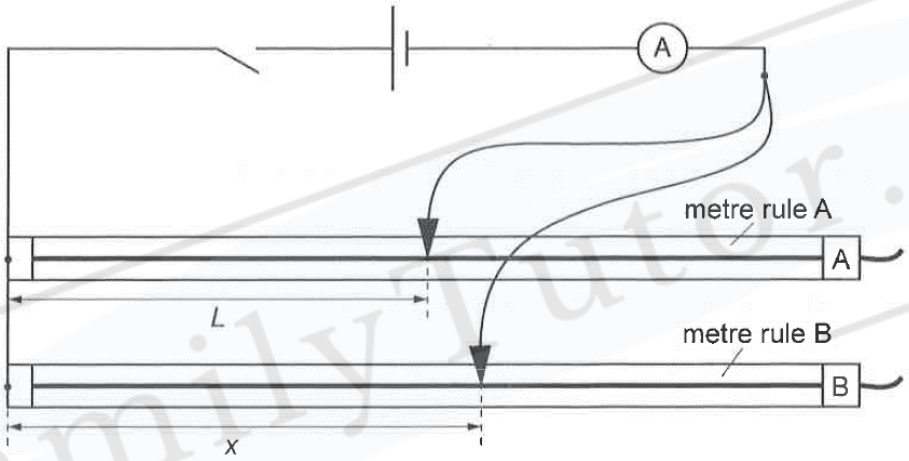

Fig. 1.1

L should be approximately half the length of the rule and *x* should be **greater** than L.

Close the switch.

Measure and record *L*, *x* and the ammeter reading *I*.

L = ……50.0 cm……..

x = ……55.0 cm……..

I = ……0.243 A……..

(c) Vary *x,* obtaining a suitable range of values between 0 cm and 100 cm, repeat **(b)**, keeping *L* constant throughout.

[Turn Over

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Solution:

x / cm	I / A	$\frac{1}{x}$ / cm^{-1}
55.0	0.243	0.0182
63.0	0.231	0.0159
70.0	0.226	0.0143
78.0	0.216	0.0128
85.0	0.212	0.0118
90.0	0.211	0.0111

[3]

(d) It is suggested that I and x are related by the expression

$$I = \frac{E}{R_A L} + \frac{E}{R_B x}$$

where E is the electromotive force (e.m.f.) of the cell.

Plot a suitable graph to determine the value of E.

Solution:

Linearised equation : $I = \left(\frac{E}{R_B}\right)\frac{1}{x} + \left(\frac{E}{R_A L}\right)$

Plot a graph of I against $\frac{1}{x}$ to obtain a straight line with gradient $\left(\frac{E}{R_B}\right)$ and vertical intercept $\left(\frac{E}{R_A L}\right)$.

$$\text{Gradient} = \frac{0.245 - 0.210}{0.0188 - 0.0112} = 4.6053 \text{ A cm}$$

Vertical-intercept = 0.245 – (4.6053)(0.0188) = 0.15842 A

$$\frac{E}{R_B} = 4.6053 \text{ A cm} \quad \therefore E = 0.269 \times 4.6053 = 1.2388 \text{ V}$$

$$\frac{E}{R_A L} = 0.15842 \text{ A} \quad \therefore E = 0.15852 \times 0.154 \times 50.0 = 1.2198 \text{ V}$$

$$\text{Therefore, average } E = \frac{1.2388 + 1.2198}{2} = 1.2293 = 1.23 \text{ V}$$

E = ……1.23…….. V [7]

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(e) Without taking further readings, sketch a line on your graph grid to show the results you would expect if the experiment was repeated with x measured on metre rule A and the same L in **1(b)** measured on metre rule B.

Label this line W. [1]

Solution:

The new equation will be : $I = \frac{E}{R_B L} + \frac{E}{R_A x}$

(Since $R_A < R_B$, new gradient > 4.6053 A cm and new vertical intercept < 0.15842 A.)

Using earlier answers,

New gradient, $\frac{E}{R_A} = \frac{1.23}{0.154} = 7.987$

New y-intercept, $\frac{E}{R_B L} = \frac{1.23}{(0.269)(50.0)} = 0.09145$

Plot Y = 7.987X + 0.09145
When X = 0.014, Y = 7.987(0.014) + 0.09145 = 0.203
When X = 0.017, Y = 7.987(0.017) + 0.09145 = 0.227

If student plotted, I against $\frac{1}{R_A L} + \frac{1}{R_B x}$, the graph should be identical to the original. They need to label the original graph W.

[Total: 15]

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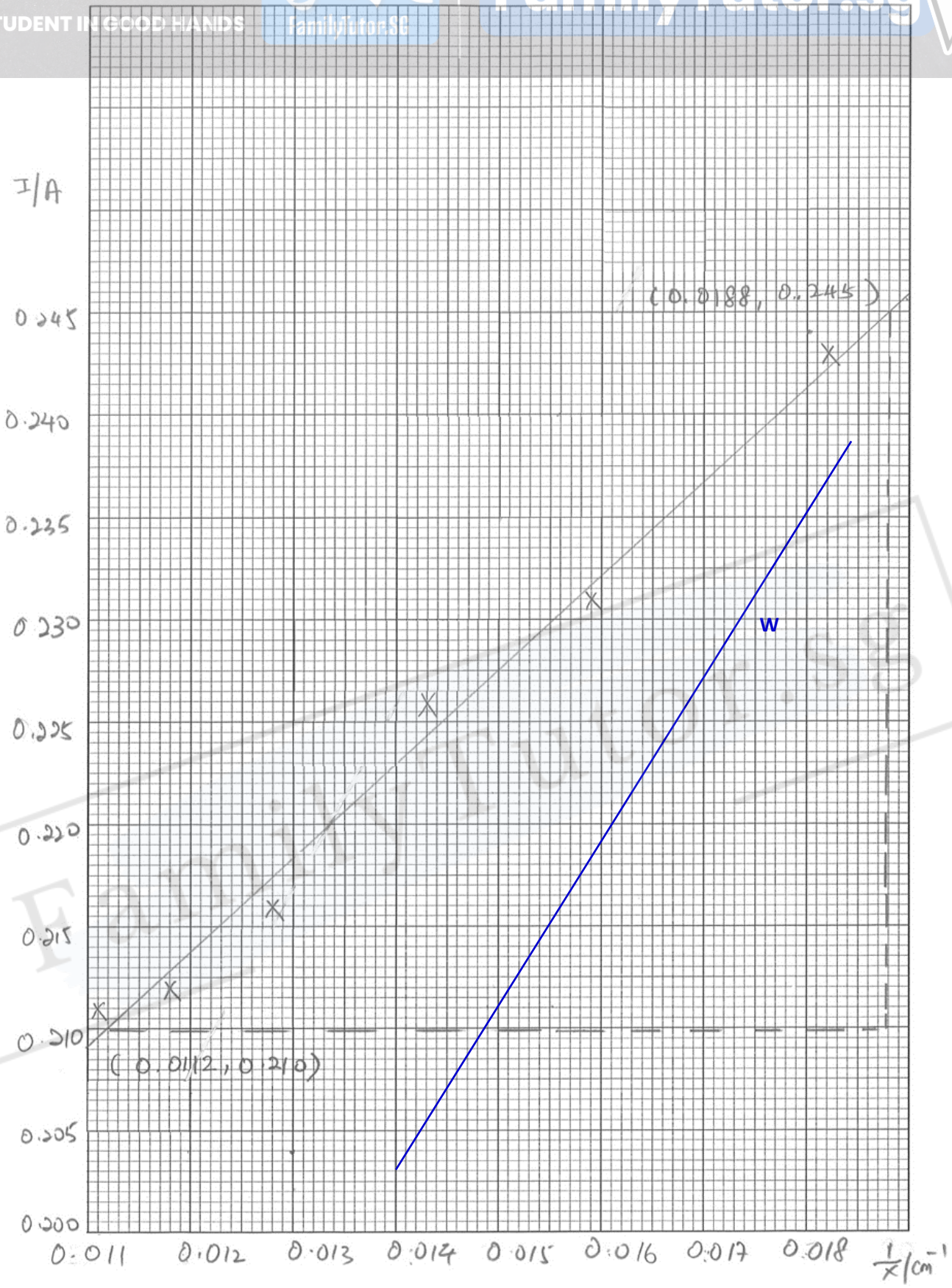

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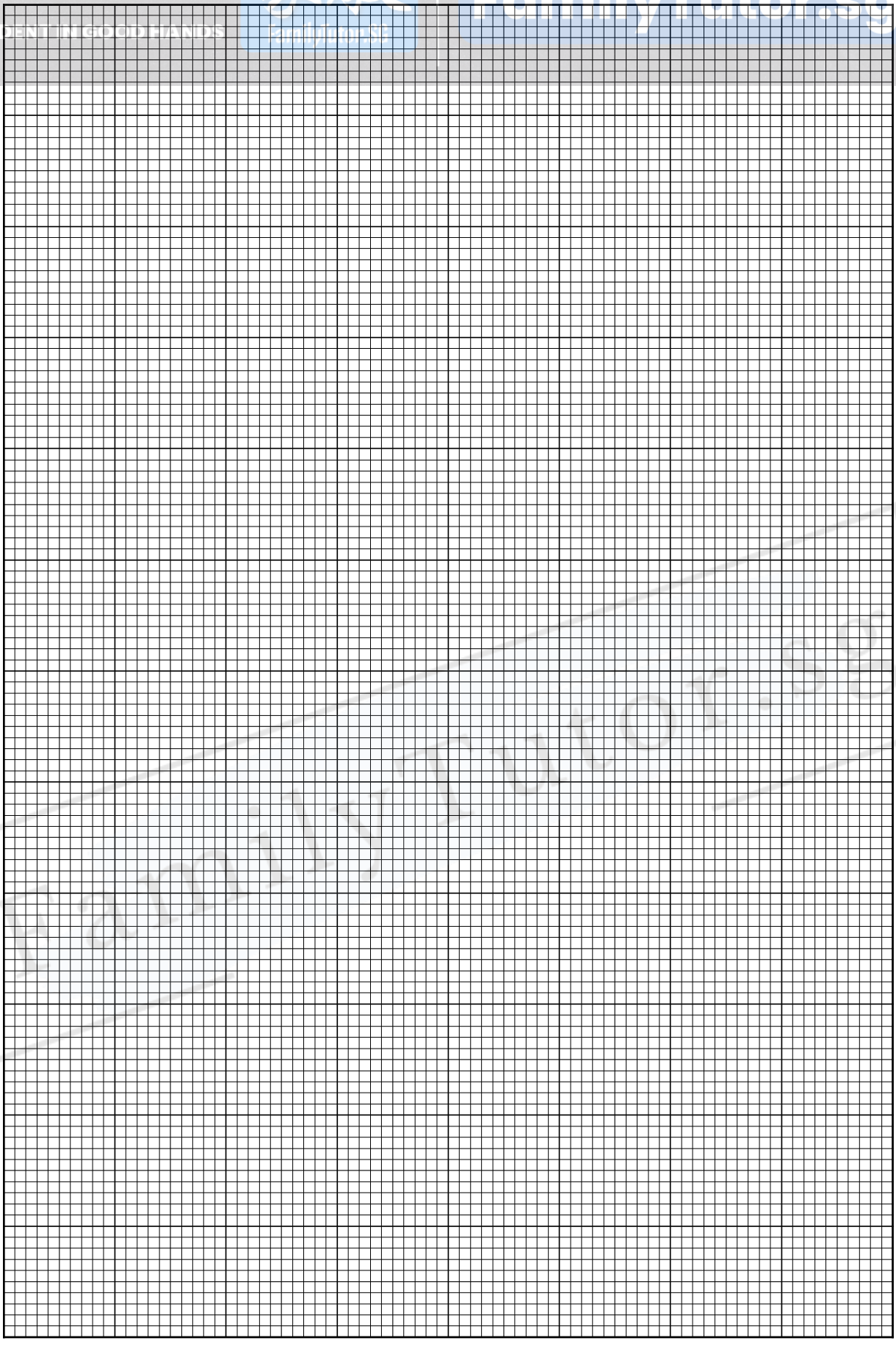

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2. In this experiment, you will investigate an oscillating system.

(a) Place the wooden strip on the pivot, as shown in Fig. 2.1.

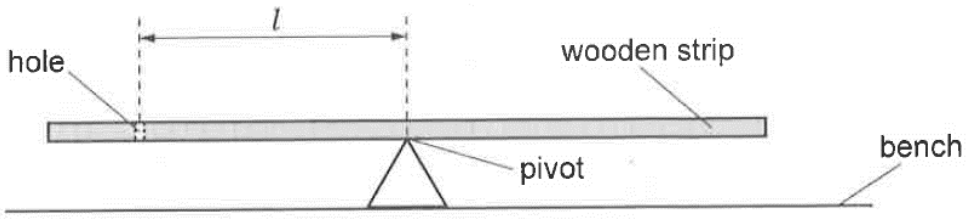

Fig. 2.1

Adjust the position of the wooden strip on the pivot until it balances. The distance between the centre of the hole in the wooden strip and the pivot is l.

Without marking on the wooden strip, measure and record l.

Solution:

$l_1 = 18.2$ cm , $l_2 = 18.1$ cm , $l_{ave} = \frac{18.2 + 18.1}{2} = 18.2$ cm

l = ……18.2 cm…… [1]

(b) Set up the apparatus as shown in Fig. 2.2.

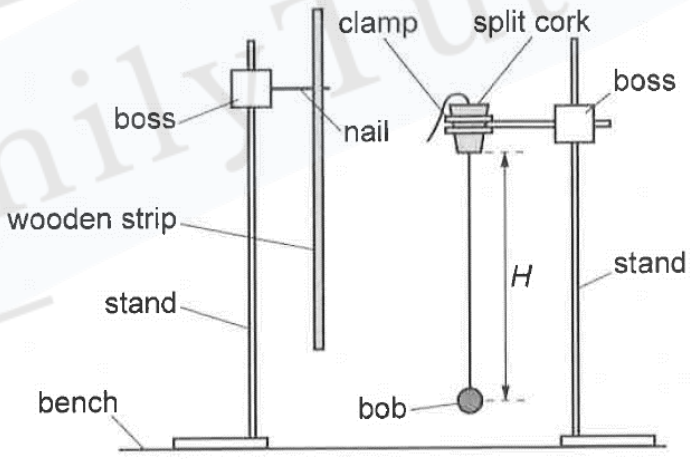

Fig. 2.2

The distance between the bottom of the split cork and the centre of the bob is H.
Adjust the string in the split cork until H is approximately 40 cm.

Displace the bob and the bottom of the wooden strip towards you through a short distance. Release the bob and the strip at the same time. The oscillations of the bob and the strip will be out of phase.

Adjust H so that the oscillations of the bob and the strip remain in phase for several cycles after release.

Measure and record H.

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Solution:

H_1 = 30.4 cm , H_2 = 30.5 cm , $H_{ave} = \frac{30.4 + 30.5}{2} = 30.5$ cm

H = ……30.5 cm…..…… [1]

(c) The quantities l and H are related by the equation

$$b = \sqrt{l(H - l)}$$

where b is a constant.

i) Calculate b.

Solution:

$b = \sqrt{18.2(30.5 - 18.2)} = 14.962$ cm $= 0.147$ m

b = ……0.147…..…….. m [2]

ii) If you were to repeat this experiment using a similar wooden strip with several holes at different positions along its length, describe the graph that you would plot to determine b.

Solution:

Linearising the above equation into: $lH = l^2 + b^2$

Plot a straight line graph of lH against l^2 where gradient is 1 and the vertical intercept is b^2.

The square root of the vertical intercept gives the value of b.

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…….... [2]

[Total: 6]

[Turn Over

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3. In this experiment, you will investigate the stiffness of some metal wires.

A long-handled broom, as shown in Fig. 3.1, must be able to support the weight of the brush at the end without collapsing. Sometimes these brooms are used vertically to reach high places such as ceilings.

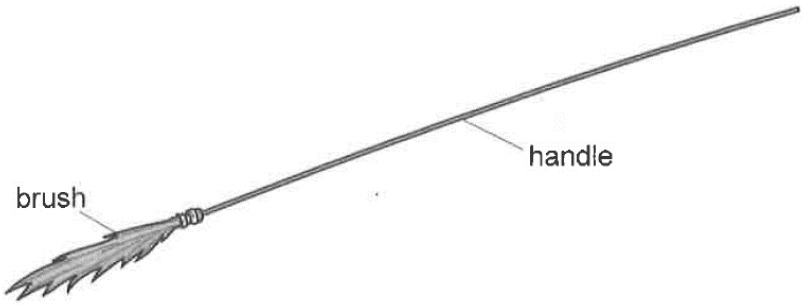

Fig. 3.1

In this experiment, you will model the broom handles using thin metal wires and investigate how the following properties of the wires affect their behaviour:

- length
- diameter
- load
- force constant.

(a) You have been provided with three wires labelled P, Q and R.

Measure and record the diameter *d* of wire P.

Solution:

No zero error (OR zero error = 0.00 mm)

d_1 = 0.45 mm , d_2 = 0.45 mm , $d_{ave} = \frac{0.45 + 0.45}{2} = 0.45$ mm

d = ……0.45 mm…….…… [1]

(b) (i) Attach the sphere of modelling clay to one end of wire P and hold the wire vertically between your thumb and first finger.
The length of wire between the centre of the sphere and the top of your thumb is *h*, as shown in Fig. 3.2.

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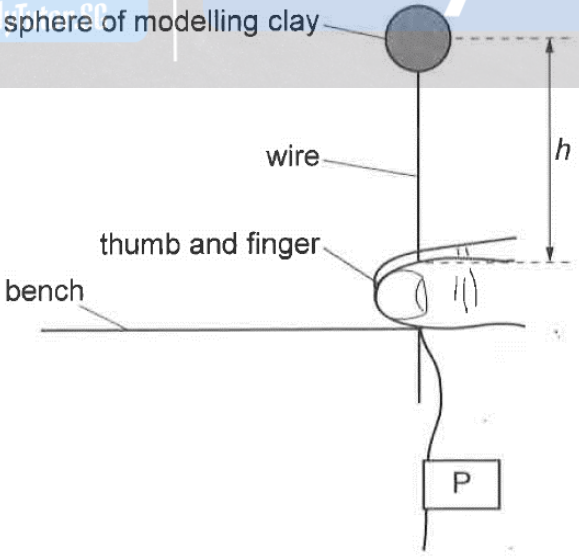

Fig. 3.2

Increase *h* until the sphere moves down and touches the bench, as shown in Fig. 3.3.

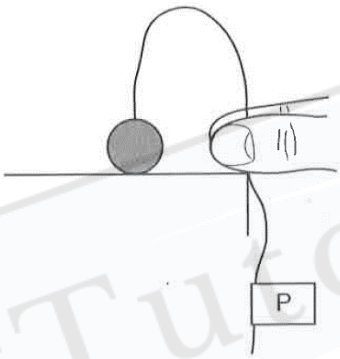

Fig. 3.3

Determine and record *h*.

Solution:

$h_1 = 10.4$ cm , $h_2 = 10.8$ mm , $h_{ave} = \frac{10.4 + 10.8}{2} = 10.6$ cm

h = ……10.6 cm…..…… [1]

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

Solution:

$\Delta h \approx 0.3$ cm

$\frac{\Delta h}{h} \times 100\% = \frac{0.3}{10.6} \times 100\% = 2.83\ \% = 3\ \%$ (1 s.f.)

Percentage uncertainty in *h* = ……3%…..…… [1]

[Turn Over

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(iii) Suggest one significant source of uncertainty in this experiment.

Solution:

1. It is difficult to determine the **centre of the sphere** and this affects accurate measurement of h.
2. The top of the thumb does provide a good reference point to measure h as it is difficult to ensure the top of the thumb is always horizontal. This affects accurate measurement of h.
3. There are kinks in the wire/ wire is not straight affecting the accurate measurement of h.

.....

.....

.....

..... [1]

(iv) Suggest an improvement that could be made to the experiment to reduce the uncertainty identified in **(b)(iii)**.

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

Solution:

1. Use Vernier caliper to mesure the diameter of the sphere of modelling clay to determine the centre of the sphere so that h can be measured accurately.
2. Clamp the wire using split wood to hold the wire instead of using the thumb. The top of the split wood will ensure a clear reference point for accurate measurement of h.
3. Straighten the wire with a pliers or use a new straight wire

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.....

..... [1]

(c) Wire Q is made from the same material as wire P, but has a different diameter.

Repeat **(a)** and **(b)(i)** for wire Q.

Solution:

d_1 = 0.36 mm , d_2 = 0.36 mm , $d_{ave} = \frac{0.36 + 0.36}{2} = 0.36$ mm

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$h_1 = 6.5$ cm , $h_2 = 6.7$ mm , $h_{ave} = \frac{6.5 + 6.7}{2} = 6.6$ cm

d = ……0.36 mm……

h = ……6.6 cm……

[3]

(d) It is suggested that

$$h = c\,d^2$$

where c is a constant.

(i) Use your values from **(a)**, **(b)(i)** and **(c)** to determine two values of c.

Give your values for c to an appropriate number of significant figures.

Solution:

Rearranging, $c = \frac{h}{d^2}$

$$c_1 = \frac{10.6}{\left(0.45 \times 10^{-1}\right)^2} = 5234.56 = 5200\, cm^{-1}$$

$$c_2 = \frac{6.6}{\left(0.36 \times 10^{-1}\right)^2} = 5092.59 = 5100\ cm^{-1}$$

first value for c = ……5200 cm^{-1}……

second value for c = ……5100 cm^{-1}……

[1]

(ii) Justify the number of significant figures given to your values for c.

Solution:

The number of significant figures of c is given to the **least s.f. (2 sf)** of h or d.

……

……

……

…… [1]

(iii) State whether the results of your experiment support the suggested relationship. Justify your conclusion by referring to your answer in **(b)(ii)**.

Solution:

Percentage difference $= \frac{5200 - 5100}{5100} \times 100\,\% = 2\%$

……

[Turn Over

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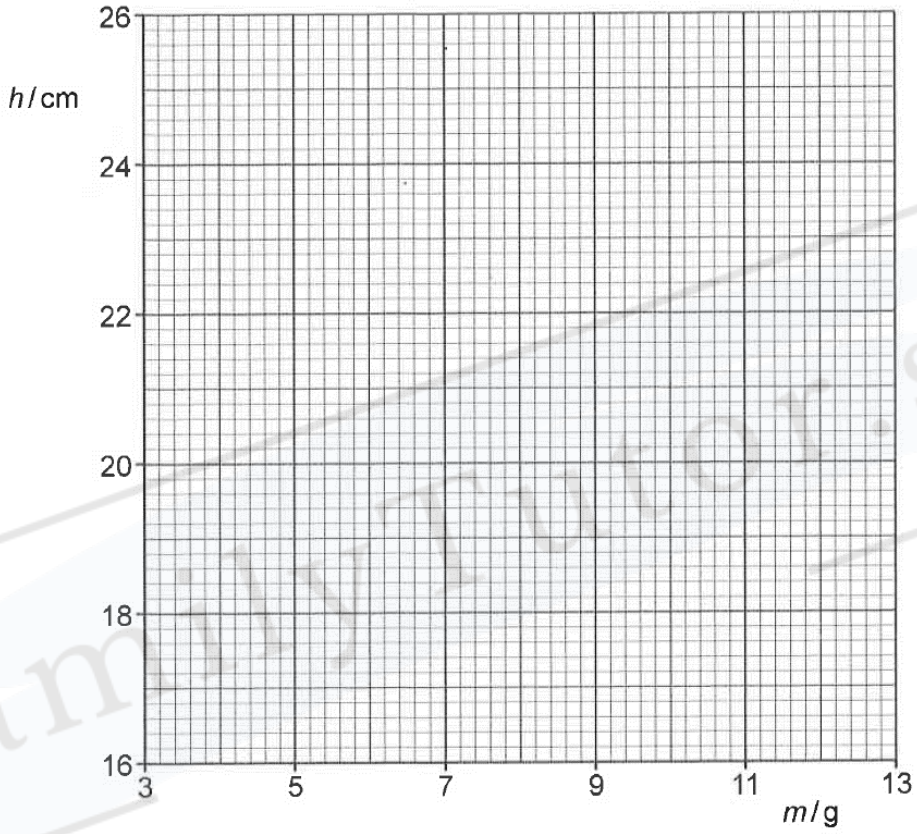
..... [1]

(e) In an investigation, the mass *m* of the sphere attached to the end of a wire was varied.

The following results for *m* and *h* were recorded.

m /g	4.4	6.1	8.1	9.9	11.8
h / cm	25.6	24.1	21.5	19.8	17.8

(i) Plot *h* against *m* on the grid and draw the straight line of best fit. [1]



Solution:

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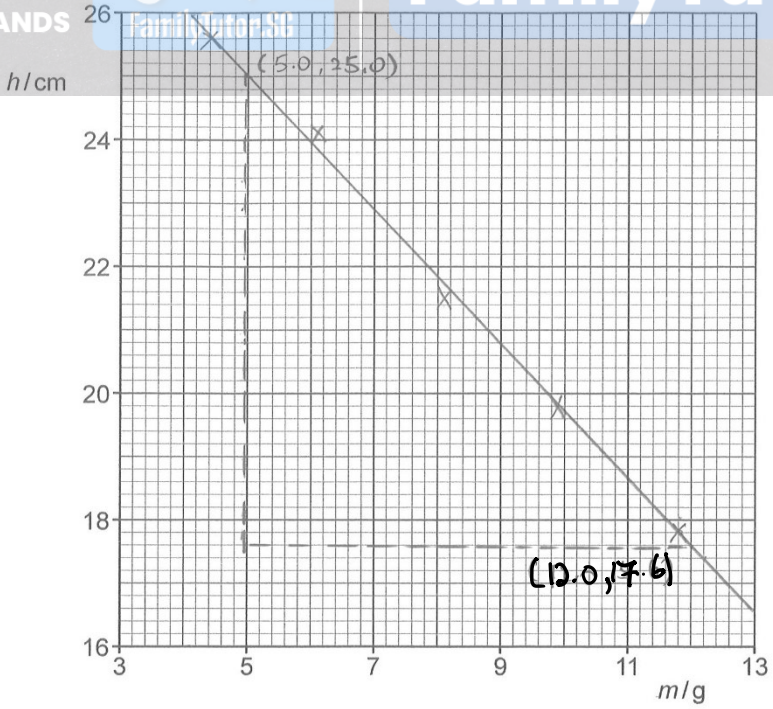

(ii) Use your graph to determine the value *h* when no sphere is attached to the wire.

Solution:

$$\text{Gradient} = \frac{25.0 - 17.6}{5.0 - 12.0} = -1.0571 \text{ cm g}^{-1}$$

Vertical intercept = 25.0 – (-1.0571)(5.0) = 30.3 cm

When no sphere is attached to the wire, h = vertical intercept = 30.3 cm

h = ……30.3…..…… cm [3]

(f) The force constant *k* for a wire in tension is defined as

$$k = \frac{YA}{h}$$

where *Y* is the stiffness of the material of the wire and the cross-sectional area *A* of the wire is given by $A = \frac{\pi d^2}{4}$.

Wires P and R are made from different materials but have the **same** diameter.

Table 3.1 shows the values of *Y* for the two wires.

Table 3.1

	Wire P	Wire R
Y / GN m^{-2}	170	120

[Turn Over

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Take measurements to determine the value of k for each material.

Tabulate your results.

Solution:

	Wire P	**Wire R**
d_{ave} / mm	0.45	0.45
h_1 / mm	10.4	7.8
h_2 / mm	10.8	7.7
h_{ave} / mm	10.6	7.8
A / m^2	$\frac{\pi x\left(0.45\times10^{-3}\right)^2}{4}$ = 1.5904 x 10^{-7}	$\frac{\pi x\left(0.45\times10^{-3}\right)^2}{4}$ = 1.5904 x 10^{-7}
k / N m^{-1}	$\frac{\left(170\times10^{9}\right)\left(1.5904\times10^{-7}\right)}{10.6\times10^{-2}}$ = 2.55 x 10^5	$\frac{\left(120\times10^{9}\right)\left(1.5904\times10^{-7}\right)}{7.8\times10^{-2}}$ = 2.45 x 10^5

[4]

(g) The force constant k of wire P can be found by another method.

Plan an investigation to find k for a fixed length of wire P in tension using the relationship

$$F = kx$$

where F is the applied load and x is the extension of the wire.

You would be provided with several masses.

You may suggest the use of any additional apparatus commonly found in a school physics laboratory.

Your answer should include a diagram and your experimental procedure.

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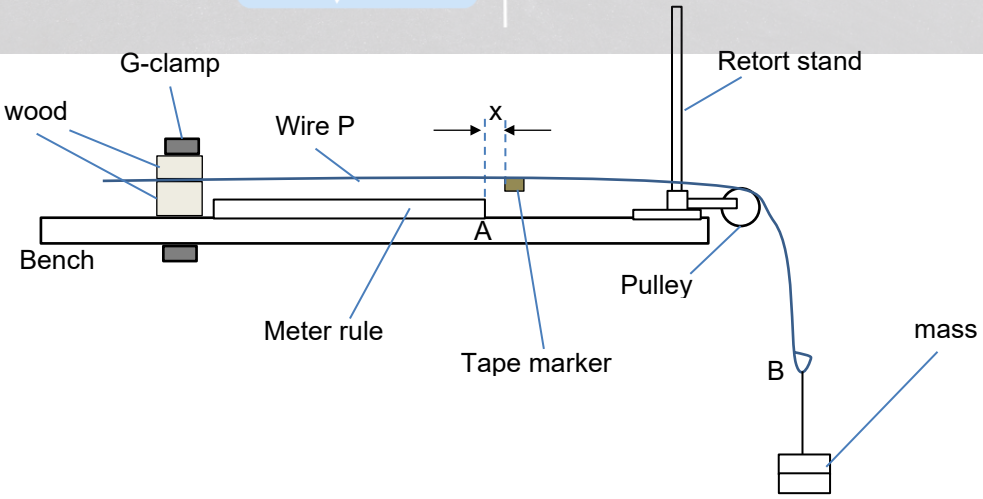

1. Set up the above without the mass.
2. The tape marker is directly above position A as shown in the diagram when there is no mass attached to wire at B.
3. Add mass at the end of the wire at B to extend the wire. When the wire is extended, the tape marker will move to the right of position A.
4. Record the mass m and calculate F = mg.
5. Measure and record the extension x between position A and the tape marker using a vernier caliper/ metre rule.
6. Repeat Step 3 and 5 to obtain 6 sets of readings.
7. Plot a graph of F against x to obtain a straight line of best-fit, where k is the gradient.

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.....[3]

[Total: 22]

[Turn Over

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4. Fig. 4.1 shows a beaker filled with water and ice cubes all at 0° C.

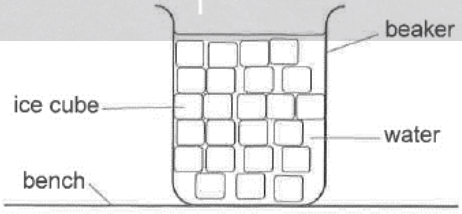

Fig. 4.1

When a constant source of heat is applied to the contents of the beaker, the ice melts.

The initial volume of each ice is the same and the number of ice cubes is *n*. The total mass of the contents of the beaker is *m*.

The time taken for the ice to melt is given by $t = k\,n^a m^b$
where *k*, *a* and *b* are constants.

Design an experiment to determine the values of *a* and *b*.

You are provided with trays and a freezer to produce ice cubes at 0° C.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

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

Diagram

……

……

……

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[Turn Over

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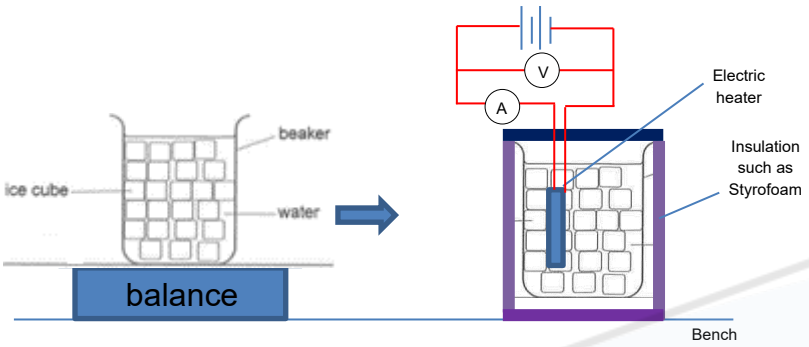
.....[12]

[Total: 12]

Solution:

Solution:
There are two parts of the experiment and two straight line graphs drawn to determine *a* and *b*.

Diagram:



1st part: Keeping the number of ice cube *n* constant, varying the mass *m*
Independent variable (IV): mass *m* of ice and water
Dependent variable (DV): time *t* for ice to melt completely
Controlled variables (CV): number of ice cubes *n*, rate of heat transfer to the beaker contents (heating source); rate of heat gain from surroundings.

Procedure:

1. Make about 20 ice cubes at 0 ˚C using the tray and freezer provided.
2. Measure the mass of a beaker that can hold about 20 ice cubes using a weighing balance. Record as M_i. Then, place the 20 ice cubes into the beaker.
3. Add as much water into the beaker such that all ice cubes float. Measure the total mass of the beaker with its contents using the weighing balance. Record as M_f. Calculate $m = M_f - M_i$.
4. Place an electric heater into the beaker with ice and water. Set a constant heat by controlling the power supply to the heater. Use a voltmeter and ammeter to verify that the power supplied to the heater is constant.
5. Place the beaker in a styrofoam insulation and cover the beaker with a thick glass lid .
6. Start the stopwatch when the power supply is switched on. When all ice cube is observed to have melted, stop the stopwatch and record the time *t* it takes for all ice to melt.
7. Repeat step 1 to 5 using similar 20 ice cubes while varying the amount of water added in step 3 for at least 6 sets of readings. In each repeated experiment, the water added must be enough to make all ice cubes float.
8. Plot a graph of lg *t* against lg *m* and obtain a straight line of best fit.
9. Calculate the gradient of the graph. The gradient of the graph gives the value of *b*.

2nd part: Keeping mass *m* constant, vary number of cube *n*
IV : *n*
DV: *t*

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CV: *m* ; rate of heat transfer to the beaker contents (heating source); rate of heat gain from the surroundings.

Procedure:

10. Repeat step 1 to step 5 of the experiment as described in part 1, but with different number of *n*, reduce from 20, for at least 6 sets of readings.
11. At different *n*, add water in step 3 above such that each repeated experiment has the same mass *m* as measured from the weighing balance.
12. Plot a graph of lg *t* against lg *n* and obtain a straight line of best fit.
13. Calculate the gradient of the graph. The gradient of the graph gives the value if *a*.

Additional Details:

- Any acceptable details to improve precision and accuracy of results.

Safety:

- Any relevant safety measure.

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DUNMAN HIGH SCHOOL
2023 H2 PHYSICS (YEAR 6)

Answers to Prelim Exam H2 Physics Paper 1

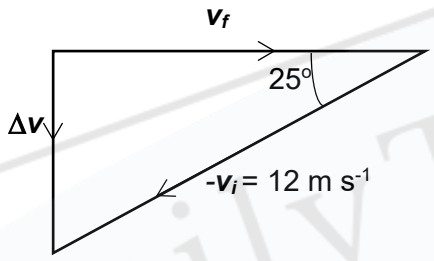
1	2	3	4	5	6	7	8	9	10
A	B	B	D	A	B	C	C	D	C
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
A	C	D	B	D	D	B	A	B	B
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
D	C	A	D	C	C	A	A	B	D

1 A

energy = power x time
= $3.0 \times 10^{9} \times 2.0 \times 10^{-12}$
= 6.0×10^{-3} J
= 6.0×10^{-15} TJ

2 B

Recall: $\Delta \boldsymbol{v} = \boldsymbol{v_f} - \boldsymbol{v_i}$



The horizontal component of $\boldsymbol{v_i} = \boldsymbol{v_f}$ since there's no horizontal acceleration, so $\Delta \boldsymbol{v}$ is vertical.

$\Delta \boldsymbol{v}$ = 12 sin 25° = 5.1 m s^{-1}

3 B

Before time instant B, the cars are moving towards each other. After time instant B, they are moving away from each other.

4 D

Kinetic energy is conserved only if the collision is elastic.

Hence, only momentum and total energy is conserved as there are no net external forces acting on the system when the two objects collide.

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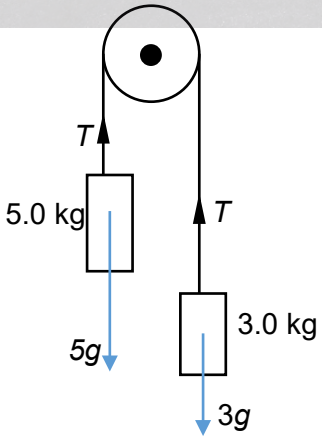
5 A



By considering the free body diagrams of the 5.0 kg and 3.0 kg masses:

$5g - T = 5a$

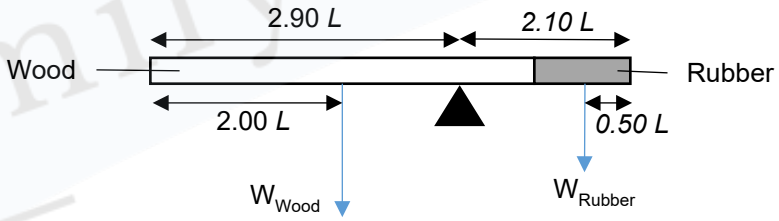
$T - 3g = 3a$

$\therefore 2g = 8a$

$a = \frac{1}{4}g$

$= 2.5 \text{ m s}^{-1}$ (to 2 s.f.)

6 B



Taking moments about the pivot,

$$W_{wood}(0.900L) = W_{rubber}(1.60L)$$

$$[\rho_{wood}(4.00L)(A)g](0.900L) = [\rho_{rubber}(L)(A)g](1.60L)$$

$$\rho_{wood}(4.00)(0.900) = \rho_{rubber}(1.60)$$

$$\frac{\rho_{rubber}}{\rho_{wood}} = \frac{4.00(0.900)}{1.60}$$

$$= 2.25$$

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7 C

$\Delta p = hpg = (0.50)(1000)(9.81) = 4910$ Pa

8 C

The work done by the driving force *F* was used to increase the car's kinetic energy as it gains speed from *u* to *v*. Hence the useful work done by the force *F* is equals to the increase in KE of the car.

9 D

$D = kv^2$,where *k* is a constant of proportionality

At 12 m s^{-1}, the driving force provided by the 2 engines is equal and opposite to the total drag.

$$P = Dv$$
$$36000 \times 2 = k(12)^3$$
$$k = \frac{720000}{(12)^3}$$

If only 1 engine is on, the new maximum speed *v*' can be found by:

$$360000 = \frac{720000}{(12)^3}(v')^3$$
$$v' = \sqrt[3]{\frac{360000}{720000}(12^3)}$$
$$= \frac{12}{\sqrt[3]{2}} = 9.5 \text{ m s}^{-1}$$

10 A

At Q, $N + mg = \frac{mv^2}{r}$

As the bead is just in contact with the wire, $N = 0$. Thus, $v^2 = rg = 0.20g$

Using conservation of energy,

$$mgh = \frac{1}{2}mv^2 + mg(0.40)$$
$$mgh = \frac{1}{2}m(0.20g) + mg(0.40)$$
$$h = 0.50 \text{ m}$$

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11 A

period of rotation = 365 days

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{(365 \times 24 \times 60 \times 60)} = 1.99 \times 10^{-7} \text{ rad s}^{-1}$$

$$v = r\omega = (1.50 \times 10^{11})(1.99 \times 10^{-7}) = 2.99 \times 10^{4} \text{ m s}^{-1}$$

12 C

Gravitational field strength $g = \frac{GM}{r^2}$ (vector)

Due to different masses of the Earth and Moon, the field strength due to the Earth (points to the left) is larger than the field strength due to the Moon (points to the right). Hence the resultant field strength is not zero and points towards the Earth. A and B are wrong.

Gravitational potential $\phi = -\frac{GM}{r}$ (scalar)

Due to different masses of the Earth and Moon, the potential does not add to zero at point P. That would eliminate D.

13 D

Heat gain by A = heat loss by water

$m_A\, c_A\, (1) = m_w\, c_w\, (4)$

Heat gain by B = heat loss by water

$m_B\, c_B\, (2) = m_w\, c_w\, (3)$

Hence, $c_A = 2.7\, c_B$

14 B

Internal energy of a system is the sum of all the kinetic energy and potential energy of all the atoms of the system.

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15 D

$$pV = nRT$$

$$p = \frac{nRT}{V}$$

$$= \frac{mRT}{M_R V}$$

$$= \frac{(1.5)(8.31)(273.15+25)}{\left(\frac{20}{1000}\right)(3.7)}$$

$$= 50222 \text{ Pa} = 50 \text{ kPa}$$

16 D

energy of oscillator $\propto (\text{amplitude})^2$

fraction of initial energy remained in the first 4.0 s, $f = \left(\frac{1.25}{5.00}\right)^2 = \frac{1}{16}$

fraction of initial energy lost in the first 4.0 s $= 1 - f = \frac{15}{16}$

17 B

Initially, the angle between the polarising filters is 90°.

After rotating 30°, the angle between them is 60°.

Using Malu's law,

$$I = I_o \cos^2 60°$$

$$\frac{I}{I_o} = \frac{1}{4}$$

Since intensity is proportional to square of amplitude,

$$\frac{A'}{A} = \sqrt{\frac{I}{I_o}} = \frac{1}{2}$$

18 A

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Standing wave on a rope has nodes at both ends.

$$L = n\frac{\lambda}{2} = 1.0$$

For wavelength 0.4 m, this corresponds to the 5th harmonic (n = 5) mode, thus A is correct.

B is wrong as there are 6 nodes for the 5th harmonic.

C is wrong as the fundamental wavelength is 2 m.

D is wrong as the midpoint of the rope may be moving (e.g. for fundamental mode, the midpoint is the antinode.

19 B

Diffraction is the most pronounced when the size of the opening is comparable to the size of the wavelength. Option B is correct because halving the frequency means doubling the wavelength to 1.0 m which is the size of the doorway.

20 B

$V = \frac{Q}{4\pi\varepsilon_0 r}$ and $E = \frac{Q}{4\pi\varepsilon_0 r^2}$, therefore, $E = \frac{V}{r}$

21 D

Option C is incorrect since the current is the same in both sections.

Since $R = \frac{\rho l}{A} \Rightarrow \frac{R}{l} = \frac{\rho}{A} \Rightarrow \frac{R}{l} \propto \frac{1}{A}$ (ρ is constant for same material), resistance per unit length of the narrow section is twice that of wide section since the constant current flows through the narrow section.

Since $V \propto R$ for constant I, the resistor with the larger resistance has a larger p.d. across it. Hence, the narrow section (with larger resistance per unit length), has larger p.d. per unit length across it. Hence options A and B are wrong.

22 C

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Effective resistance of the 3 parallel resistors,

$$R_{\text{eff}} = \left(\frac{1}{1.0} + \frac{1}{2.0} + \frac{1}{5.0}\right)^{-1} = 0.588\,\Omega$$

Potential difference across each resistor, $V = IR_{\text{eff}} = (5.0)(0.588) = 2.94$ V

Current through 2.0 Ω resistor, $I_2 = V/R = 2.94/2.0 = 1.47 \approx 1.5$ A

23 A

The bulb with the largest current flowing through it will brightest as power = I^2R. Hence bulb P is the brightest.

24 D

The direction of the force is given by Fleming's left-hand rule. The direction of the force is 90° to the plane containing the magnetic field and the current.

25 C

Before the rod lands on the slope, it is traveling in the direction of the Earth's magnetic field. There is zero change in magnetic flux linking the rod. As the rod lands and rolls down the slope, the rate of change of magnetic flux increases uniformly. The magnetic flux changes constantly after it rolls off the slope.

26 C

$$\langle P \rangle = \frac{1}{2} I_0^2 R = P$$

$$\langle P \rangle = \frac{1}{2} [(I_0)_{\text{new}}]^2 (2R) = 4P$$

$$\rightarrow (I_0)_{\text{new}} = \sqrt{2}\, I_0, \quad I_{rms} = \frac{1}{\sqrt{2}} (I_0)_{\text{new}} = I_0$$

27 A

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$p = \frac{h}{\lambda}$, momentum of photon is independent of the intensity of light.

28 A

As a result of wave-particle duality, we cannot simultaneously know both the position and momentum of a particle, such as a photon or electron, with perfect precision.

29 B

By conservation of charge and mass number, X = 2.

No. of hydrogen nuclei = $0.001 / (1.008 \times 1.66 \times 10^{-27}) = 5.98 \times 10^{23}$

Energy released, in MeV, in 1 reaction = $1.6 \times 10^{12} / (5.98 \times 10^{23} \times 1.6 \times 10^{-13})$
= 16.73 MeV

Total $BE_{He-4} - BE_{Li-7}$ = energy released, 16.73 MeV (note BE of H-1 is 0, as it is only 1 proton by itself)

$2 \times 28.3 - BE_{Li-7} = 16.73$

BE_{Li-7} = 39.9 MeV

30 D

$$\frac{\text{number of atoms of X}}{\text{number of atoms of Y}} = \frac{(\frac{1}{2})^{\frac{3T}{T}}(N_0)_x}{(\frac{7}{8})(N_0)_x} = \frac{1}{7}$$

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TEST QUESTIONS AND ANSWER KEYS

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Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS

9749/01

Paper 1 Multiple Choice

25 September 2023
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

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

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

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

This document consists of **14** printed pages and **0** blank page.

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Data

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

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	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	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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1 A power station generates power at 3.0 GW.

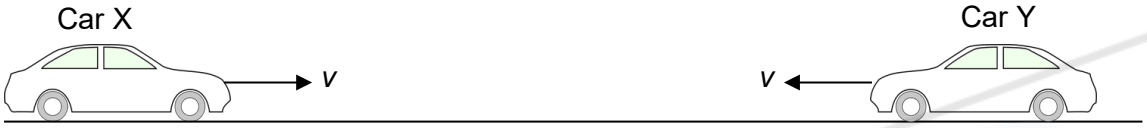
What is the energy produced in a time interval of 2.0 ps?

A 6.0×10^{-15} TJ **B** 6.0×10^{-6} MJ **C** 6.0×10^{3} nJ **D** 6.0×10^{6} μJ

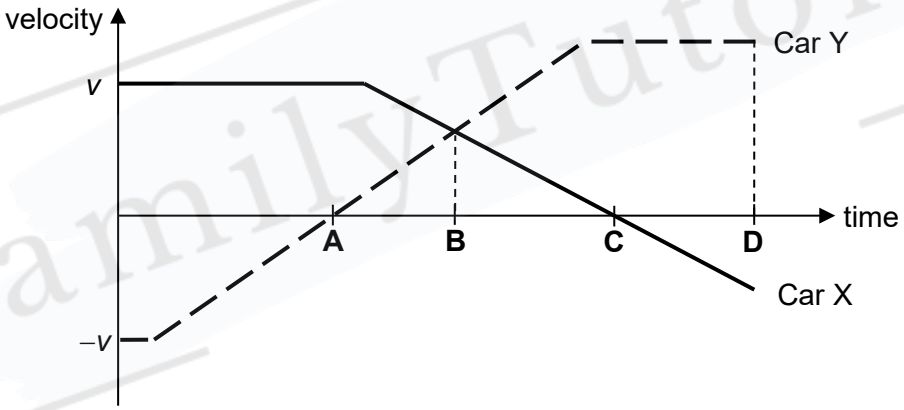
2 A stone is thrown with a velocity of 12 m s^{-1} at an angle of 25° above the horizontal. What is the magnitude of the change in velocity from its starting point to the highest point in its path?

A 1.1 m s^{-1} **B** 5.1 m s^{-1} **C** 5.8 m s^{-1} **D** 12 m s^{-1}

3 Car X and Car Y are at a distance apart and they move towards each other with the same initial speed *v*.



The graph shows the variation of velocity of the cars with time.



At which time are the cars at their distance of closest approach?

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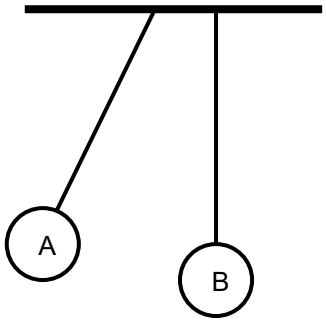
4 Two steel bobs A and B are suspended on strings. Bob A is displaced leftwards as shown. After bob A is released, the bobs collide.



Which quantities must be conserved in the collision?

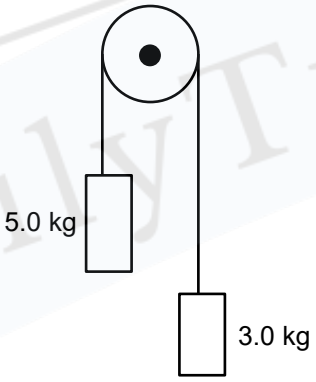
A momentum, kinetic energy, and total energy.

B kinetic energy and total energy only.

C momentum and kinetic energy only.

D momentum and total energy only.

5 The pulley in the diagram below is frictionless.



What is the magnitude of the acceleration of the system, assuming that air resistance is negligible?

A 2.5 m s^{-2} **B** 3.7 m s^{-2} **C** 6.3 m s^{-2} **D** 9.8 m s^{-2}

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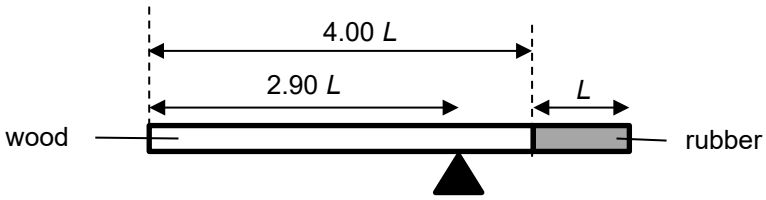
6 A uniform rod has a wooden section and a solid rubber handle as shown.

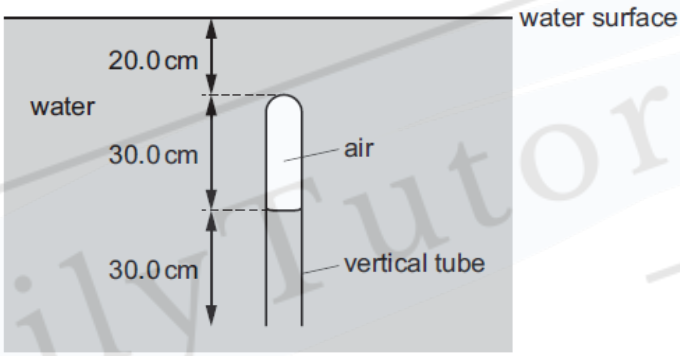


The length of the handle is L, and the length of the wooden section is 4.00 L. The rod balances at 2.90 L from the wooden end.

What is the ratio $\frac{\text{density of rubber}}{\text{density of wood}}$?

A 1.71 **B** 2.25 **C** 2.50 **D** 3.27

7 A vertical tube, closed at one end, is immersed in water. A column of air is trapped inside the tube as shown.



The density of water is 1000 kg m^{-3}.

What is the difference between the pressure of the air in the tube and the atmospheric pressure?

A 1960 Pa **B** 2940 Pa **C** 4910 Pa **D** 7850 Pa

8 The driving force F of a car of mass m causes the car to accelerate. During a time interval of t, it travelled a distance of s and its speed increases from u to v.

What is the useful work done by the car's engine?

A Fs **B** $\frac{Fs}{t}$ **C** $\frac{m(v^2-u^2)}{2}$ **D** $m(v-u)$

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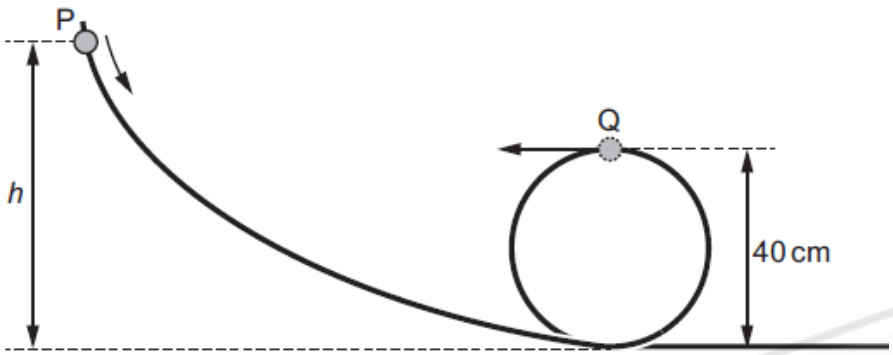
9 A speed boat with two engines, each of power output of 36 kW, can travel at a maximum speed of 12 m s^{-1}. The total drag force D on the boat is related to the speed v of the boat by the following equation:

$$D \propto v^2$$

What is the maximum speed of the boat when only one engine is working?

A 3.0 m s^{-1} **B** 6.0 m s^{-1} **C** 8.5 m s^{-1} **D** 9.5 m s^{-1}

10 A bead is released from rest at point P and slides along a wire, as shown.



not to scale

The wire loops around and forms a vertical circle of diameter 40 cm. At point Q, the bead is just in contact with the wire. Air resistance and friction on the wire are negligible.

What is the height h from which the bead is released?

A 0.30 m **B** 0.40 m **C** 0.50 m **D** 0.60 m

11 What is the mean speed and the mean angular velocity of the Earth in its orbit around the Sun?

The mean radius of the orbit is 1.50 x 10^{11} m.

	speed / m s^{-1}	angular velocity / rad s^{-1}
A	2.99 x 10^{4}	1.99 x 10^{-7}
B	2.99 x 10^{4}	7.27 x 10^{-5}
C	1.09 x 10^{7}	7.27 x 10^{-5}
D	1.09 x 10^{7}	1.99 x 10^{-7}

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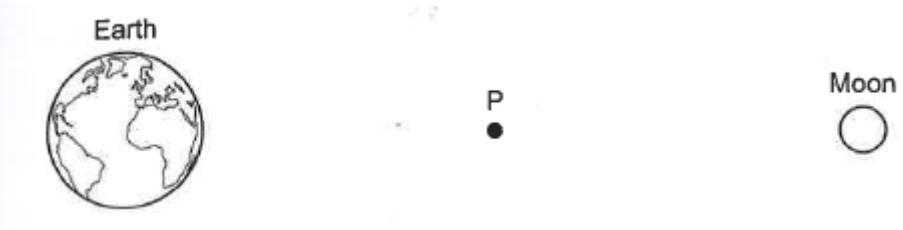
12 The diagram shows a point P midway between the centre of the Earth and the centre of the Moon.



Which statement is true at point P?

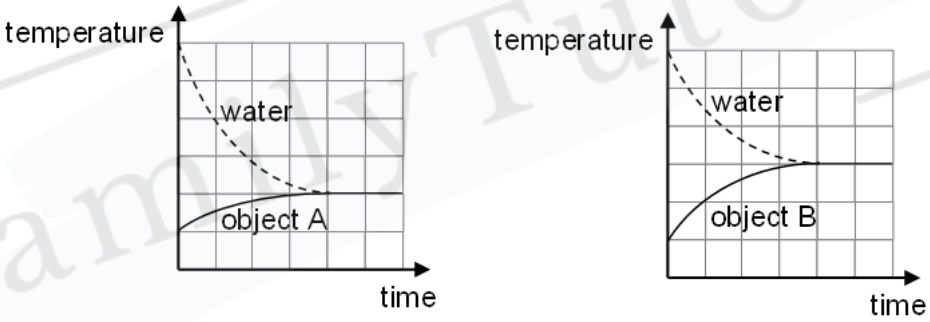
A The gravitational field points towards the Moon.

B The gravitational field strength is zero.

C The gravitational potential is negative.

D The gravitational potential is zero.

13 Object A is dropped into a thermally insulated container of water and allowed to come to thermal equilibrium with the water. The experiment is repeated with a different object B. The mass and initial temperature of water are the same in the two experiments. The mass and initial temperature of objects A and B are also the same. The following graphs show the variation with time of the temperature of the objects and the water.



If c_A and c_B are the specific heat capacities of object A and object B respectively, what is the ratio of $\frac{c_A}{c_B}$?

A 0.38 **B** 1.5 **C** 2.0 **D** 2.7

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14 What is the internal energy of a system?

A The total kinetic energy of the system.

B The energy of the atoms of the system.

C The total potential energy of the system.

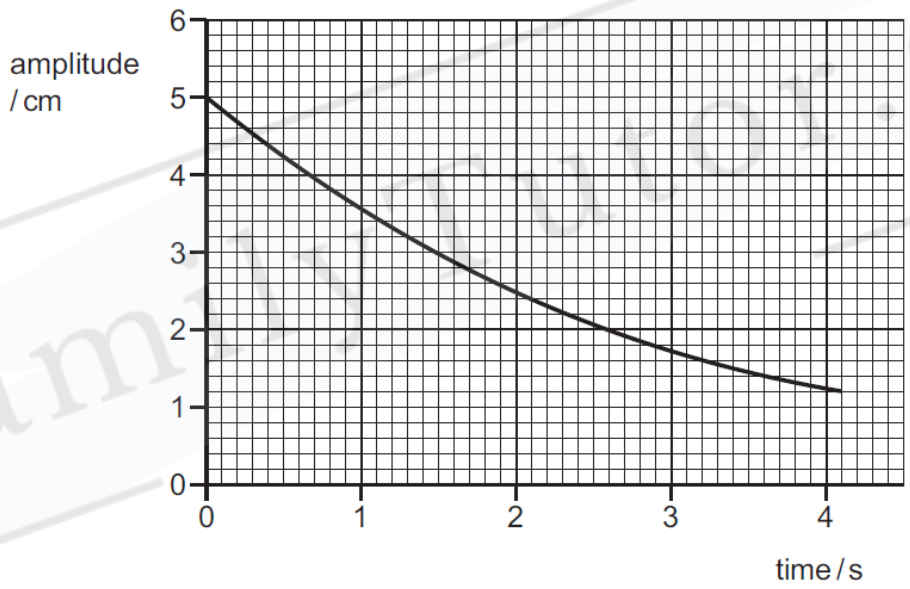
D The amount of heat supplied to the system.

15 An ideal gas has a volume of 3.7 m^3 and contains 1.5 kg of neon-20 atoms. Its temperature is 25 °C.

What is the pressure of the gas?

A 4.2 Pa **B** 50 Pa **C** 4.2 kPa **D** 50 kPa

16 The graph shows how the amplitude of a simple pendulum decays with time from an initial amplitude of 5.0 cm.



What is the fraction of the initial energy that has been lost in the first 4.0 s?

A $\frac{1}{16}$ **B** $\frac{1}{4}$ **C** $\frac{3}{4}$ **D** $\frac{15}{16}$

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17 Plane polarised light of amplitude A is incident on a polarising filter aligned so that no light is transmitted. The filter is now rotated through an angle of 30°.

What is the amplitude of the transmitted light?

A $0.25A$ **B** $0.50A$ **C** $0.75A$ **D** $0.87A$

18 A standing wave is set up on a rope of length 1.0 m fixed at both ends.

Which statement is correct?

A A harmonic of wavelength 0.40 m may be set up on the rope.

B There are five nodes on the rope for the 5^{th} harmonic.

C The fundamental mode has a wavelength of 1.0 m.

D The midpoint of the rope is always stationary.

19 A sound wave of wavelength 0.50 m passes through a doorway of width 1.0 m.

Which change increases the amount of diffraction that takes place?

A Double the amplitude of the sound wave.

B Halve the frequency of the sound wave.

C Halve the period of the sound wave.

D Double the width of the doorway.

20 The electric potential at point P a distance r from a point charge is V.

What is the electric field strength at P?

A $\frac{V}{r^2}$ **B** $\frac{V}{r}$ **C** Vr **D** Vr^2

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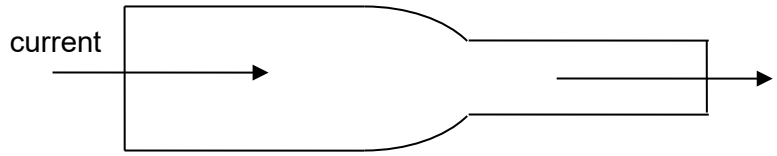
21 The figure shows the top view of a metal strip of uniform thickness. The width of the narrow section is half the width of the wide section.



Which statement is correct?

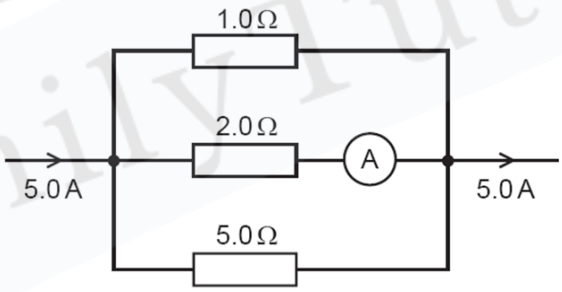
A The potential difference per unit length of the narrow section is the same as the potential difference per unit length of the wide section.

B The potential difference per unit length of the narrow section is smaller than the potential difference per unit length of the wide section.

C The resistance of the narrow section will be smaller and hence more current will flow through as compared to the wide section.

D The resistance per unit length of the narrow section is twice that of the wide section.

22 The diagram shows part of a current-carrying circuit. The ammeter has negligible resistance.



What is the reading on the ammeter?

A 0.70 A **B** 1.3 A **C** 1.5 A **D** 1.7 A

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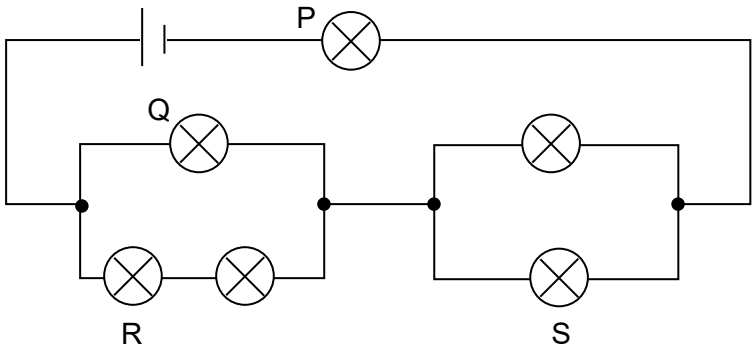
23 Six identical light bulbs are connected as shown.

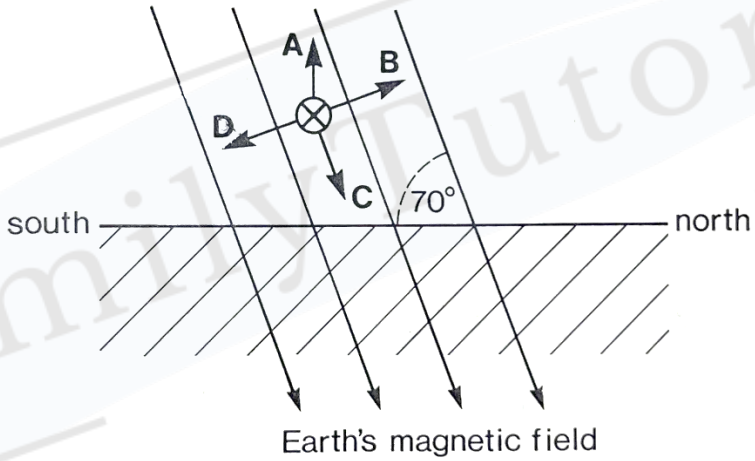


Which bulb is the brightest?

A P **B** Q **C** R **D** S

24 A horizontal power cable carries a steady current in an east-to-west direction, i.e. into the plane of the diagram.

Which arrow shows the direction of the force on the cable caused by the Earth's magnetic field, in a region where this field is at 70° to the horizontal?



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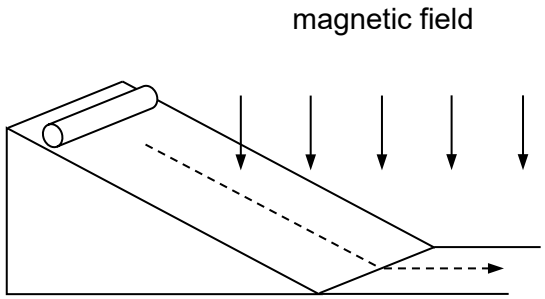
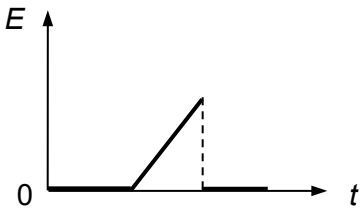
25 In a region of uniform magnetic field directed vertically downwards, a metal rod falls vertically from rest and lands on to a slope. It continues to roll down and off the slope as shown.

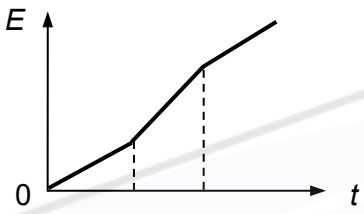


Which graph best shows the variation with time *t* of the e.m.f. *E* induced in the rod, from the time it is released?

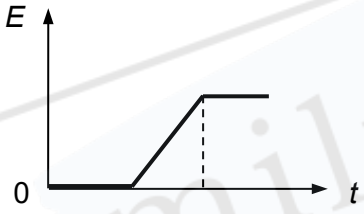
A



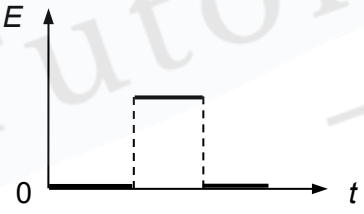
B



C



D



26 A sinusoidal alternating current of peak value I_o passes through a resistor of resistance *R*. The mean power developed by the current in the resistor is *P*.

Another sinusoidal alternating current passes through a resistor of resistance 2*R*. If the mean power developed by this current in it is 4*P*, what is the root-mean-square value of this current?

A 2.0 I_o **B** 1.4 I_o **C** 1.0 I_o **D** 0.70 I_o

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27 The intensity of a beam of monochromatic light is doubled.

Which one of the following represents the corresponding change, if any, in the momentum of each photon of the beam?

A remained the same

B increased fourfold

C doubled

D halved

28 Heisenberg's Uncertainty Principle is a consequence of

A the wave-particle duality of physical entities.

B the existence of discrete energy levels in atoms.

C relativistic effects as particles move at speeds close to the speed of light.

D the fact that all measuring instruments have a minimum resolution which limits their precision.

29 In the following induced nuclear reaction, when one Lithium-7 nucleus reacts with one Hydrogen-1 nucleus, X number of Helium-4 nuclei are produced.

$$^{7}_{3}\text{Li} + {}^{1}_{1}\text{H} \rightarrow \text{X}\left({}^{4}_{2}\text{He}\right) + \text{energy}$$

During the reaction, 1.6×10^{12} J of energy is released when 1.0 g of Hydrogen-1 (mass of 1 Hydrogen-1 nucleus = 1.008 *u*) and sufficient Lithium-7 are used. The binding energy of a Helium-4 nucleus is 28.3 MeV.

What is the binding energy of a Lithium-7 nucleus?

A 11.6 MeV **B** 39.9 MeV **C** 56.6 MeV **D** 68.2 MeV

30 Nuclide X decays to stable nuclide Y with a half-life of *T* years.

Geologists discovered that nuclide Y found in a particular rock sample all came from nuclide X which was present when the rock was formed.

The rock is thought to be 3*T* years old.

What is the expected ratio $\frac{\text{number of atoms of X}}{\text{number of atoms of Y}}$ for this rock?

A $\frac{1}{2}$ **B** $\frac{1}{3}$ **C** $\frac{1}{6}$ **D** $\frac{1}{7}$

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DUNMAN HIGH SCHOOL
2023 H2 PHYSICS (YEAR 6)

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Answers to Prelim Exam H2 Physics Paper 2

Qn	Answer	Marks
1(a)	Speed is a physical quantity and can only be defined in terms of other physical quantities. Distance is a physical quantity, but second is a unit for time which cannot be used to define speed.	B1 B1
1(b)	Vertically, from $v = u + gt$ and taking upward as positive, $-u\sin\theta = u\sin\theta - gT$ Time of flight, $T = \dfrac{2u\sin\theta}{g}$ Horizontally, from $s = ut$ $R = (u\cos\theta)(T)$ $= (u\cos\theta)\left(\dfrac{2u\sin\theta}{g}\right)$ $= \dfrac{2u^2\sin\theta\cos\theta}{g}$	M1 M1 A1 A0
	Marker's comments: It is a "show" type of question and thus important that all steps, including substitution must be explained and shown.	
1(c)	Maximum R occurs when $\sin 2\theta = 1$. Hence $\theta = 45^o$	A1
1(d)	$R_0 = \dfrac{u^2}{g}$ $\dfrac{45.36\text{ km}}{1\text{ h}} = \dfrac{45.36(1000)\text{ m}}{(60)(60)\text{ s}} = 12.6\text{ m s}^{-1}$ $g = \dfrac{u^2}{R_0}$ $= \dfrac{(12.6)^2}{16.3}$ $= 9.7399\text{ m s}^{-2}$ $\dfrac{\Delta g}{g} = 2\dfrac{\Delta u}{u} + \dfrac{\Delta R_0}{R_0}$	C1 A1

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	$\frac{\Delta g}{9.7399} = 2\left(\frac{3}{100}\right) + \frac{4}{100}$ $\Delta g = 0.97$ $= 1\ \text{m s}^{-2}$ (to 1 s.f.) Therefore, $g = (10 \pm 1)\ \text{m s}^{-2}$	A1 A1
	Marker's comments: Uncertainty should only be left to 1 sig fig. The final answer and its uncertainty should have the same d.p. It is important to convert the speed to m s^{-1} to obtain g in units of m s^{-2}. Also, there were mistakes in understanding the meaning of percentage uncertainty.	
2(a)	The upthrust is the <u>resultant upward</u> force due to the <u>larger</u> pressure exerted by the fluid at the bottom compared to the top surface of the body.	B1
2(b)	Upthrust $= W_{\text{displaced fluid}}$ $= \rho_{fluid} V_{cannon} g$ $= 1050\left(\frac{800}{8000}\right)(9.81)$ $= 1030\ \text{N}$ (shown)	M1 A0
	Marker's comments: It is a "show" type of question and thus important that all steps, including substitution must be explained and shown.	
2(c)	The rate of change of momentum of a body is directly proportional to the <u>resultant</u> force acting on the body and occurs in the direction of the <u>resultant</u> force.	B1
2(d)	During its upward motion, the cannon experiences viscous <u>drag force</u> which acts in the opposite direction of its motion and <u>increases with the speed of the cannon.</u> Net force on canon = upthrust – (weight + drag force) <u>decreases</u> (since weight and upthrust are constant) Since the net upward force decreases over time, the momentum increases non-linearly (since the net force is directly proportional to the rate of change of momentum)	B1 B1
	Marker's comments: Very often, drag force is not mentioned. There were misconception that the upthrust decreases causing net force to decrease or the velocity decreases while the momentum increases.	

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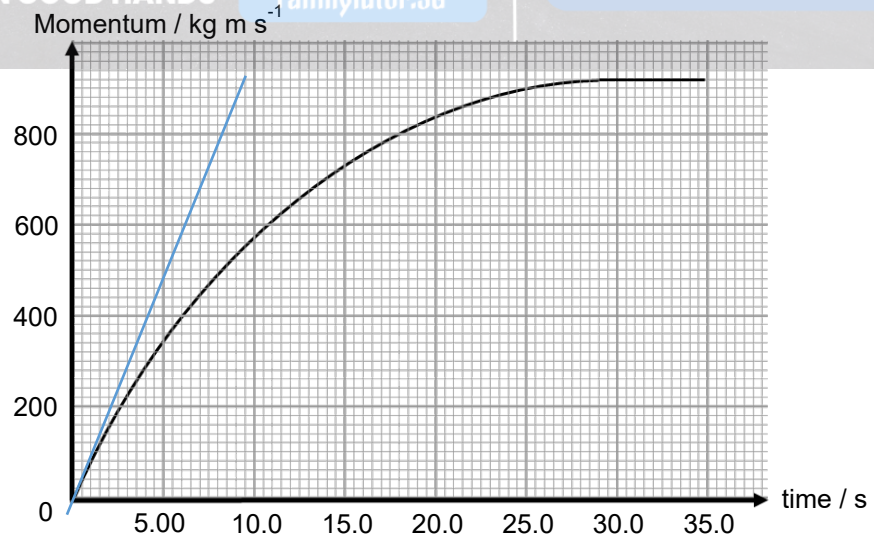
2(e)	 $\text{gradient of tangent line} = F_{net}$ $= \frac{400-0}{4-0}$ $= 100 \text{ N}$ (M1 for tangent line and computing gradient correctly) Net force on cannon = upthrust of cannon and bag – weight of cannon $F_{net} = \underline{U} - W$ $100 = U - (800)(9.81)$ $U = 7948$ N Hence upthrust on bag = 7948 – 1030 = 6918 N For the bag, $\underline{U} = V\rho g$ $6918 = V(1050)(9.81)$ $V = 0.672$ m	M1 C1 A1
	Marker's comments: Poorly attempted. Gradient not drawn to obtain the initial net force.	
3(a)	friction on the mass provides the centripetal force for the circular motion of the mass	B1
	For mud to remain on the plate, $0.72W \geq md\omega^2$ $0.72mg \geq 0.35m\omega^2$ $\omega \leq 4.49 \text{ rad s}^{-1}$	M1 C1

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	number of revolutions $\leq \frac{4.49}{2\pi} \times 60$ $= 42\ \text{min}^{-1}$	A1
	Marker's comments: The question says to explain your working. As such, a statement that friction provides centripetal force to explain before equating the two forces. There were mistakes made in units of ω or to convert rad s^{-1} to number (an integer) of revolutions per minute.	
3(b)	centripetal force increases as *r* increases/ centripetal force is larger at the edge	M1
	so mud slips off at the edge first.	A1
	Marker's comments: Mud will slip off the plate when friction is <u>not</u> enough to provide the required centripetal force. Students also did not realise that ω is the same for mud near the centre or edge.	
4(a)	acceleration is directly proportional to its displacement from a fixed point	B1
	acceleration is always in opposite direction to its displacement/always towards the fixed point)	B1
	Marker's comments: Majority of candidates got it wrong.	
4(b)	<table><tr><th></th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr><tr><td>displacement</td><td>+</td><td>0</td><td>–</td><td>0</td><td>+</td></tr><tr><td>velocity</td><td>0</td><td>–</td><td>0</td><td>+</td><td>0</td></tr><tr><td>acceleration</td><td>–</td><td>0</td><td>+</td><td>0</td><td>–</td></tr></table>	
	displacement line correct	B1
	acceleration line opposite to displacement line	B1
	velocity line has B D & F as zero with answers to C and E consistent with their displacement line	B1
	Marker's comments: Candidates demonstrated understanding of vector concepts.	
4(c) (i)	phase difference between displacement and velocity is $\pi/2$ OR $3\pi/2$ radians OR 90°	B1
4(c) (ii)	displacement and acceleration are exactly out of phase OR out of phase by π radians OR 180°	B1
4(d) (i)1	amplitude = 8.0 cm	A1

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4(d)(i)2	T = 2.0 s so f = 0.50 Hz	A1
4(d)(ii)1	$F = mA\omega^2$ = 0.020 × 0.080 × $(2\pi/2.0)^2$ = 0.0158 N (or 0.016 N)	A1
4(d)(ii)2	negative cosine graph of any amplitude for at least 3.5 s	B1
	Marker's comments: Poorly and wrongly drawn graph. Some negative sine graph were also drawn.	
5(a)	electric field strength is the force acting per unit positive charge	B1
5(b)	equally spaced, parallel straight lines with arrows down over most of space between plates curved lines shown at edges (showing weaker, non-uniform field)	B1 B1
	Marker's comments: Common mistakes of unequal spacing between field lines and wrong direction of electric field were observed.	
5(c)(i)	(W =) VQ	B1
5(c)(ii)	(W =) Fd	B1
5(d)	$VQ = Fd$ so $F / Q = V / d$ i.e., force per unit charge = potential gradient	B1
	(magnitude of) electric field strength between the plates is <u>equal to</u> the potential gradient	B1
	Marker's comments: Candidates could not use the answers in the previous part to deduce the relationship. Some used electric field is force per unit positive charge instead of getting the expression for electric field to deduce the relationship to potential gradient.	
6(a)	As V increases, I increases initially. Further increase of V will cause a less than proportionate increase in I Since resistance is the ratio of potential difference to current, the resistance of the filament lamp increases.	B1 B1
	Marker's comments: Common mistakes stated by candidates that the resistance is the reciprocal of the gradient of the I-V graph.	

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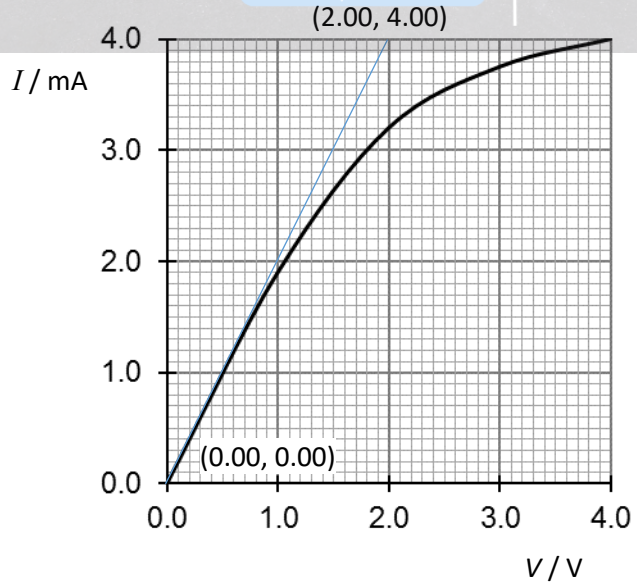
6(b)	 The minimum resistance can be determined by drawing the tangent of the graph at the origin. gradient of tangent $= \frac{(4.00-0.00)\times10^{-3}}{2.00-0.00} = 2.00\times10^{-3}$ Hence, resistance $= \frac{1}{2.00\times10^{-3}} = 500\ \Omega$	M1 C1 A1
6(c)	From Fig. 6.1, when V = 4.00 V, I = 4.00 mA resistance of wire $R = \frac{4.00}{4.00\times10^{-3}} = 1000\ \Omega$ resistivity $\rho = \frac{RA}{L}$ $= \frac{(1000)\left(\frac{\pi}{4}\times(0.046\times10^{-3})^2\right)}{2.0}$ $= 8.3\times10^{-7}\ \Omega$ m	M1 C1 A1
6(d)	From Fig. 6.1, when I = 1.0 mA, V = 0.500 V = terminal p.d. across cell $E - Ir = 0.500$ $E - (1/1000)(0.50) = 0.500$ $E = 0.5005$ V	C1 A1

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7(a) (i)	electron	B1
7(a) (ii)	any two: • can be deflected by electric and magnetic fields or negatively charged • absorbed by few (1 – 4) mm of aluminum / 0.5 to 2 m or metres for range in air • speed up to 0.99c / range of speeds / energies	B2
7(a) (iii)	decay occurs and cannot be affected by external / environmental factors such as chemical / pressure / temperature / humidity (any two stated factors)	B1
7(b)	3 and 0 for superscript numbers 2 and –1 for subscript numbers	B1
7(c)	energy = $5.7 \times 10^3 \times 1.6 \times 10^{-19}$ (= 9.12×10^{-16} J) $v^2 = \frac{2 \times 9.12 \times 10^{-16}}{9.11 \times 10^{-31}}$ v = 4.5×10^7 m s^{-1}	C1 A1
8(a) (i)	It represents the rated power output that the turbine is expected to generate under ideal operating conditions. The actual power output can vary based on factors such as wind speed and availability, air density, turbulence, temperature, altitude, and other environmental conditions.	B1
8(a) (ii)	The energy demand or consumption of homes can vary significantly depending on factors such as the size of the house, the number of occupants, energy-efficient appliances, and individual usage patterns.	B1
8(b)	Minimum height = 56 – 44/2 = 34 m	A1
8(c) (i)1	600 kW	A1
8(c) (i)2	15.0 m s^{-1}	A1
8(c) (ii)1	$E_{max} = \frac{1}{2}\pi r^2 v^3 \rho = \frac{1}{2}\pi\left(\frac{44}{2}\right)^2 (15.0)^3 (1.25)$ $= 3.21 \times 10^6$ W	C1 A1

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8(c)(ii)2	Overall efficiency $= \frac{P_{out}}{P_{in}} \times 100\% = \frac{600 \times 10^3}{3.21 \times 10^6} \times 100\%$ $= 18.7\%$	C1 A1
8(c)(iii)	$P_{remaining} = P_{in} - P_{out} - 10\%P_{in}$ $= 2.29 \times 10^6$ W (3 s.f.)	C1 A1
8(c)(iv)1	25 m s^{-1}	A1
8(c)(iv)2	A safety measure: it helps <u>avoid overloading of the electrical system</u> and generator, <u>preventing equipment damage</u> or electrical failures. OR At high wind speeds, the forces acting on the blades can become <u>excessive</u>, potentially causing <u>damage</u> such as blade failure, gearbox stress, or tower vibrations. [If the cut-out mechanism also involves shutting down the turbine and feather the blades – turn them out of the wind) to prevent over-rotation.]	B1 [B1]
8(d)(i)	Alternating current because in Fig. 8.3, it shows a frequency of 50 Hz. (Accept explanation using A.C. generator concept: e.g., as the hub and blades rotate, they drive the generator's rotor, which contains magnets or magnetic fields. This rotor is mounted on a shaft and rotates within proximity to a stationary coil. This relative motion results in a dynamic change in magnetic flux linkage, which, in turn, induces an e.m.f. in the coil. This induced voltage takes the form of AC because the rotor's rotation periodically alters the magnetic field's orientation relative to the coil.)	B1 B1
8(d)(ii)	$P_{nominal} = I_{nominal} V$ $I_{nominal} = \frac{500 \times 10^3}{690}$ $= 725$ A (3 s.f.)	C1 A1
8(e)(i)	The <u>rotor blades</u> of a wind turbine are typically the <u>highest</u> and most exposed part of the entire structure, and most likely to be struck by lightning. Their height and exposure, positioning, blade geometry (e.g., pointed tips) make them more susceptible.	B1 B1
8(e)(ii)	Installing a <u>lightning protection system</u> (lightning rods in blades to attract lightning strikes) and <u>proper grounding</u> (connecting metal parts of the turbine with conductive cables or grounding systems) to create low resistance path to dissipate the lightning current to the ground. Additional information: Wind turbine blades are commonly made using composite materials (e.g., fiberglass-reinforced composites) that are non-	B1 B1

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	conductive. Manufacturers must often incorporate lightning protection systems into the blade design to mitigate the risk associated with lightning strikes.	

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DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS

9749/02

Paper 2 Structured Questions

15 September 2023

2 hours

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the question paper.

The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use appropriate units.

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

For Examiner's Use	
1	/10
2	/9
3	/6
4	/11
5	/7
6	/10
7	/7
8	/20
Total	/80

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

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Data

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

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Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	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	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 An experiment to determine the acceleration of free fall g is conducted by projecting a stone with speed u at an angle θ to the horizontal. The horizontal distance R travelled by the stone when it returns to the level of projection is measured. Air resistance is negligible.

(a) In determining the speed of the stone, a student defines speed as "distance travelled per second".

Explain why this definition is incorrect.

.....

.....

.....

.....[2]

(b) By expressing the time of flight of the stone T in terms of g, u and θ, show that R is given by the expression

$$R = \frac{2u^2 \sin\theta\cos\theta}{g}$$

[3]

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(c) The expression in **(b)** can be written as

$$R = \frac{u^2 \sin 2\theta}{g}$$

The experiment is conducted to obtain the maximum range R_0.

State the value of θ to obtain R_0.

θ = ... ° [1]

(d) The values of u and R_0 are 45.36 km h^{-1} and 16.3 m, with percentage uncertainties of 3% and 4% respectively.

Calculate the value of g and present the answer together with its uncertainty.

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g = ... ± ..... m s^{-2} [4]

[Total: 10]

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2 A lifting bag is a diving equipment which is used to lift heavy objects underwater by means of the bag's buoyancy. To retrieve a submerged cannon of mass 800 kg and density 8000 kg m^{-3} resting on the seabed back to the surface, an uninflated lifting bag of negligible mass and volume was attached to the cannon by a diver. The density of seawater is 1050 kg m^{-3}.

(a) Explain the origin of *upthrust*.

……

……

……[1]

(b) Show that upthrust acting on the cannon is 1030 N.

[1]

Air was suddenly released into the lifting bag, causing it to inflate and the cannon to be lifted off the seabed. The variation with time of the momentum of the cannon is shown in Fig. 2.1.

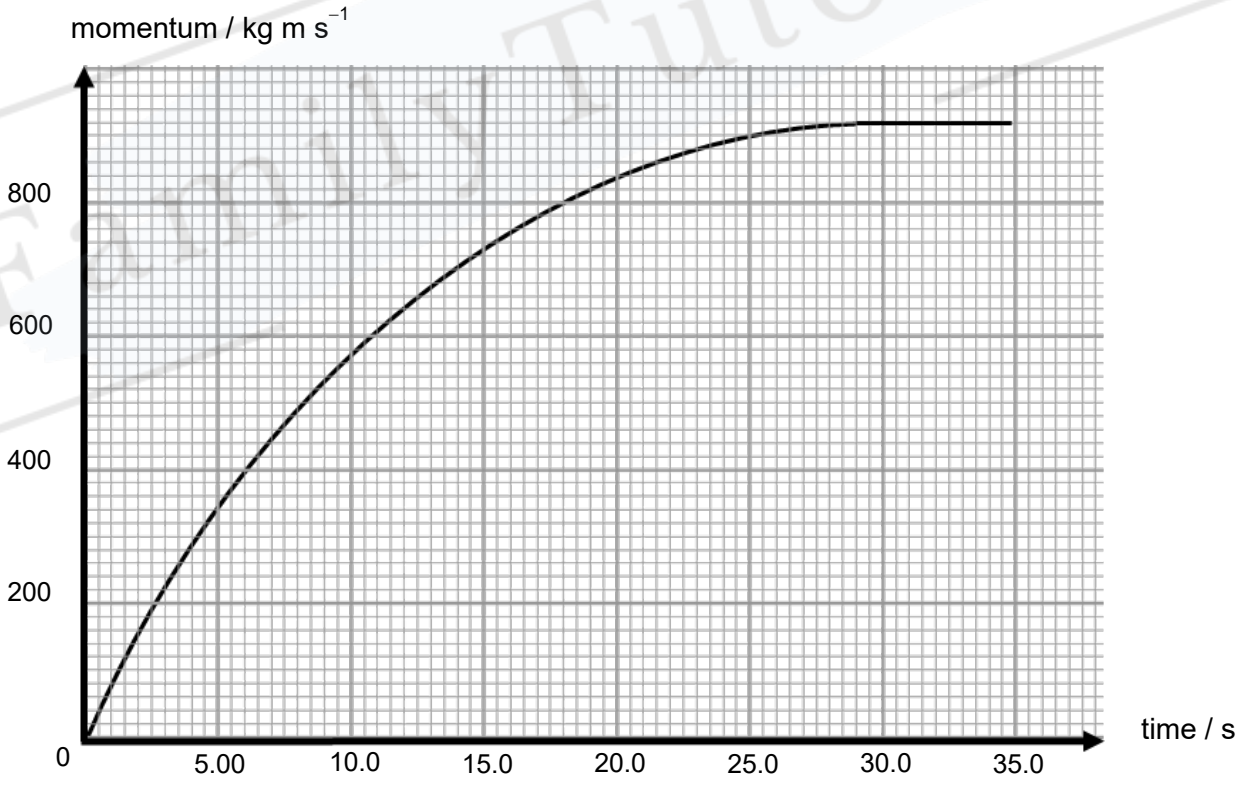

Fig. 2.1

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

……

……

…… [2]

(d) Explain why the momentum of the cannon increases non-linearly as shown in Fig. 2.1.

……

……

……

……

…… [2]

(e) Using Fig. 2.1, estimate the volume of air that was released into the lifting bag.

volume of air = …… m^3 [3]

[Total: 9]

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3 A horizontal flat plate is free to rotate about a vertical axis through its centre, as shown in Fig. 3.1.

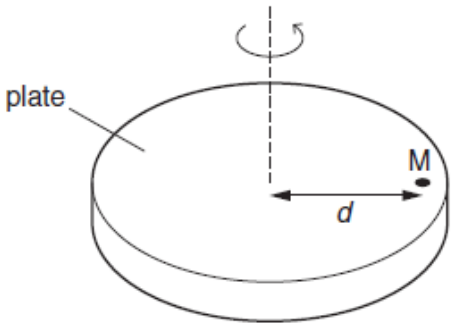

Fig. 3.1

A small mass M is placed on the plate, a distance *d* from the axis of rotation. The speed of rotation of the plate is gradually increased from zero until the mass is seen to slide off the plate.

The maximum frictional force *F* between the plate and the mass is given by the expression

$$F = 0.72W$$

where *W* is the weight of the mass M.

The distance *d* is 35 cm.

(a) Determine the maximum number of revolutions of the plate per minute for the mass M to remain on the plate. Explain your working.

number of revolutions per minute = ... [4]

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(b) The plate is covered, when stationary, with mud.

Suggest and explain whether mud near the edge of the plate or near the centre will first leave the plate as the angular speed of the plate is slowly increased.

.....

.....

.....

.....

.....

..... [2]

[Total: 6]

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4 Galileo used a simple pendulum to take the time for objects to roll down an inclined plane. Fig. 4.1 shows a simple pendulum.

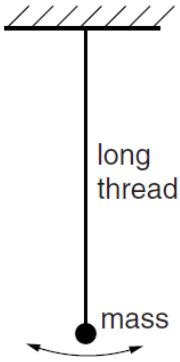

Fig. 4.1 (not to scale)

A simple pendulum oscillates with simple harmonic motion.

(a) State what is meant by *simple harmonic motion*.

.....

.....

.....

.....

..... [2]

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(b) The pendulum is displaced to one side and then released at time $t = 0$. Fig. 4.2 shows the positions of the mass at various times during a single oscillation.

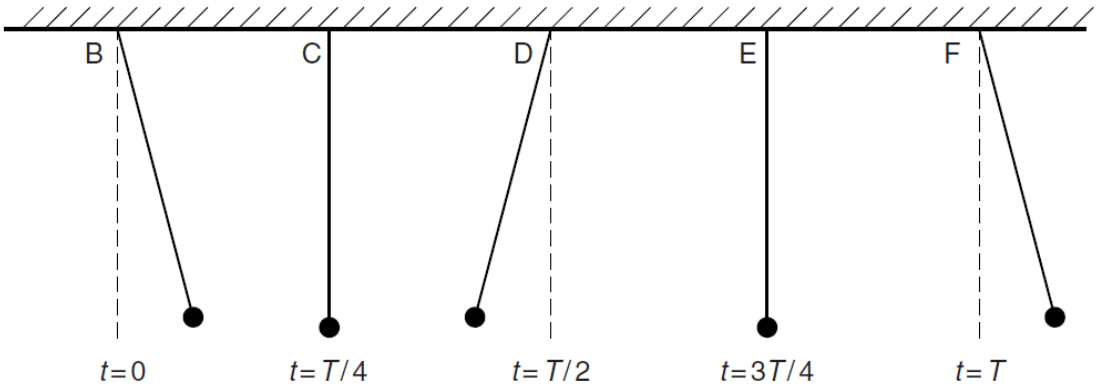

Fig. 4.2 (not to scale)

Complete the table below to describe the directions of the displacement, velocity and acceleration of the mass at times B to F using the symbols +, 0 and –.

Apply the convention that displacements, velocities and accelerations to the right are positive.

	B	C	D	E	F
displacement					
velocity					
acceleration					

[3]

(c) State the phase difference, for the pendulum in **(b)**, between

(i) the displacement and the velocity,

……[1]

(ii) the displacement and the acceleration.

……[1]

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[Turn over

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(d) Fig. 4.3 shows the variation of displacement x with time t for a particular pendulum.

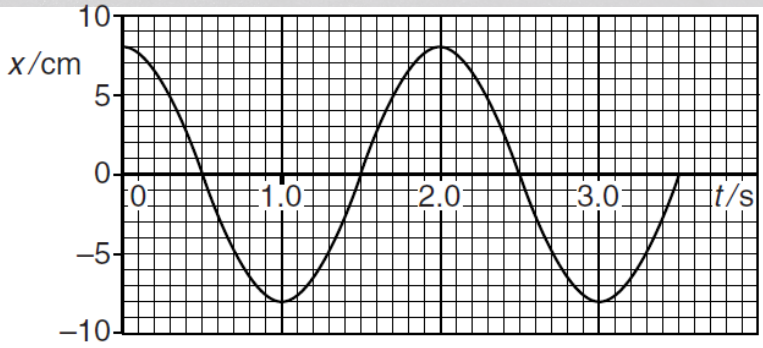

Fig. 4.3

(i) Use information from Fig. 4.3 to determine

1. amplitude,

amplitude = ... cm [1]

2. the frequency of oscillation.

frequency = ... Hz [1]

(ii) The mass m of the pendulum is 20 g.

1. Calculate the maximum force exerted on the mass.

maximum force = ... N [1]

2. On Fig. 4.4, sketch a graph to show how, for the time period given in Fig. 4.3, the force F varies with time t.

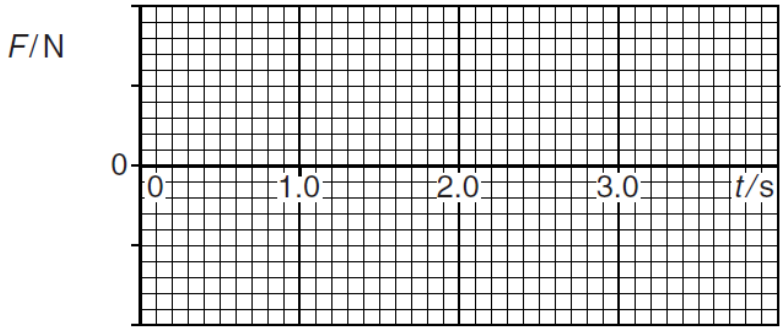

Fig. 4.4

[1]

[Total: 11]

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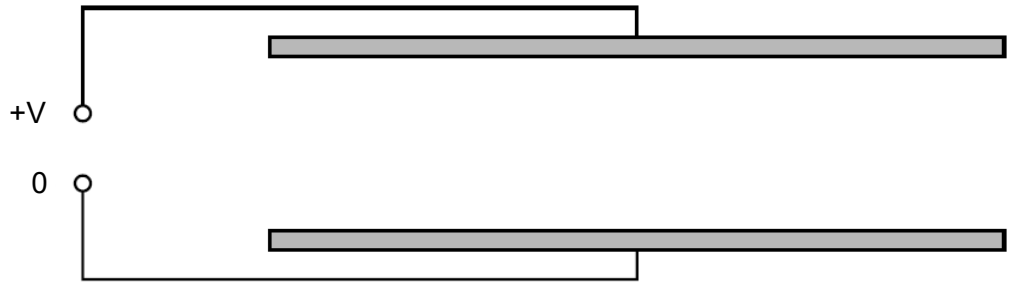
5 **(a)** Define *electric field strength*.

.....

.....[1]

(b) In Fig. 5.1 draw the electric field lines between the parallel plates throughout the region, including the edges.



[2]

Fig. 5.1

(c) The plates in Fig. 5.1 are separated by a distance *d* and there is a potential difference *V* between them. A small charge of +*Q*, is moved from the centre of the negative plate up to the positive plate.

State an expression for the work *W* done on the charge

(i) in terms of *V* and *Q*,

W = ... [1]

(ii) in terms of the force *F* on the charge and *d*.

W = ... [1]

(d) Use your answers to **(c)** to deduce the relationship between the electric field strength between the plates and the potential gradient.

[2]

[Total: 7]

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6 The variation with the potential difference V across a filament wire of current I is shown in Fig. 6.1.

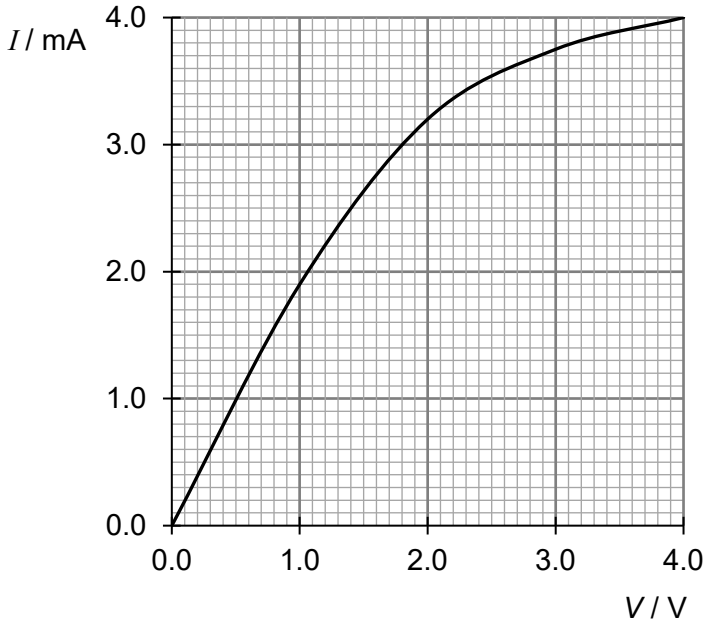

Fig. 6.1

(a) Explain how Fig. 6.1 shows that the resistance of the filament wire increases with potential difference.

.....

.....

.....

.....

..... [2]

(b) Hence, or otherwise, use Fig. 6.1 to determine the minimum value of the resistance of the filament wire.

minimum resistance = ... Ω [3]

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(c) The filament wire is 2.0 m long and has a diameter of 0.046 mm.

Determine the resistivity of the wire when V is 4.0 V.

resistivity = ... Ω m [3]

(d) When the filament wire is connected in series with an ideal ammeter and a cell with internal resistance 0.50 Ω, the ammeter reads 1.0 mA.

Determine the e.m.f. of the cell. Give your answer to 4 significant figures.

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

[Total: 10]

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7 **(a)** β-radiation is emitted during the spontaneous radioactive decay of an unstable nucleus.

(i) State the nature of a β-radiation.

…… [1]

(ii) State two properties of β-radiation.

1. ……

2. ……

[2]

(iii) Explain the meaning of *spontaneous* radioactive decay.

……

…… [1]

(b) The following equation represents the decay of a nucleus of hydrogen-3 by the emission of β radiation.

Complete the equation.

$$^{3}_{1}\text{H} \longrightarrow \overset{\ldots\ldots}{\underset{\ldots\ldots}{\ldots}}\text{He} + \overset{\ldots\ldots}{\underset{\ldots\ldots}{\ldots}}\beta$$

[1]

(c) The β-particle is emitted with an energy of 5.7×10^3 eV.

Calculate the speed of the β-particle.

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

[Total: 7]

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8 Wind power can be used for the generation of electric power. Fig. 8.1 illustrate one particular type of wind turbine.

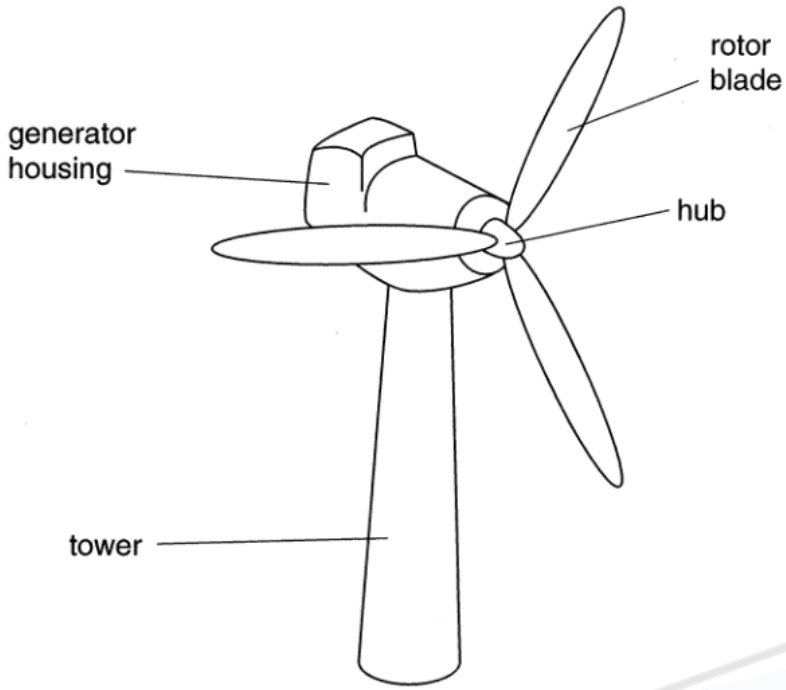

Fig. 8.1

The wind causes the rotor blades to turn and these drive an electric generator. The electric generator is situated in the housing at the top of the tower, as illustrated in Fig. 8.2.

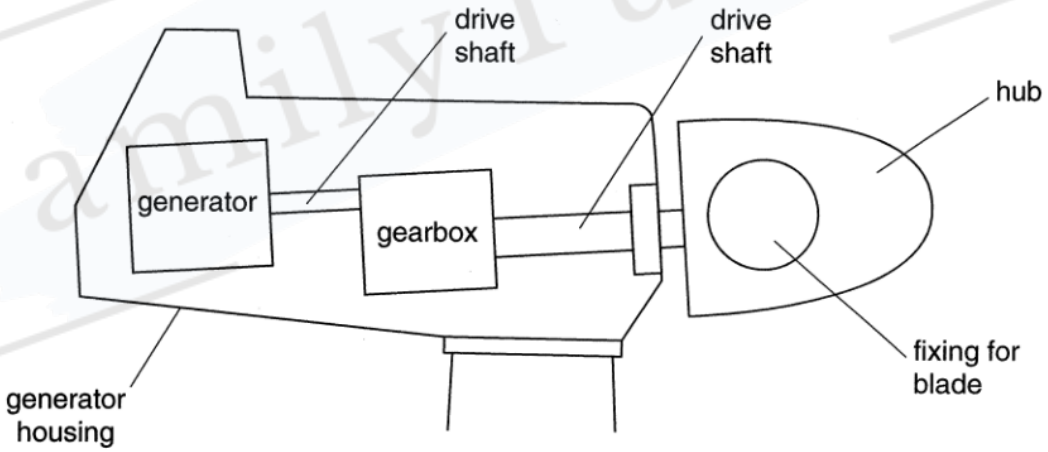

Fig. 8.2

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Some information provide by a manufacturer of wind turbines are given in Fig. 8.3.

height of tower from ground to hub	56 m
rotor diameter	44 m
number of blades	3
nominal output	500 kW
voltage	690 V
frequency	50 Hz

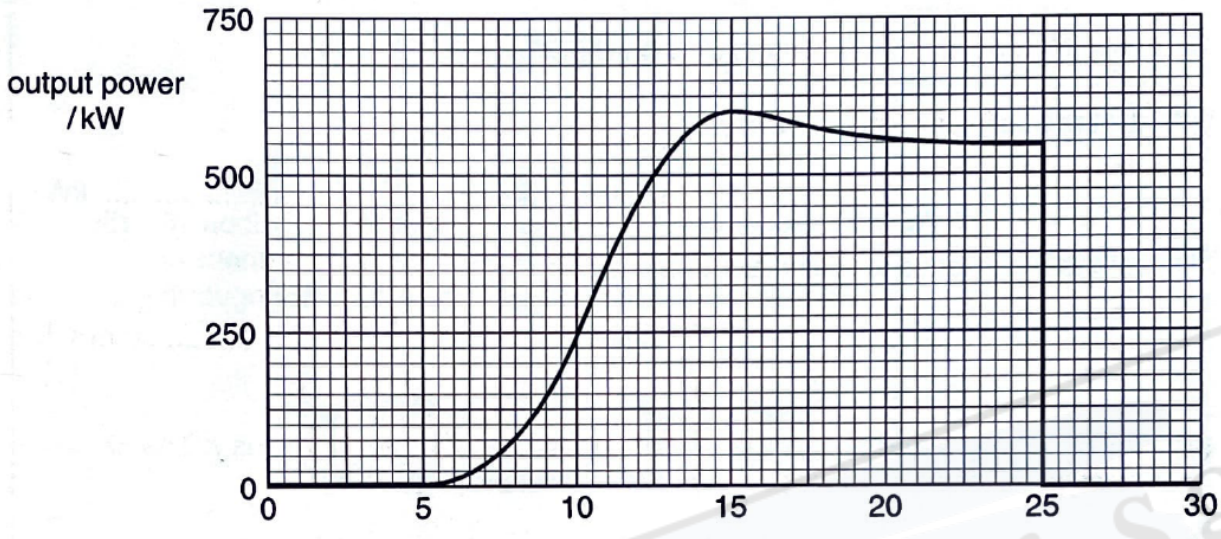

Fig. 8.3

One such wind turbine is built near a town. The local newspaper reported that the wind turbine 'could serve 200 homes'.

(a) Suggest one reason,

(i) why the manufacturer specifies a *nominal* output power for the wind turbine,

……..

……..

……..[1]

(ii) why the report that the wind turbine can serve 200 homes can be misleading.

……..

……..

……..[1]

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(b) Determine the minimum height of the tip of a rotor blade above the ground level.

height = ... m [1]

(c) **(i)** Use the manufacturer's data to give values of

1. the maximum power output,

maximum power = ... kW [1]

2. the wind speed for this maximum power.

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

(ii) Air of density ρ and speed v is incident normally on a rotor of radius r. The kinetic energy E of the air incident on the rotor in unit time is given by

$$E = \tfrac{1}{2}\pi r^2 v^3 \rho.$$

The air has density 1.25 kg m^{-3}.

Calculate, for the wind turbine operating at maximum output power,

1. the kinetic energy of air incident per second on the rotor (the incident wind power),

incident wind power = ... W [2]

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2. the overall efficiency of generation of electric power.

efficiency = …….. % [2]

(iii) In addition to the power usefully transformed in the wind turbine, 10% of the incident wind power is lost. Calculate the power of wind after it has passed through the rotor.

power = …….. W [2]

(iv) At high wind speeds, the turbine is 'cut out', that is, the generator is no longer turned by the blades.

1. Use Fig. 8.3 to determine this cut-out speed.

cut-out speed = …….. m s^{-1} [1]

2. Suggest one reason why it is necessary to have a cut-out speed.

……..

……..

……..[1]

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(d) **(i)** State whether the generator produces direct current or alternating current, explaining how you came to your conclusion.

……

……

……[2]

(ii) Calculate the nominal current from the generator.

current = …… A [2]

(e) The wind turbine must be protected from lightning strike.

(i) Suggest, with reasons, which part of the wind turbine is most likely to be struck by lightning.

……

……

……

……[2]

(ii) Suggest how the risk of damage by lightning may be minimised.

……

……

……

……[1]

[Total: 20]

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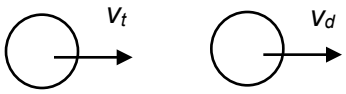
DUNMAN HIGH SCHOOL
2023 H2 PHYSICS (YEAR 6)

Answers to Prelim Exam H2 Physics Paper 3

1	**(a)**	The principle of conservation of momentum states that the total momentum of a system of bodies is constant provided no resultant external force acts on the system.	B1
	(b)	The total momentum of the two-nuclei system is non-zero. Thus, if one of the nuclei is at rest, then the other nucleus must possess a non-zero momentum (i.e. it is moving). Hence the two nuclei cannot be at rest simultaneously.	B1 B1
	(c)	Taking right to be positive, By conservation of momentum, $3mv - 2mv = 3mv_t + 2mv_d$ $v = 3v_t + 2v_d$  after collision relative speed of approach = relative speed of separation $2v = v_d - v_t$ Solving simultaneously for v_t and v_d, $v_d = 1.4v$ $v_t = -0.6v$ (i.e. tritium nucleus is travelling leftward)	C1 C1 A1 for both correct answers
		Marker's comments: There were answers that did not treat momentum as a vector. Answers should never be left in fraction form.	
	(d)	Let F_{avg} be the average force exerted by the deuterium nucleus on the tritium nucleus, $F_{avg} = \frac{\Delta p_{tritium}}{t}$ $= \frac{3m(-0.6v - v)}{t}$ $= -\frac{4.8mv}{t}$ (negative sign indicates it points to the left) Magnitude of the average force = $\frac{4.8mv}{t}$	C1 A1
		Marker's comments: The magnitude of the average force should be the same for either deuterium or tritium nucleus. There were mistakes in using the wrong mass or wrong change in velocity. The final numerical value should be shown and not left in fraction form.	

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2	**(a)**	Loss in GPE $= mgh$ $= 70.0(9.81)(1.50) = 1030$ J	A1
	(b)	kinetic energy of man $= \frac{1}{2}mv^2$ $= \frac{1}{2}(70.0)(2.00)^2 = 140$ J	A1
	(c)(i)	The perpendicular distance between the line of action of the weight and the pivot is zero.	B1
	(c)(ii)	The man will fall a further distance equal to the extension of the spring, x before coming to a stop. Assuming no loss in energy to the surroundings, By conservation of energy, loss in k.e. + loss in g.p.e. = gain in e.p.e $(1030 + 140) + 70x = \frac{1}{2}kx^2$ $(1030 + 140) + 70x = \frac{1}{2}(10000)x^2$ Solving: $x = 0.556$ m $\sin\theta = \frac{x}{2.40}$ $\theta = \sin^{-1}\left(\frac{0.557}{2.40}\right)$ $= 13.4°$ (to 3 s.f.)	M1 M1 M1 M1 M1 A0
		Marker's comments: The board is NOT in rotational equilibrium, i.e. sum of clockwise moments is NOT equal to sum of anti-clockwise moments.	
	(c)(iii)	$F = kx$ $= (10000)(2.40 \sin 13.4°)$ $= 5560$ N	A1
	(c)(iv)	The board is in translational equilibrium so net force acting on the diving board is zero. $N = W_{board} + W_{man} + W_{spring}$ $= 300 + 70(9.81) + 5560$ $= 6550$ N (3 s.f.)	C1 A1
		Marker's comments: Students should attempt to provide explanation for their working and not simply show the arithmetic to arrive at the answer.	

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3	**(a)**	The gravitational field strength at a point is the gravitational force exerted per unit mass placed at that point.	B1
	(b)	Gravitational force on the satellite provides the centripetal force for the circular motion of the satellite. $\frac{GMm}{r^2} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$	C1
		$r^3 = \frac{GM}{4\pi^2}T^2$ $= \frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{4\pi^2}(94\times60)^2$	C1
		$r = 6.9 \times 10^6$ m	A1
	(c)(i)	From $\frac{GMm}{r^2} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$ $r^3\omega^2$ = constant or $\frac{r^3}{T^2}$ = constant $\frac{(6.9 \times 10^6)^3}{(94)^2} = \frac{r^3}{(150)^2}$ $r = 9.42 \times 10^6$ m $v = r\omega$ $= (9.42\times10^6)\left(\frac{2\pi}{150\times60}\right)$ $= 6600$ m s^{-1} (to 2 s.f.)	M1 M1 M1 A0
	(c)(ii)	Gravitational potential energy $U = -\frac{GMm}{r}$ Change in gravitational potential energy $= U_{final} - U_{initial}$ $= -GMm\left(\frac{1}{r_{final}} - \frac{1}{r_{initial}}\right)$ $= -(6.67 \times 10^{-11})(6.0 \times 10^{24})(1200)\left(\frac{1}{9.4 \times 10^6} - \frac{1}{6.9 \times 10^6}\right)$ $= 1.9 \times 10^{10}$ J	C1 A1

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4 (a) An ideal gas obeys the equation of state $PV = nRT$ at all temperatures T, volume V, pressure P and number of moles n. — B1

(b)

	work done on gas / J	heat supplied o gas / J	increase in internal energy of gas / J
A to B	+360	0	**+360** (&)
B to C	0	+670	**+670** (&)
C to D	**−810** (&)	0	−810
D to A	**0** (@)	**−220** (@)	**−220** (#)

&: first, second and third line correct — B1
#: −220 correct in right hand column — B1
@: other two figures correct in bottom row — B1

(c) the gas molecules bounce off the receding piston at lower speeds — B1
there is a decrease in kinetic energy of the molecules — B1

5 (a)(i) out of the page — B1

(a)(ii) magnetic force provides centripetal force: — B1

$Bev = mv^2/r$
$v = Ber / m$ — B1

(b)(i) gain in kinetic energy = $\frac{1}{2} m v^2 = eV$ OR work done = $eEd = \frac{1}{2} m v^2$ — B1

(b)(ii) [use $v = Ber / m$ and $\frac{1}{2} m v^2 = eV$ to obtain]
$r^2 = 2Vm / eB^2$ OR $r = [2Vm / eB^2]^{1/2}$ — C1

correct substitution for V, m, e and B^2 — C1

$r = 1.6 \times 10^{-2}$ m — A1

(c) the force acting on the electron is always perpendicular to its direction of motion — B1
no work is done on the electron (thus no change in its kinetic energy or speed) — B1

6 (a)
$$V_{r.m.s.} = \sqrt{\frac{2^2(0.002) + 1^2(0.002)}{0.010}} = 1.0 \text{ V}$$ — M1

Steady voltage of 1.0 V will produce the same heating effect as $V_{r.m.s.}$ of 1.0 V. — A1

Marker's comments: Common mistakes like without taking the square root value of the mean square voltage was observed.

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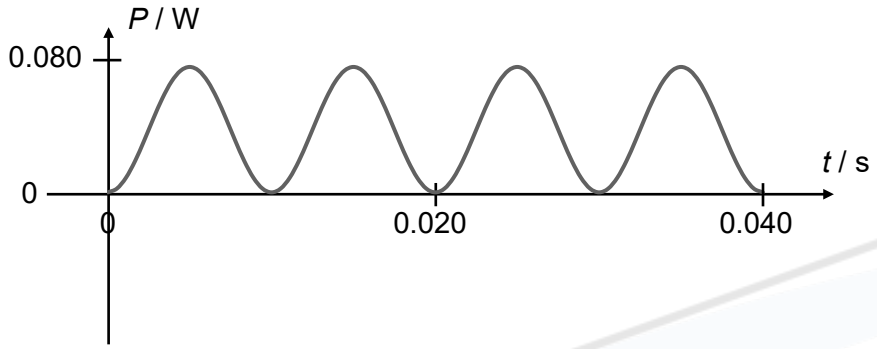
	(b)	Transmission of electrical energy at high voltage means that the current is low according to $P = IV$. Power loss through joule heating (I^2R) is hence lowered as less electrical energy is dissipated as heat in the cables of resistance R.	B1 B1
		Marker's comments: no mention of power loss as heat dissipation was very common among the answers given by candidates.	
	(c)(i)	$\frac{V_s}{V_p} = \frac{N_s}{N_p}$ $V_s = 71 \times 6.5 \times 10^{-3} = 0.46$ V	A1
	(c)(ii)	 Correct shape: $0.080\sin^2\left[(2\pi f)t\right]$. Correct labelling of values: peak power and period.	B1 B1
		Marker's comments: Most answers given was a sine curve instead of sine square curve.	
	(c)(iii)	**1.** In the forward biased direction, the diode has no resistance. Current flows downwards through resistor R. In the reverse biased direction, diode has infinite resistance. There is no current flowing through resistor R.	B1 B1
	(c)(iii)	**2.** In the <u>forward biased direction</u>, there is a <u>half-wave sinusoidal voltage</u> across resistor R, having the same frequency as that of the input voltage. In the reverse biased direction, there is no voltage across resistor R.	B1
		Marker's comments: No mention of why there was a current in one direction and no current in the other direction.	

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7	**(a)**	92 protons and 92 electrons 143 neutrons (in the nucleus)	B1 B1
	(b)(i)	α-particle travels short distance in air	B1
		Marker's comments: Majority of candidates did not state the effect of interaction of alpha particles with air.	
	(b)(ii)	very small proportion in backwards direction / large angles majority pass through with no /small deflections either most of mass is in very small volume (nucleus) and is charged or most of atom is empty space	B1 B1 B1
		Marker's comments: Qualitative answers were poorly presented to explain the observations.	
	(c)	$I = Q / t = nq / t$ $n / t = (1.5 \times 10^{-12}) / (2 \times 1.60 \times 10^{-19})$ $n / t = 4.7 \times 10^{6}\ s^{-1}$	 C1 A1
		Marker's comments: Power of ten was wrongly quoted.	
8	**(a)(i)1.**	number of oscillations per unit time (not per second)	B1
	(a)(i)2.	$n\lambda$	A1
	(a)(ii)	v = distance / time = $n\lambda / t$ $n / t = f$, hence $v = f\lambda$	M1 A1
	(b)	1 period, $T = 3 \times 2.0$ ms = 6.0 ms $f = 1 / T = 1 / (6.0 \times 10^{-3}) = 170$ Hz	C1 A1
	(c)(i)	Sources emitting waves with a constant phase difference.	B1
	(c)(ii)	$f = v / \lambda$ $f = (3.00 \times 10^{8}) / (6.0 \times 10^{-2})$ $= 5.0 \times 10^{9}$ Hz	 C1 A1
	(c)(iii)	path difference = 3λ (integer number of wavelengths) hence no phase difference between the waves arriving at X hence constructive interference occurs → maximum intensity	M1 M1 A1
	(c)(iv)	decrease in the distance between adjacent maxima / minima	B1

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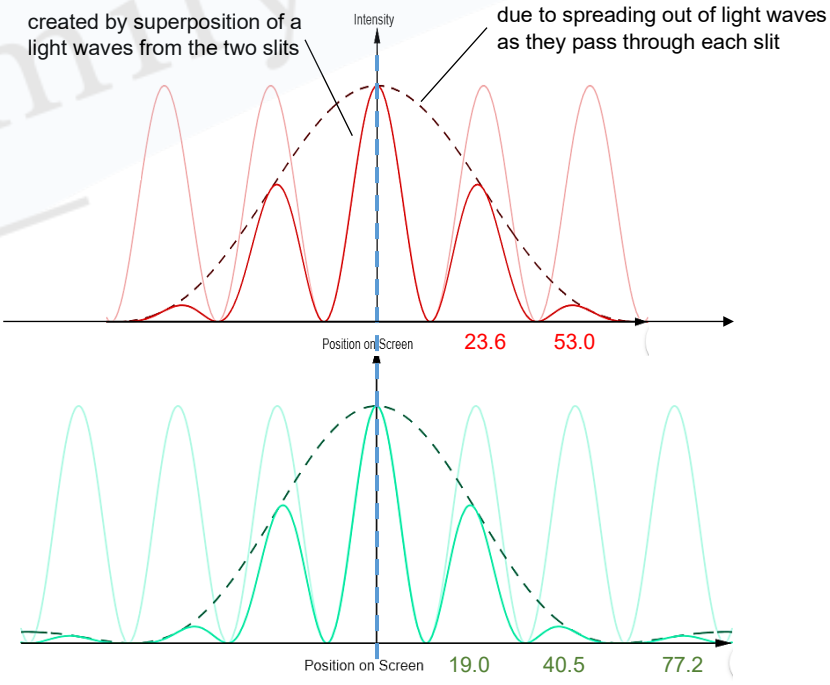
	(d)(i)		B4

order, *n*	angle for red maximum / °	angle for green maximum / °
0	0	0
1	23.6	19.0
2	53.0	40.5
3	Nil	77.2
4	Nil	Nil

Each correct row 1 mark. (using $d \sin\theta_n = n\lambda$)
(no credit for blank)

	(d)(ii)	two overlapping interference patterns as red and green light have different wavelengths: brightness of each line/band decreases (since less light passes through the two slits) and the pattern of lines/bands are fuzzy instead of sharp/narrow	B1
		Any two from: • red bands wider than green bands • red bands (longer wavelength) wider apart than green bands • equally spaced fringes within each band • missing orders as the intensities are reduced by diffraction effects	B2
		e.g., individual double slits pattern for red (upper) and green light:  	

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9	(a)	discrete quantity / packet / quantum of energy of electromagnetic radiation energy of photon = Planck constant × frequency	B1 B1
	(b)	- existence of threshold frequency for incident light - rate of emission of electrons is proportional to intensity of incident light - max. kinetic energy of electron dependent on frequency of incident light - max. kinetic energy independent of intensity of incident light (any three, 1 each, max 3)	B1 B1 B1 B1
	(c)	either $E = hc/\lambda$ $= hc/(450\text{ nm})$ $= 4.4\times10^{-19}$ J or 2.8 eV as 2.8 eV < 3.5 eV, ⇒ no emission or $\Phi = hc/\lambda_0$ $\Rightarrow 3.5\text{ eV} = hc/\lambda_0$ $\Rightarrow \lambda_0 = 355\text{ nm}$ as 355 nm < 450 nm, ⇒ no emission	C1 M1 A1
	OR	or $\Phi = hf_0$ $\Rightarrow 3.5\text{ eV} = hf_0$ $\Rightarrow f_0 = 8.45\times10^{14}$ Hz $450\text{ nm} \rightarrow 6.67\times10^{14}$ Hz as 6.67×10^{14} Hz < 8.45×10^{14} Hz ⇒ no emission	C1 M1 A1
	(d)(i)	when electrons/atoms are in their lowest energy/minimum energy/most stable (state)	B1
	(d)(ii)	excitation promotes an electron to a higher energy level. ionization occurs when an electron receives enough energy to leave the atom.	B1 B1
	(e)	electrons occupy <u>discrete</u> energy levels / difference in energy levels are discrete. energy of photon is proportional to frequency ($E = hf$) atom/electron can be excited only when energy of photon exactly matches the difference in energy levels (1 to 1 interaction / all energy of photon absorbed)	B1 B1 B1

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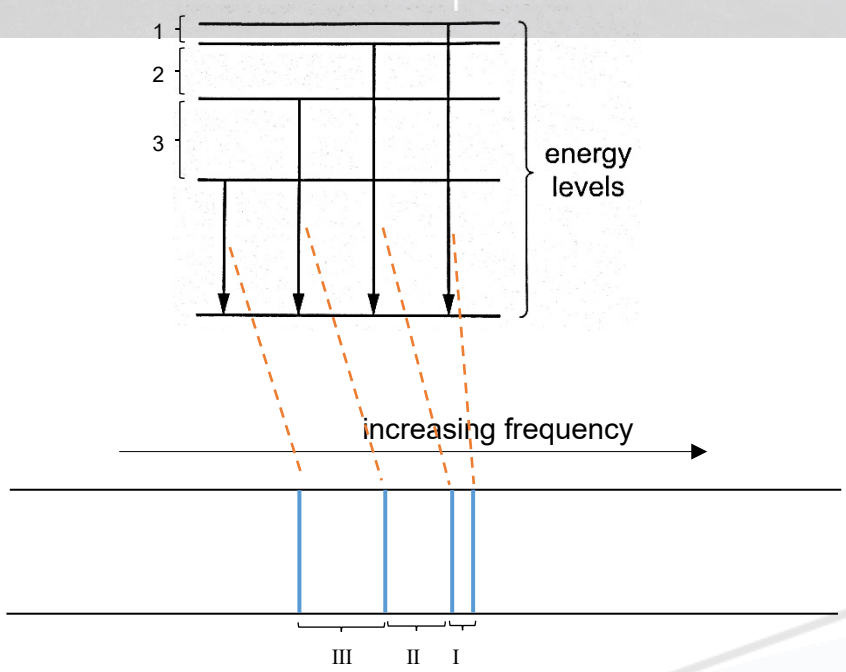
	(f)	Four lines drawn. Correct spacings:  (since the energy levels are drawn to scale, the spacings III, II and I should correspond to the spacings 3, 2 and 1, respectively)	M1 A1
	(g)(i)	Δx decreases and Δp increases	B1
	(g)(ii)	link between momentum p and kinetic energy E_K: $\frac{p^2}{2m} = E_K$ increased uncertainty in momentum implies increased uncertainty in kinetic energy	B1 B1
	(g)(iii)	For very small orbits the uncertainty in the kinetic energy becomes large enough (to make the total energy positive) that the electron will escape	B1

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Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS

9749/03

Paper 3 Longer Structured Questions

21 September 2023

2 hours

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

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

For Examiner's Use	
Section A	
1	/8
2	/10
3	/9
4	/6
5	/9
6	/10
7	/8
Section B	
8 / 9	/20
Total	/80

This document consists of **25** printed pages and **1** blank page.

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Data

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

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	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	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

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

1 A tritium nucleus moves towards a deuterium nucleus as illustrated in Fig. 1.1.

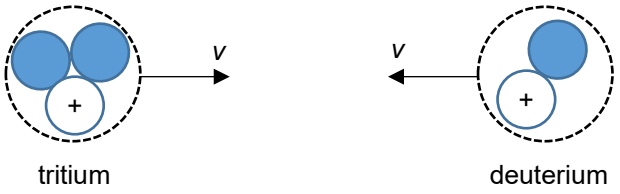

Fig. 1.1

The two nuclei initially have the same speed *v* and the interaction between the two nuclei is elastic. The tritium nucleus consists of two neutrons and a proton. The deuterium nucleus consists of a neutron and a proton. Assume that the proton and the neutron have the same mass *m*.

(a) State the *principle of conservation of momentum*.

.....

.....

.....

..... [1]

(b) Explain why it is not possible for the nuclei to stop at the same instant.

.....

.....

.....

.....

..... [2]

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(c) Determine the final velocities of each nucleus in terms of v.

final velocity of deuterium = ...

final velocity of tritium = ... [3]

(d) Given that the interaction between the two nuclei took a total time of t seconds, express the magnitude of the average force that the deuterium nucleus exerts on the tritium nucleus in terms of m, v and t.

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magnitude of average force = ……..... [2]

[Total: 8]

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2 A 70.0 kg man standing on a platform makes a leap upwards with an initial speed of 2.00 m s^{-1} before falling towards a diving board that is located 1.50 m below the platform as shown in Fig. 2.1.

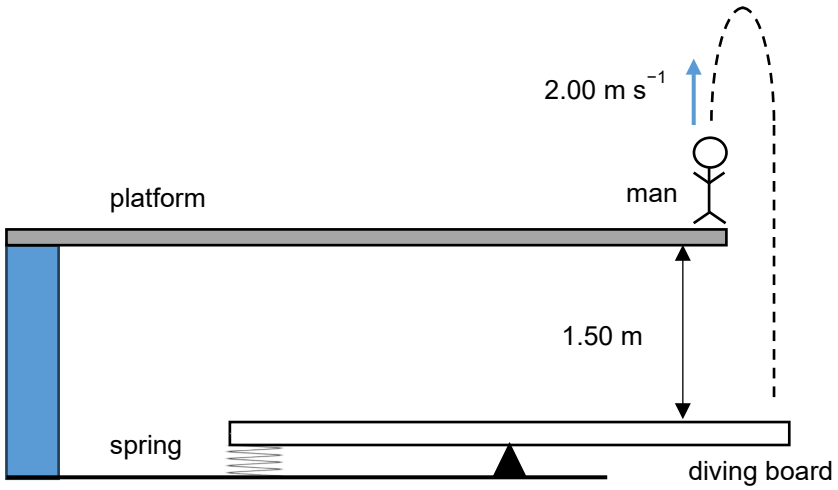

Fig. 2.1

(a) Calculate the loss in gravitational potential energy as the man falls from the platform to a point just before he hits the diving board.

loss in gravitational potential energy = ... J [1]

(b) Calculate the initial kinetic energy possessed by the man at the start of his jump.

initial kinetic energy = ... J [1]

(c) The uniform rigid diving board has a length 4.80 m and weight 300 N. It is pivoted at a point 2.40 m away from its left end and is attached to an unstretched spring with a force constant of 10.0 kN m^{-1} on one end.

When the man hits the diving board on the opposite end after jumping off the platform, the board rotates and causes the spring to stretch until the man comes to a momentary stop. At the instant that the man is momentarily at rest, the diving board makes an angle θ to the horizontal as shown in Fig. 2.2.

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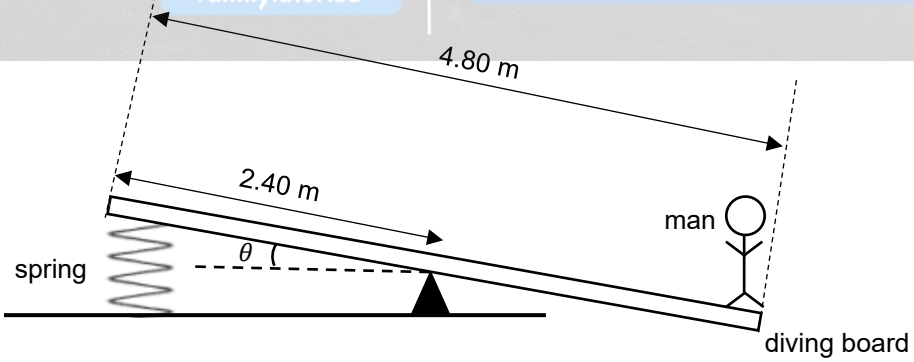

Fig. 2.2

(i) Explain why the weight of the diving board does not produce any moments at the pivot.

.....

.....

..... [1]

(ii) Show that the angle of tilt θ is 13.4°. Explain your workings and state any assumptions made.

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[4]

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(iii) Assuming that the spring only exerts a force vertically on the diving board, calculate the force exerted by the spring on the diving board.

force = ... N [1]

(iv) Calculate the magnitude of the normal contact force exerted by the pivot on the diving board.

magnitude of normal contact force = ... N [2]

[Total: 10]

3 The Earth may be assumed to be an isolated uniform sphere with its mass of 6.0×10^{24} kg concentrated at its centre.

A satellite of mass 1200 kg is in a circular orbit about the Earth in the Earth's gravitational field. The period of the orbit is 94 minutes.

(a) Define *gravitational field strength*.

.....

..... [1]

(b) Calculate the radius of the orbit.

radius = ... m [3]

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(c) Rockets on the satellite are fired so that the satellite enters a different circular orbit that has a period of 150 minutes.

(i) Show that the linear speed of the satellite in its new orbit is 6.6×10^3 m s^{-1}.

[3]

(ii) Determine the change in the potential energy of the satellite.

change in potential energy = ... J [2]

[Total: 9]

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4 A cycle of changes in pressure, volume and temperature of gas inside the cylinder of a petrol engine is illustrated in Fig. 4.1. The gas is assumed to be ideal.

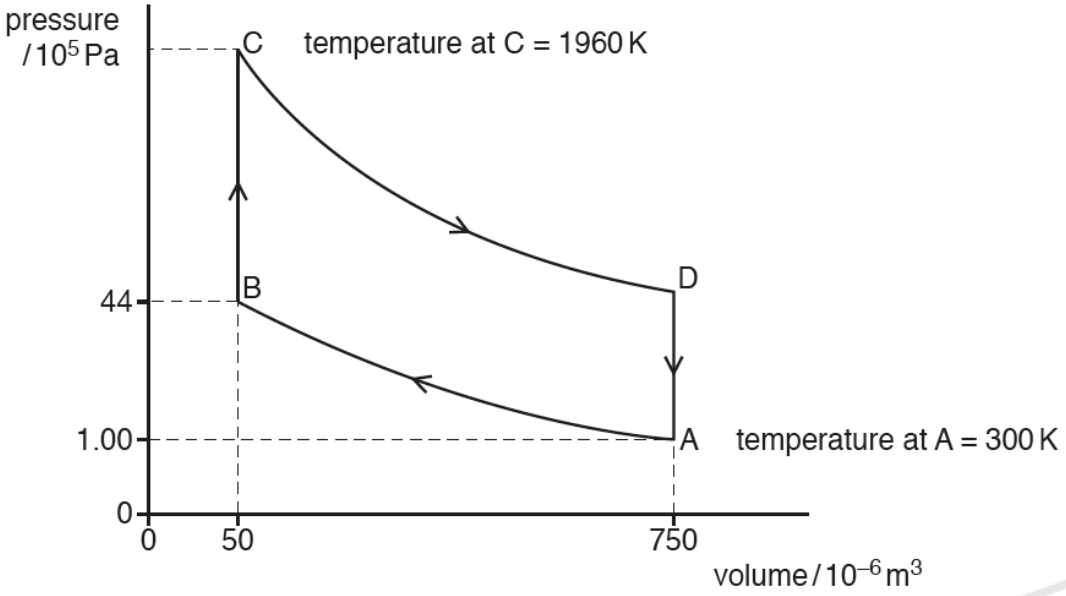

Fig. 4.1 (not to scale)

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.

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

.....

.....

..... [1]

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(b) Complete the table in Fig. 4.2 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.

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	0	+ 670	
C to D		0	− 810
D to A			

Fig. 4.2 [3]

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

.....

.....

.....

.....

..... [2]

[Total: 6]

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5 Fig. 5.1 shows the horizontal path of an electron travelling in a vacuum.

The electron leaves the electron gun with a constant speed v. The electron of mass m and charge e then enters a region of uniform magnetic field of flux density B.

The electron follows a circular path of radius r within the magnetic field.

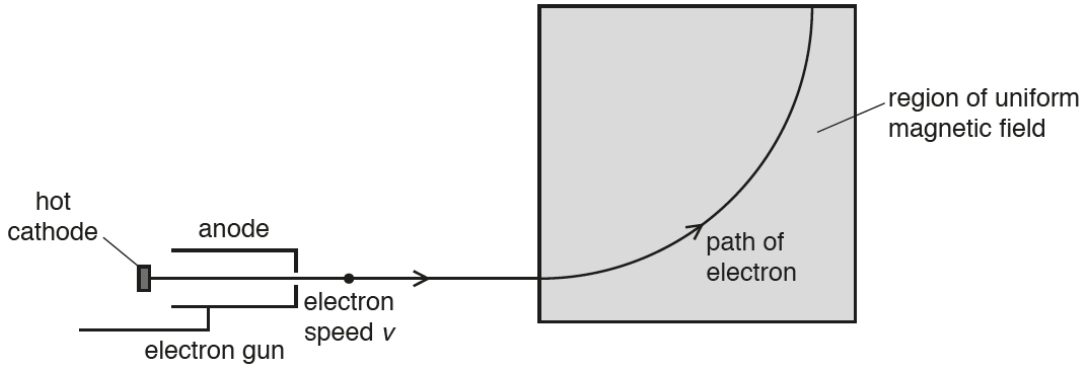

Fig. 5.1 (not to scale)

(a) **(i)** State the direction of the magnetic field.

..... [1]

(ii) Derive an expression for the speed of the electron in terms of B, e, r and m.

[2]

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(b) The electron gun produces the electron by emission from the hot cathode. The electron is then accelerated from rest to speed v by the electric field between the anode and the cathode, where there is a potential difference of V.

(i) State the equation relating the gain in kinetic energy of the electron and the work done on it by the electric field.

[1]

(ii) The charge per unit mass of an electron e/m is called its specific charge. Its numerical value is 1.76×10^{11} C kg^{-1}.

Determine the radius of the circular path of an electron in Fig. 5.1 when the magnetic field has flux density 5.00 mT and the magnitude of the potential difference between the anode and the cathode is 576 V.

radius = ... m [3]

(c) Explain why the speed of the electron remains constant as it moves within the magnetic field.

……..

……..

……..

……..

…… [2]

[Total: 9]

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[Turn over

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6 **(a)** An alternating voltage of period 10 ms is being applied directly across a resistor of 5.0 Ω in a circuit. The variation with time *t* of voltage *V* is shown in Fig. 6.1.

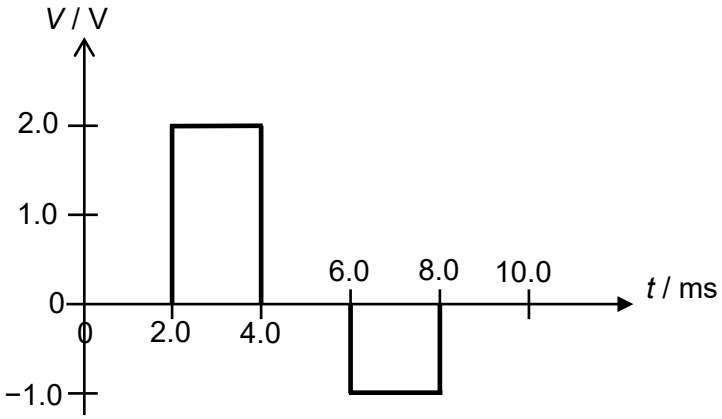

Fig. 6.1

Calculate the steady voltage that would produce an identical heating effect in the same resistor.

voltage = ... V [2]

(b) Explain why it is necessary to use high voltages for the efficient transmission of electrical energy.

.....

.....

.....

.....

..... [2]

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(c) A sinusoidal voltage of 6.5 mV r.m.s. and 50 Hz is now connected to the primary coil of a transformer as shown in Fig. 6.2.

The transformer is assumed to be ideal and its turns ratio, $\frac{N_{secondary}}{N_{primary}}$ is 71.

The secondary coil is connected to a resistor *R*.

An average power of 0.040 W is produced in resistor *R*.

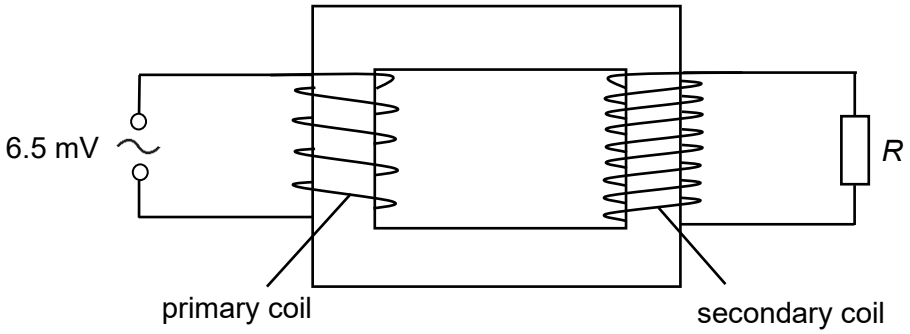

Fig. 6.2

(i) Calculate the r.m.s output voltage supplied to resistor *R*.

r.m.s. voltage = ... V [1]

(ii) In Fig. 6.3, sketch the variation with time *t* of the power *P* dissipated in the resistor *R*. Label all values on the axes.

Fig. 6.3

[2]

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(iii) An ideal diode is now connected to the secondary coil with resistor *R* as shown in Fig. 6.4.

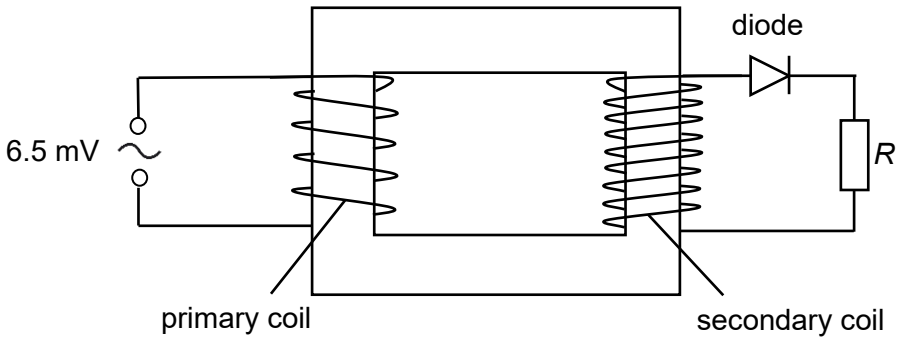

Fig. 6.4

Describe the variation with time of the

1. current flow through resistor *R*, and

……

……

……

…… [2]

2. voltage across resistor *R*.

……

……

…… [1]

[Total: 10]

7 **(a)** Describe the structure of an atom of $^{235}_{92}U$.

……

……

…… [2]

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(b) The deflection of α-particles by a thin metal foil is investigated with the arrangement shown in Fig. 7.1. All the apparatus is enclosed in a vacuum.

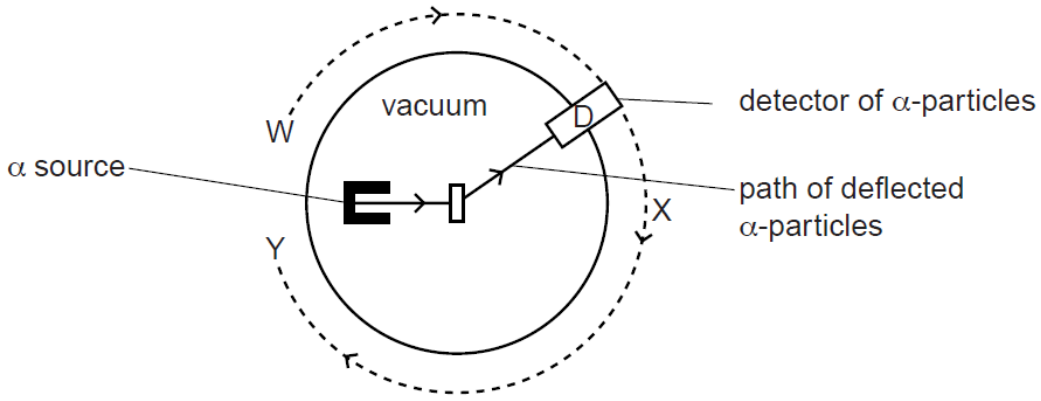

Fig. 7.1

The detector of α-particles, D, is moved around the path labelled WXY.

(i) Explain why the apparatus is enclosed in a vacuum.

.....

..... [1]

(ii) State and explain the readings detected by D when it is moved along WXY.

.....

.....

.....

.....

.....

..... [3]

(c) A beam of α-particles produces a current of 1.5 pA. Calculate the number of α-particles per second passing a point in the beam.

number = ... s^{-1} [2]

[Total: 8]

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Section B

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

8 **(a)** A source of sound has frequency *f*. Sound of wavelength λ is produced by the source.

(i) State

1. what is meant by the *frequency* of the source,

.....

..... [1]

2. the distance moved, in terms of λ, by a wavefront during *n* oscillations of the source.

distance = ... [1]

(ii) Hence derive an expression for the speed *v* of the wave in terms of *f* and λ.

[2]

(b) The waveform of a sound wave produced on the screen of a cathode ray oscilloscope (c.r.o.) is shown in Fig. 8.1.

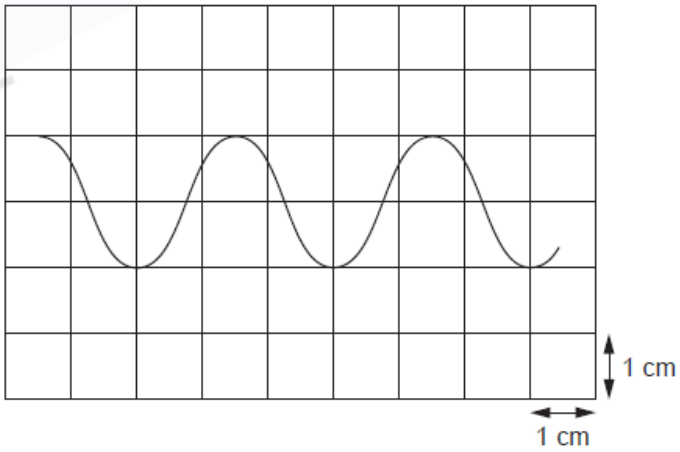

Fig. 8.1

The time base setting of the c.r.o is 2.0 ms cm^{-1}.

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Determine the frequency of the sound wave.

frequency = ... Hz [2]

(c) Microwaves of the same amplitude and wavelength are emitted in phase from two coherent sources P and Q. The sources are arranged as shown in Fig. 8.2.

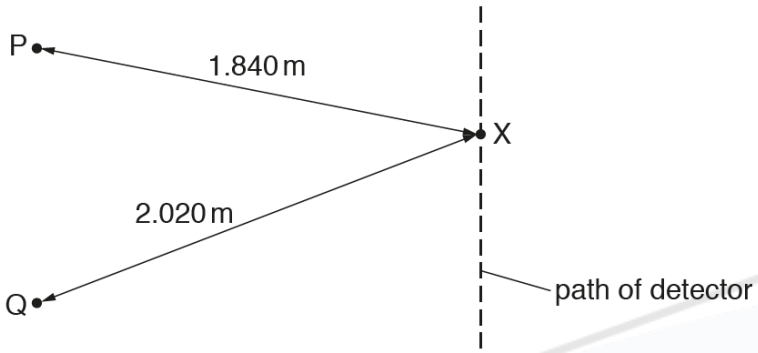

Fig. 8.2

A microwave detector is moved along a path that is parallel to the line joining P and Q. A series of intensity maxima and minima are detected.

When the detector is at point X, the distance PX is 1.840 m and the distance QX is 2.020 m. The microwaves have a wavelength of 6.0 cm.

(i) State what is meant by *coherent sources.*

.....

..... [1]

(ii) Calculate the frequency of the microwave.

frequency = ... Hz [2]

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(iii) Describe and explain the intensity of the microwaves detected at X.

.....

.....

.....

.....

.....

..... [3]

(iv) The wavelength of the microwaves is then decreased.

Describe the effect on the interference pattern along the path of the detector.

.....

.....

..... [1]

(d) Red and green light of wavelengths 640 nm and 520 nm respectively are simultaneously directed through a narrow slit on to a diffraction grating. The grating is perpendicular to the light and has a line spacing of 1.60 μm.

(i) Complete Fig.8.3 by calculating the values of all the angles of maxima for both colours. Indicate **nil** if there are no maxima detected.

order, *n*	**angle for red maximum / °**	**angle for green maximum / °**
0	0	0
1		
2		
3		
4		

[4]

Fig. 8.3

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(ii) The grating is replaced with a double slit of the same spacing. Describe and explain how the new pattern produced differs from the one for the diffraction grating.

……

……

……

……

……

……

…… [3]

[Total: 20]

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9 **(a)** State what is meant by a *photon*.

……

……

…… [2]

(b) It has been observed that, where photoelectric emission of electrons takes place, there is negligible time delay between illumination of the surface and emission of an electron.

State three other pieces of evidence provided by the photoelectric effect for the particulate nature of electromagnetic radiation.

1. ……

……

2. ……

……

3. ……

……

[3]

(c) The work function energy of a metal surface is 3.5 eV. Light of wavelength 450 nm is incident on the surface.

Determine whether electrons will be emitted, by the photoelectric effect, from the surface.

[3]

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(d) When free electrons collide with atoms in their ground state, the atoms can be excited or ionised.

(i) State what is meant by *ground state*.

……

…… [1]

(ii) Explain the difference between *excitation* and *ionisation*.

……

……

……

……

……

……

…… [2]

(e) An atom can also become excited by the absorption of photons. Explain why only photons of certain frequencies can cause excitation in a particular atom.

……

……

……

……

……

……

……

……

…… [3]

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[Turn over

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(f) Fig. 9.1 shows five electron energy levels in an atom and some transitions between them.

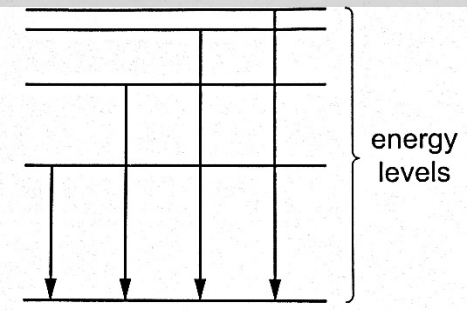

Fig. 9.1

The line spectrum produced is in the visible region of the electromagnetic spectrum.

Sketch, on Fig. 9.2, the line emission spectrum that corresponds to the four energy level changes, assuming that the energy levels are drawn roughly to scale.

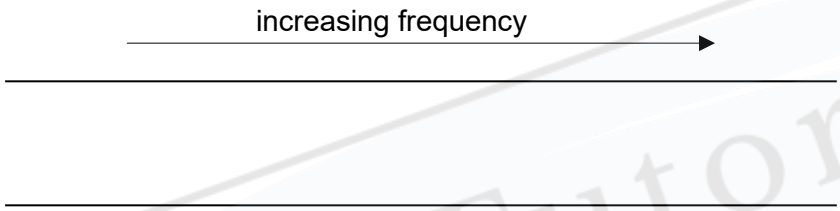

Fig. 9.2

[2]

(g) Ernest Rutherford proposed a planetary model for the hydrogen atom. In the model, a single electron is treated as a point-like charged particle, moving in a circular orbit around a stationary proton (the nucleus) as shown in Fig. 9.3.

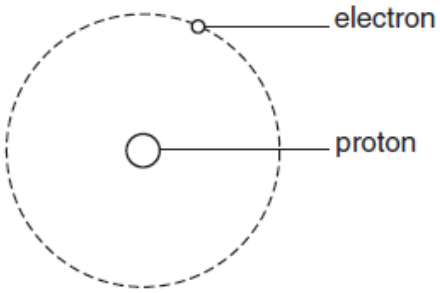

Fig. 9.3

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Rutherford's planetary model allows any size for the electron orbits, but quantum theory puts a lower limit on the size of the hydrogen atom. To understand why this is the case, we can use the Heisenberg uncertainty principle for position and momentum.

$$\Delta p \Delta x \geq h$$

Δp is the uncertainty in the (x-component) of momentum of the electron, and Δx is the uncertainty in the (x-component) of the position of the electron.

(i) State the changes in Δp and Δx when the atom is made smaller by reducing the radius of the electron orbit.

.....

..... [1]

(ii) Explain how the change in Δp affects the kinetic energy of the orbiting electron.

.....

.....

.....

..... [2]

(iii) By considering your answers to **(g) (ii)**, explain why there is a minimum radius for an electron orbit in the hydrogen atom.

.....

.....

..... [1]

[Total: 20]

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DHS H2 Physics Y6 Prelim Exam 2023 Paper 4 Mark Scheme

<table>
<tr><th>Qn</th><th>Marking Point</th><th>Marks</th></tr>
<tr><td>1(b)(ii)</td><td>I recorded to the nearest 0.1 mA and correct unit.</td><td>1</td></tr>
<tr><td>1(c)</td><td>Quality of raw readings:

3 marks for 8 - 7 sensible readings ($\pm 5\ mA$)
2 marks for 6 - 5 sensible readings ($\pm 5\ mA$)
1 mark for 4 sensible readings ($\pm 5\ mA$)
0 mark for 3 or fewer readings

<table>
<tr><th>R / Ω</th><th>I / mA</th><th>P / W</th></tr>
<tr><td>10</td><td>31.8</td><td>0.0101</td></tr>
<tr><td>20</td><td>28.4</td><td>0.0161</td></tr>
<tr><td>33</td><td>24.3</td><td>0.0195</td></tr>
<tr><td>43</td><td>21.7</td><td>0.0202</td></tr>
<tr><td>50</td><td>20.2</td><td>0.0204</td></tr>
<tr><td>60</td><td>18.4</td><td>0.0203</td></tr>
<tr><td>70</td><td>16.8</td><td>0.0198</td></tr>
<tr><td>100</td><td>13.4</td><td>0.0180</td></tr>
</table></td><td>3</td></tr>
<tr><td></td><td>Correct calculation of P, to the correct significant figures (3 s.f.).</td><td>1</td></tr>
<tr><td>1(d)</td><td>All observations must be plotted. Work to an accuracy of half a small square.</td><td>1</td></tr>
<tr><td></td><td>Correct shape (curve).</td><td>1</td></tr>
<tr><td></td><td>Best-fit curve drawn correctly - judge by scatter of points about the line drawn. There must be an even distribution of points on either side of the line. Line must not be kinked.</td><td>1</td></tr>
<tr><td>1(e)</td><td>Value of R with unit read off correctly at maximum value of P.
Acceptable range 40 to 60 Ω.</td><td>1</td></tr>
<tr><td></td><td>TOTAL MARKS FOR Q1:</td><td>9</td></tr>
</table>

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Qn	Marking Point	Marks
2(a)(i)	Value of *M* in the range 10.0 to 11.0 g with unit and to the correct decimal placing (3 d.p.).	**1**
2(a)(ii)	Correct calculation of *m* dividing *M* by 25, with unit.	**1**
2(a)(iii)	Justification for significant figures in *m* linked to the s.f. in *M*. (5 s.f.).	**1**
2(b)(i)	Value of *S* in the range 1.0 – 2.0 g with consistent unit.	**1**
2(b)(ii)	Correct calculation of *c*.	**1**
2(c)(i)	Values of *p* and *q* such that $p + q = 25$	**1**
	Evidence of repeated values of *p*.	**1**
2(c)(ii)	Percentage uncertainty in *p* based on absolute uncertainty of 1 or 2, recorded to maximum of 2.s.f.	**1**
2(d)	Quality: second value of *q* less than first value of *q*.	**1**
2(e)(i)	Two values of *k* calculated correctly, and unitless.	**1**
2(e)(ii)	Valid comment consistent with calculated values of *k*, testing against a criterion stated by the candidate. □ Calculated correctly $\%k_{difference} = \frac{\Delta k}{k_{ave}} \times 100\%$ (1 Mark) □ Chose a criterion from the value in 2(c)(ii). (1 Mark) □ Concluded that results do not support the suggestion if $\%k_{difference}$ > the criterion chosen. OR Concluded results support the suggestion if $\%k_{difference} \leq$ the criterion chosen.	**2**
	TOTAL MARKS FOR Q2:	**12**

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Qn	Marking Point	Marks
3(b)(i)	Value of l recorded with correct unit to nearest 1 mm. Range of l between 45.0 – 55.0 cm. Evidence of repeated readings.	1
3(b)(ii)	Percentage uncertainty based on absolute uncertainty $0.2 \geq \Delta l \geq 0.5$ cm recorded to maximum of 2.s.f.	1
3(c)(i)	Value of t recorded with correct unit to 0.1 s. Evidence of repeated readings.	1
3(c)(ii)	Percentage uncertainty based on absolute uncertainty $0.2 \geq \Delta t \geq 0.5$ s recorded to maximum of 2.s.f.	1
3(d)	Values of l, t recorded to correct d.p. and units.	1
	Quality: second value of t is less than value in (c)(i).	1
3(e)(i)	Two values of k calculated correctly.	1
	Units of k given correctly. ($m^{0.5}$ s^{-1})	1
3(e)(ii)	Justification for s.f. in k linked to the s.f. in t and l. (least number of s.f. among them.).	1
3(e)(iii)	Valid comment consistent with calculated values of k, testing against a criterion stated by the candidate. □ Calculated correctly $\%k_{difference} = \frac{\Delta k}{k_{ave}} \times 100\%$ (1 mark) □ Chose a criterion from the SUM of 3(b)(ii) and 3(c)(ii) (1 mark) □ Concluded that results do not support the suggestion if $\%k_{difference}$ > the criterion chosen. OR Concluded results support the suggestion if $\%k_{difference} \leq$ the criterion chosen.	2
3(e)(iv)	Number of times calculated correctly, using 60 / t.	1
3(f)	Possible sources of errors: • It is difficult to judge when the pendulums are exactly lined up, affecting t. • It is difficult to judge exactly the centre of the bob, affecting length l. • 2 values of k are not enough to draw a valid conclusion.	1
3(g)(i)	All 5 points plotted correctly (to half a small square).	1
	Line of best fit drawn correctly (judge by scatter of points about the line drawn. There must be an even distribution of points on either side of the line. Line must not be kinked.	1
3(g)(ii)	Gradient calculated correctly.	1

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3(g)(iii)	Vertical intercept calculated correctly to be non-zero.	**1**
	Correct conclusion: Since the graph **does not pass through the origin**, $\frac{1}{t}$ is not directly proportional to $\frac{1}{\sqrt{L}}$	**1**
3(h)	Diagram correctly drawn and labelled. (single pendulum, clamped to a retort stand which is resting on a table.)	**1**
	Correct procedure with appropriate measuring instruments used: • Measure mass using electronic mass balance. • Measure time taken *t* for *N* oscillations using a stopwatch. • Calculate period *T* using $T = t / N$ (must be stated).	**1**
	Correct control of variable (length of string *L*) with appropriate measuring instrument used (metre rule).	**1**
	Correct analysis: Plot a graph of *T* against *m.* If the relationship is valid, a straight line passing through the origin will be obtained.	**1**
	TOTAL MARKS FOR Q3:	**22**

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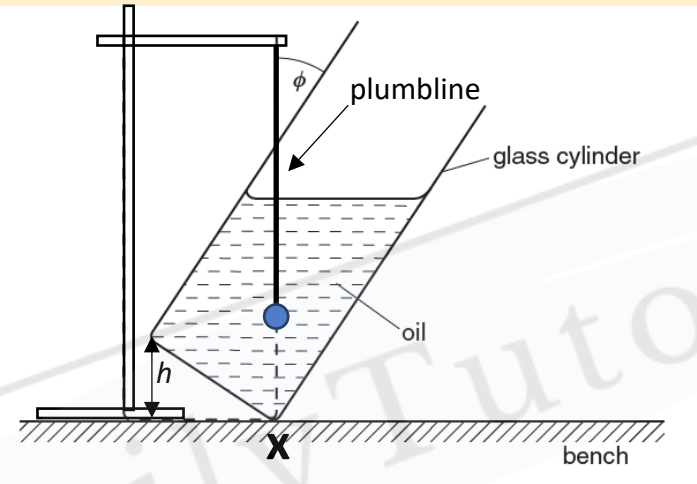
Question 4 Mark Scheme

	Marking Point	Marks
	Problem Definition A1: identify independent and dependent variables. Dependent variable: ϕ. (or tan ϕ.), maximum angle from vertical before the cylinder topples. Independent variable (for expt 1): m, mass of oil in the cylinder Independent variable (for expt 2): d, diameter of the cylinder A2: identify 1 correct control variable. Possible control variables: density of oil, type of glass cylinder (same shape, material).	1 1
	Labelled Diagram  **X** marks the spot to tilt cylinder B1: labelled diagram drawn.	1
	Method of Data Collection B2: identifying 2 experiments required (experiment 1: vary mass, keep diameter constant; experiment 2: vary diameter, keep mass constant) B3: method to determine the different masses of oil in the cylinder, using electronic mass balance. (measure the mass m_0 of the empty cylinder, then pour the oil into the cylinder and measure the total mass m_T. Mass of the oil $m = m_T - m_0$) B4: method to determine the different internal diameters of cylinder, using a vernier calipers. (measure the internal diameter d of the cylinder using the internal (inside) jaws of the vernier calipers) B5: procedure to determine angle properly stated. (Mark a point on bench (**x**) and slowly (gently/gradually) tilt the cylinder of oil until the cylinder is just about to topple. Measure the angle ϕ using a protractor.)	1 1 1 1

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B6: Feasible details of determining angle ϕ. (either by having a plumbline or using trigonometry by finding h (to be labelled clearly). (Measure the angle ϕ using a protractor and a plumbline mounted on a retort stand with the plumbline aligned vertically with the point (**x**) marked on the bench) OR At the point when the cylinder is just about to topple, measure the height of the raised edge of the cylinder, h, using a metre rule. The angle ϕ is equal to $\sin^{-1}(h/d)$	**1**
<u>Method of Analysis</u> C1: linearisation of relationship $\ln(\tan\phi) = \ln(k) + p\ln(d) + q\ln(m)$ C2: Expt 1: plot $\ln(\tan\phi)$ against $\ln(m)$, straight line with gradient q, y-intercept $\ln(k) + p\ln(d)$ Expt 2: plot $\ln(\tan\phi)$ against $\ln(d)$, straight line with gradient p, y-intercept $\ln(k) + q\ln(m)$	**1** **1**
<u>Safety (max 1)</u> D1: Safety correctly identified and explained. Wear gloves to handle the cylinder to prevent skin irritation if the oil spilled onto the hand. OR Place padding (or items with cushioning effects) to prevent glass cylinder from breaking if fallen.	**1**
<u>Additional details: (max 3)</u> E1: Place sandpaper (or any rough material) on the bench to prevent sliding of the cylinder. E2: Measure diameter of cylinder d in different directions and take average to reduce random errors. E3: Use of video with slow motion playback to determine ϕ.. E4: take preliminary measurements to establish an approximate angle ϕ. before redoing the experiment by positioning the cylinder near ϕ. for fine-tuning. E5: Use large protractor with higher precision to reduce percentage uncertainty.	**3**
MAXIMUM TOTAL MARKS FOR Q4:	**12**

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DHS Preliminary Examination 2023 H2 Physics Paper 4 Preparation List

Question 1

No.	Description	Qty	Remarks
1	2 V battery power supply	1	
2	switch	1	
3	digital multimeter with 2 leads	1	200 mA setting, no need to pre-set
4	connecting leads	9	Excluding dmm leads
5	47 Ω resistor	1	To be labelled with its value in Ω
6	10 Ω resistor	2	To be labelled with its value in Ω
7	100 Ω resistor	3	To be labelled with its value in Ω

Question 2

No.	Description	Qty	Remarks
1	identical paper clips each with a length of approximately 3 cm.	25	The 25 paper clips should be joined together to form a chain.
2	spheres of modelling clay (plasticine) each of mass 1.5 g.	2	The 2 spheres should be placed in a small container.
3	wooden strip with approximate dimensions 90 cm x 4 cm x 2 cm. A metre rule can be used as the wooden strip.	1	Sandpaper should be used to smooth the widest surfaces and any sawn edges of the strip.
4	metre rule	1	
5	electronic balance	1	Shared between two candidates.

Questions 1 and 2 should be placed on the ODD-numbered benches, clearly labelled.

Question 3

No.	Description	Qty	Remarks
1	retort stands	1	
2	bosses	2	
3	clamps	2	
4	strings[1]	2	90 cm each
5	wooden blocks	4	used to clamp the strings
6	meter rule	1	
7	stopwatch	1	
8	pendulum bob	2	small ones

Question 3 should be placed on the EVEN-numbered benches, clearly labelled.

[1] The strings should be replaced for every candidate.

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Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS

9749/04

Paper 4 Practical

21 August 2023
2 hours 30 minutes

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Give details of the practical shift and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Shift
Laboratory

Answer **all** questions in the spaces provided on the question paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

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

For Examiner's Use	
1	9
2	12
3	22
4	12
Total	55

This document consists of **19** printed pages and **3** blank pages.

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1 In this experiment, you will investigate how the power P dissipated in a resistor varies with the resistance R of the resistor.

Set up the circuit shown in Fig. 1.1. Use the 10 Ω resistor for the value of resistance R.

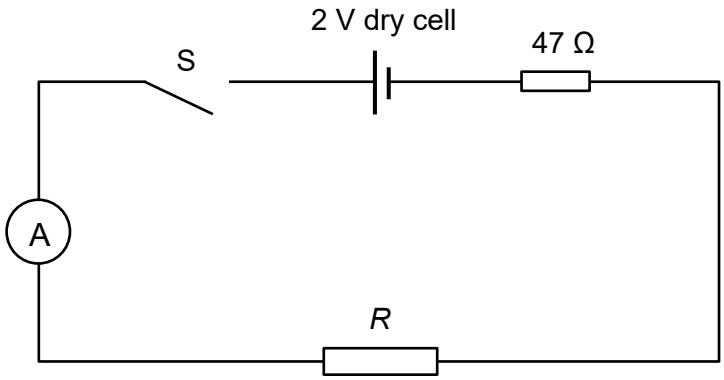

Fig. 1.1

(a) **(i)** Close the switch S.

(ii) Measure and record the current I.

I = ... [1]

(iii) Open the switch.

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(b) Use the two 10 Ω and three 100 Ω resistors to obtain the value of the resistance R as shown in the Fig.1.2. For each value of R, repeat **(a)**.

Also calculate the power dissipated P where $P = I^2R$.

R / Ω	I / mA	P / W
10		
20		
33		
43		
50		
60		
70		
100		

Fig. 1.2 [4]

(c) Plot a graph of P against R. [3]

(d) From your graph, state the value of R when P is a maximum.

R = ... [1]

[Total: 9]

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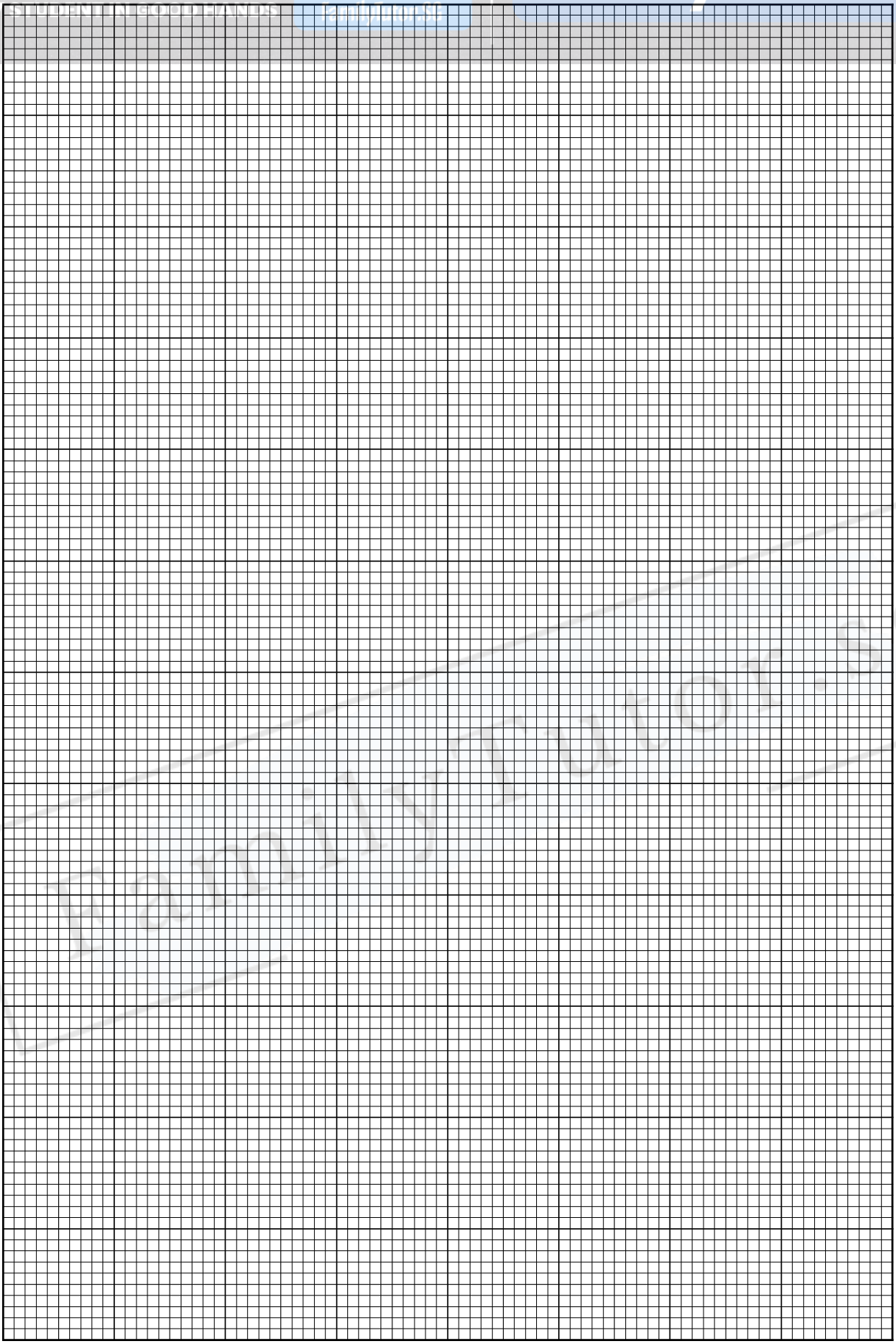

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2 In this experiment, you will investigate the movement of a chain of paper clips.

(a) (i) You have been provided with a chain of paper clips.

Measure and record the mass M of the chain.

M = ... [1]

(ii) Using your answer in **(a)(i)**, calculate the mass m of **one** paper clip.

m = ... [1]

(iii) Justify the number of significant figures that you have given for your value of m.

.....

.....

.....[1]

(b) (i) You have been provided with two identical spheres of modelling clay.

Measure and record the mass S of one of the spheres.

S = ... [1]

(ii) Calculate c where

$$c = \frac{S}{m} .$$

c = ... [1]

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(c) (i) You have been provided with a wooden strip on the bench which is fixed in position. One end of the wooden strip overhangs the bench, as shown in Fig. 2.1.

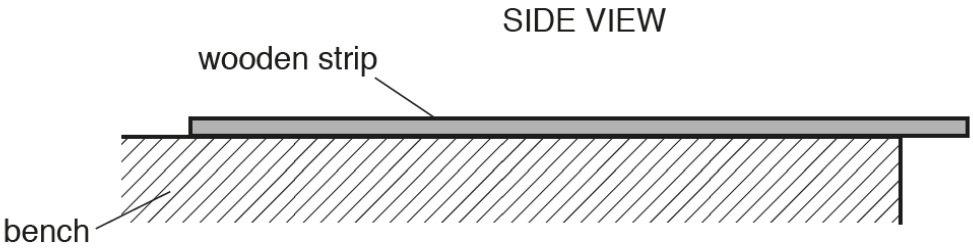

Fig. 2.1

Place the chain on the wooden strip and place one of the spheres on the paper clip at the end of the chain, as shown in Fig. 2.2. The sphere must **not** touch the wooden strip.

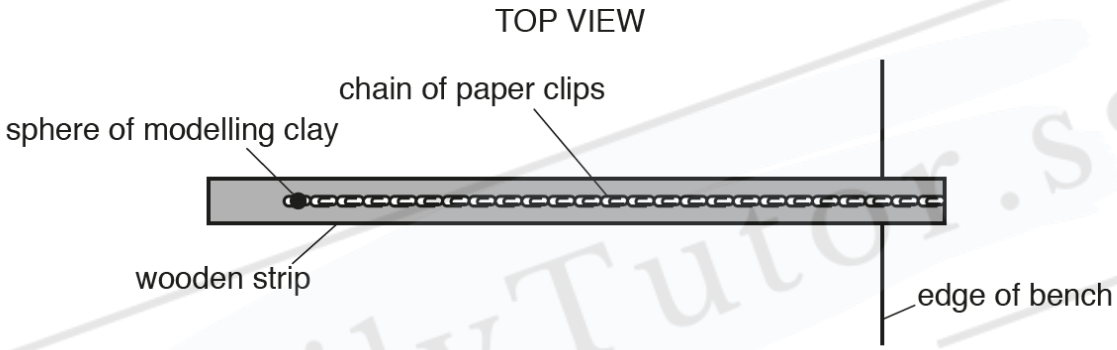

Fig. 2.2

Gradually move the paper clips off the end of the wooden strip so that they hang down, as shown in Fig. 2.3.

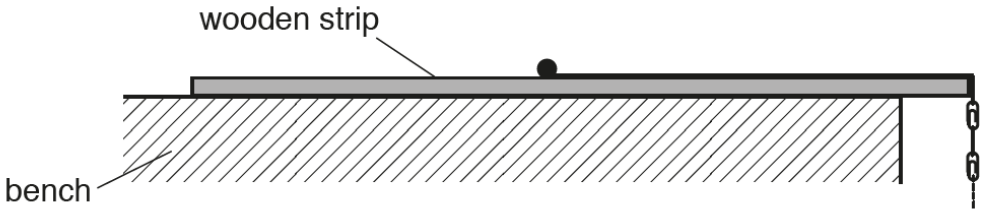

Fig. 2.3

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When the chain starts to slip, count and record the number p of paper clips hanging off the end of the wooden strip and the number q of paper clips remaining on the strip.

p = ...

q = ...
[2]

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

percentage uncertainty = ... [1]

(d) Replace the chain on the wooden strip and place both spheres on the paper clips at the end of the strip, as shown in Fig. 2.4.

Fig. 2.4

Determine p and q.

p = ...

q = ...
[1]

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(e) It is suggested that the relationship between p, q and c is

$$p = k\,(q + nc)$$

where n is the number of spheres on the chain and k is a constant.

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

first value of k = ...

second value of k = ...
[1]

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

.....

.....

.....

..... [2]

[Total: 12]

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3 In this experiment, you will observe the motion of two simple pendulums, and measure the interval between successive times at which the pendulums are moving together.

You will investigate how this time interval is affected when the length of one of the pendulums is changed.

(a) Set up two pendulums side by side as shown in Fig. 3.1, with each string clamped between two wooden blocks.

Set the length of pendulum A to about 0.65 m. Pendulum A should be left at its set length throughout the experiment.

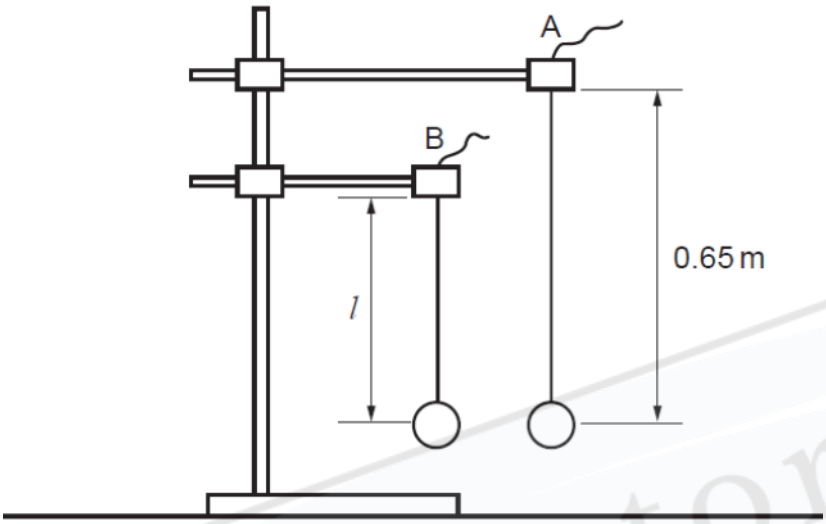

Fig. 3.1

(b) **(i)** Adjust pendulum B so that its length l is about 0.5 m.

Measure and record the value of l.

l = ... [1]

(ii) Estimate the percentage uncertainty of l.

percentage uncertainty = ... [1]

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(c) Set both pendulums into motion with small oscillations.

Start the stopwatch when the two pendulums are lined up as shown in Fig. 3.2 and are moving in the same direction.

side view

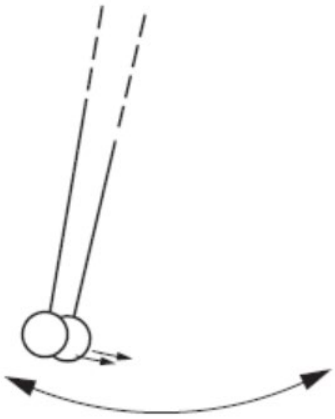

Fig. 3.2

(i) Determine the time t that elapses before the next occasion when the two pendulums are lined up and moving in the same direction.

t = ... [1]

(ii) Calculate the percentage uncertainty of t.

percentage uncertainty = ... [1]

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(d) Change the length of l to about 0.4 m.

Repeat **(b)(i)** and **(c)(i)**.

l = ...

t = ...
[2]

(e) It is suggested that

$$\frac{1}{t} = \frac{k}{\sqrt{l}}$$

where k is a constant.

(i) Use your values from **(b)(i)**, **(c)(i)** and **(d)** to determine two values of k. Give your values of k to an appropriate number of significant figures.

first value of k = ...

second value of k = ...
[2]

(ii) Justify the number of significant figures that you have given for your values of k.

.....

.....

.....[1]

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(iii) Explain whether your results support the suggested relationship. Justify your conclusion by referring to your values in **(b)(ii)** and **(c)(ii)**.

……..

……..

……..

…… [2]

(iv) Using the results obtained in **(e)(i)**, calculate the number of times pendulum B which is initially in phase will go out of phase and back in phase again in 1 minute when l is 10 cm.

number of times = …… [1]

(f) Describe a source of uncertainty or limitation of the procedure for this experiment.

……

……

…… [1]

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(g) In a separate investigation, the length L of pendulum B was varied. The results of $\frac{1}{t}$ and $\frac{1}{\sqrt{L}}$ were recorded in Fig. 3.3.

$\frac{1}{t}$ / s^{-1}	0.03	0.05	0.08	0.13	0.18
$\frac{1}{\sqrt{L}}$ / m$^{-1/2}$	1.29	1.35	1.40	1.50	1.60

Fig. 3.3

(i) Plot a graph of $\frac{1}{t}$ against $\frac{1}{\sqrt{L}}$ on the grid in Fig. 3.4 and draw the line of best fit.

[2]

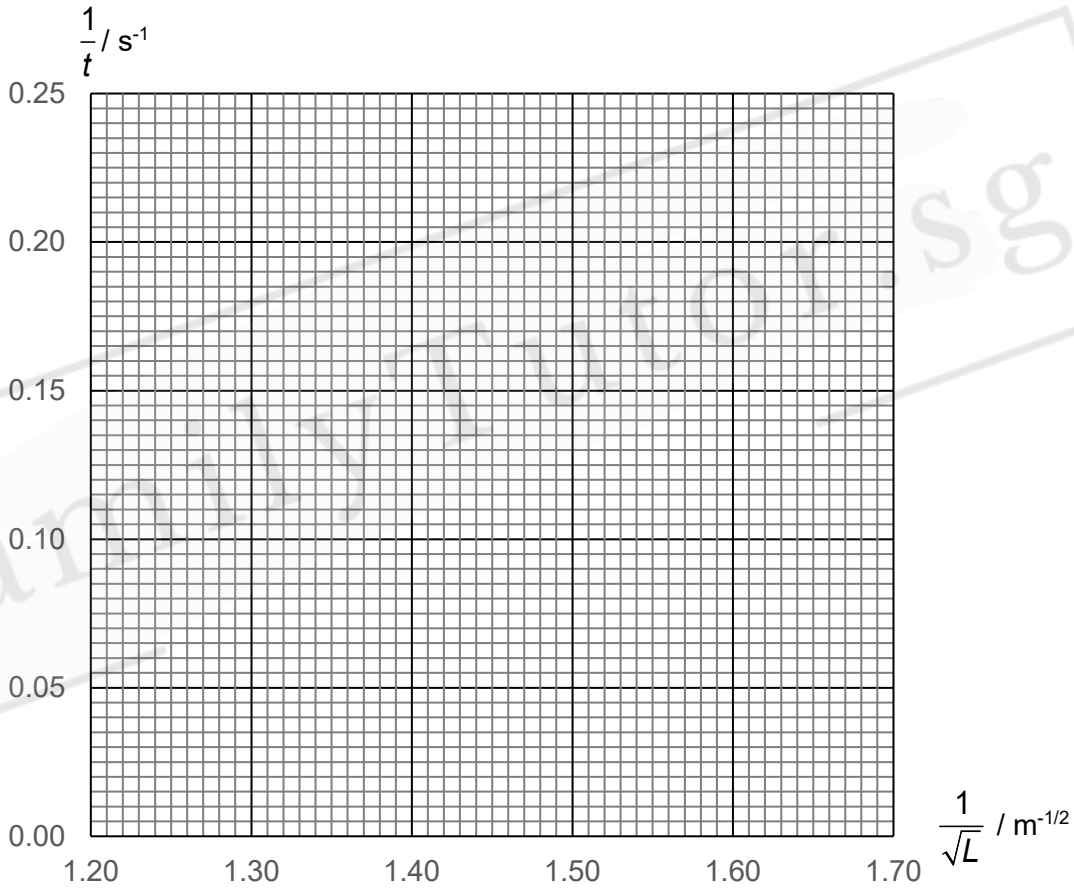

Fig. 3.4

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(ii) Determine the gradient of your graph in **(g)(i)**.

gradient = ... [1]

(iii) With reference to your graph in **(g)(i)**, state and explain if $\frac{1}{t}$ is directly proportional to $\frac{1}{\sqrt{L}}$.

.....

.....

.....[2]

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(h) A student wishes to investigate if the period T of a simple pendulum when it oscillates with small oscillations is directly proportional to the mass m of the pendulum.

Design an experiment to investigate this relationship.

You are provided with pendulums of different masses.

Your account should include:

- a diagram
- your experimental procedure
- control of variables
- how you would use your results to investigate the relationship.

.....

.....

.....

.....

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.....

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..... [4]

[Total: 22]

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4 A student is investigating the angle at which a glass cylinder containing oil topples, as shown in Fig.4.

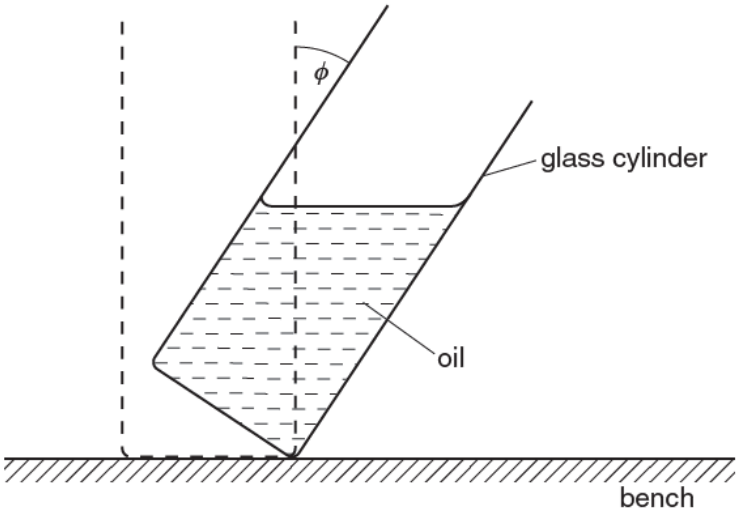

Fig. 4

A cylinder of diameter d containing a mass m of oil can be tilted through a maximum angle of ϕ from the vertical before it topples.

It is suggested that the relationship between d, m and ϕ is

$$\tan \phi = k\, d^{\,p}\, m^{\,q}$$

where k, p and q are constants.

Design an experiment to determine the values of p and q.

You are provided with several glass cylinders of different diameters.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

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

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Diagram

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TEST QUESTIONS AND ANSWER KEYS

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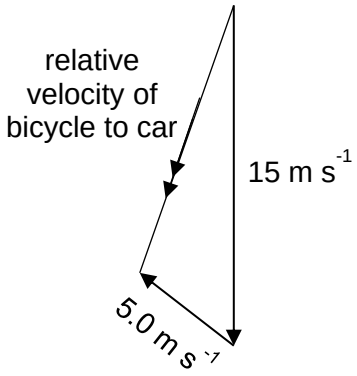
Paper 1 – Multiple Choice Questions

1	**Answer: A**
	 relative velocity of bicycle to car = velocity of bicycle – velocity of car = velocity of bicycle + (– velocity of car)

2	**Answer: A**
	Horizontally, $u\cos 30°t = 3.0 \Rightarrow t = \dfrac{3.0}{u\cos 30°}$ **Vertically**, taking upwards as positive, $u\sin 30°t - \dfrac{1}{2}gt^2 = -0.25$ Sub-in the expression for t above, $3.0\dfrac{\sin 30°}{\cos 30°} - \dfrac{1}{2}g\left(\dfrac{3.0}{u\cos 30°}\right)^2 = -0.25$ Solving, $u^2 = 29.7$, $u = 5.4$ m s^{-1} Option C: forgot to take square root Option B: took vertical displacement to be 0.25 m Option D: took vertical displacement to be 0.25 m and forgot to take square root

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3	**Answer: B**
	<u>From FBD of block A:</u> $F_{net} = ma$ $12 + 2.0 \times 9.81 \times \sin 35° - T = 2.0a$ $23.25 - T = 2.0a$ --> Eqn(1) **<u>From FBD of block B:</u>** $F_{net} = ma$ $T - 20 - 5.0 \times 9.81 \times \sin 20° - 20 = 5.0a$ $T - 36.78 = 5.0a$ --> Eqn(2) From Eqn(1), $58.125 - 2.5T = 5.0a$ -→ Eqn(3) (3) – (2): $94.905 - 3.5T = 0$ $T = 27$ N

4	**Answer: B**
	Horizontally, $50v_1 \cos 60^o - 50v_2 \cos 60^o = 0$ $v_1 = v_2$ Vertically, $50v_1 \sin 60^o + 50v_2 \sin 60^o - 100(8) = 0$ $50v \sin 60^o + 50v \sin 60^o - 100(8) = 0$ $v = 9.2$ m s^{-1}

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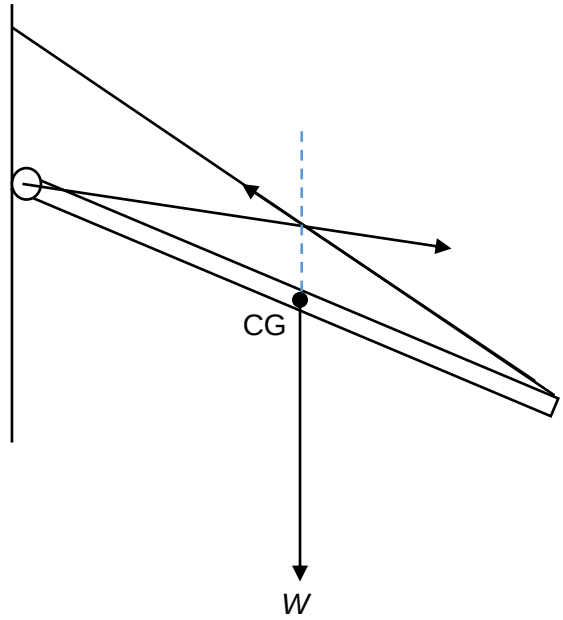
5	**Answer: A**
	 When 3 nonparallel forces act on a object in equilibrium, the must intersect at a point.

6	**Answer: B**
	Let d be the initial height from ground, h be the height at t. For E_P-s graph, $E_P = mgh$ $= mg(d-s)$ => Sketch $y = b - cx$ (where b, c are constants) For E_P-t graph, $E_P = mgd - mgs$ $= mgd - mg(ut+1/2gt^2)$ $= mgd - ½\ mg^2t^2$ => Sketch $y = p - qx^2$ (where p, q are constants)

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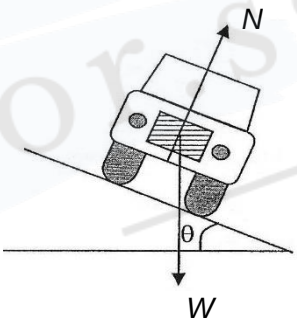
7	**Answer: C**
	$F = ma$ $F_{driving} - k(20)^2 = 1000(0.50)$ $F_{driving} = 500 + 400k$ $P = F_{driving}v$ $40 \times 10^3 = (500 + 400k)(20)$ $k = 3.75$ $P_{new} = F_{driving}v$ $P_{new} = F_{friction}v$ $P_{new} = kv^3 = (3.75)(25)^3 = 59$ kW

8	**Answer: C**
	Horizontal component of Normal contact force provides centripetal force $F_{net} = ma_c$ $N\sin\theta = \frac{mv^2}{r}$ ....(1) For vertical equilibrium: $N\cos\theta = mg$ .... (2) $\frac{(1)}{(2)}$: $\tan\theta = \frac{v^2}{rg}$ $v = \sqrt{50 \times 9.81 \times \tan 25°}$ $= 15.1$ m s^{-1} 

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9	**Answer: D**
	Gain in GPE = Loss in KE $mgr(1+\cos\theta)=\frac{1}{2}m(v_i^2-v_f^2)$ $gr(1+\cos\theta)=\frac{1}{2}(v_i^2-v_f^2)$ $(9.81)(7.7)(1+\cos 30^o)=\frac{1}{2}(25^2-v_f^2)$ $V_f = 18.5\ m\ s^{-1}$ Assume rod in tension $mg+F=\frac{mv^2}{r}$ $(3.5)(9.81)+F=\frac{(3.5)(18.5)^2}{7.7}$ F = 121 N (tension)

10	**Answer: B**
	$pV=nRT$ $z=nR(273.15)$ ---(1) $x=nRT_3$ ---(2) $\frac{(1)}{(2)}:\frac{z}{x}=\frac{273.15}{T_3}$ $T_3=273.15\frac{x}{z}$

11	**Answer: C**
	$p_xV_x = n_xRT$ $p_yV_y = n_yRT$ pV = nRT assuming no gas particles escaped out of the flasks, $n = n_x + n_y$ Therefore, $pV = (n_x + n_y)RT$ $= p_xV_x + p_yV_y$

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12	**Answer: D**
	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ $(1.00 \times 10^5) = \frac{1}{3}(1.60)\langle c^2 \rangle$ c_{rms} = 433 ms^{-1}

13	**Answer: A**
	$P_{supplied} = \frac{m}{t} l_f + h_{rate\ of\ heat\ loss}$ $P = \frac{m}{t} l_f + h_{rate\ of\ heat\ loss}$ $650 = \frac{(3.0)}{2.0 \times 60} l_f + h_{rate\ of\ heat\ loss}$ $1200 = \frac{(3.0)}{1.0 \times 60} l_f + h_{rate\ of\ heat\ loss}$ $1200 - 650 = \left[\frac{(3.0)}{1.0 \times 60} - \frac{(3.0)}{2.0 \times 60}\right] l_f$ $l_f = 22$ kJ kg^{-1}

14	**Answer: D**
	ΔU is zero as there is no change in temperature. W is zero as the volume of the refrigerator is assumed to be constant. Since, Q = ΔU – W, Q is also zero.

15	**Answer: B**
	At t = 0 s, the projection is at maximum amplitude. Hence displacement-time graph is cosine. Differentiating will give velocity-time and acceleration-time.

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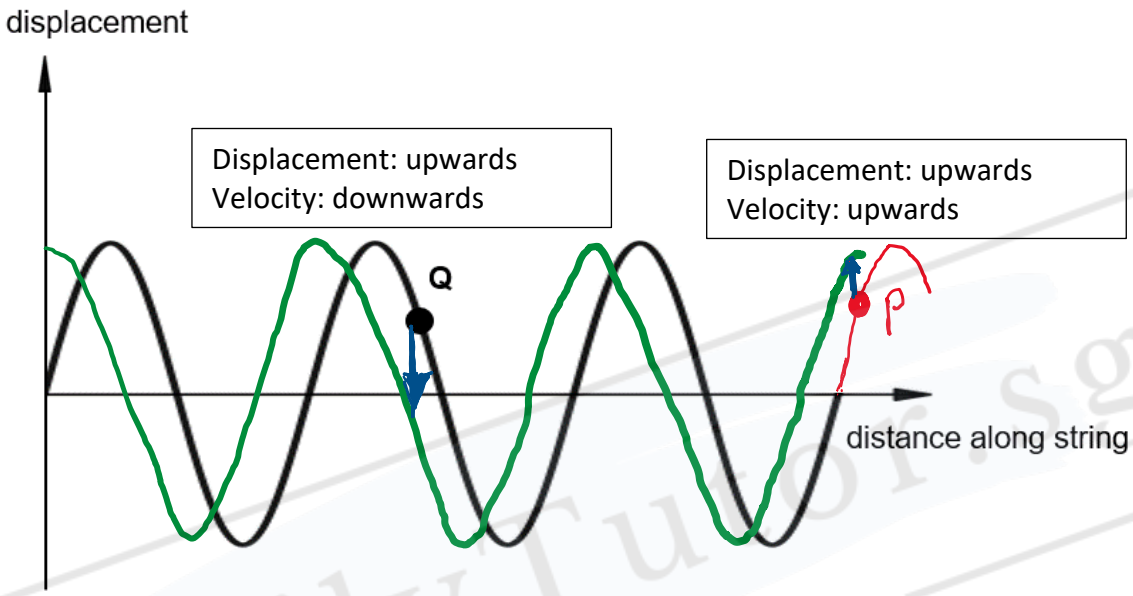
16	**Answer: C**
	The pulse undergoes 180^0 phase change upon hitting the fixed point O, options reduce to either C or D. However, the smaller amplitude portion will travel first before the larger amplitude portion as it is the portion that encounters fixed point O first. Thus, answer is C.

17	**Answer: A**
	

18	**Answer: A**
	The wavelength being 5.0 m, the path difference (147.5 – 135 = 12.5 m) corresponds to 2.5 wavelengths. Hence, the two waves meet in anti-phase. Intensity = k(amplitude)^2, k is a constant $\frac{I}{4I} = \frac{k * A_1^2}{k * A_2^2} \Rightarrow \frac{A_1}{A_2} = \frac{1}{2}$, or $A_2 = 2A_1$ When meet in anti-phase, the two vectors are in opposite direction. The resultant vector is the difference between them: $A_{tot} = A_2 - A_1 = 2A_1 - A_1 = A_1$ Hence, the resulting intensity is $I_{resultant} = kA_{tot}^2 = kA_1^2 = I$

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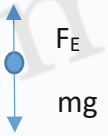
19	**Answer: B**
	$\sin\theta = \frac{\lambda}{2b} = \frac{1}{2}$ $\sin\theta \approx \frac{1}{2}\theta$ if angles are small *b* is doubled, double of the wave energy is allowed to pass through the slit. Since double of the energy is now spread over half the area, the maximum intensity is increased to 4 times.

20	**Answer: D**
	$x = \frac{\lambda D}{a}$ $y = \frac{\left(600\times10^{-9}\right)(1.00)}{a}$ $y = \frac{\left(400\times10^{-9}\right)D}{a}$ D = 1.50 m

21	**Answer: A**
	 At equilibrium, mg = F_E = qV/d When V increases to 2V, Resultant force, ma = q(2V)/d – mg = 2mg – mg = mg Therefore, a = g

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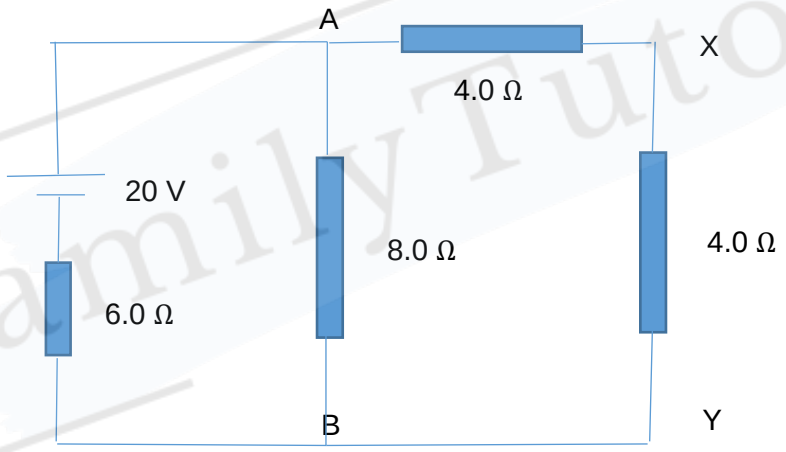
22	**Answer: A**
	I = nAvq I, n and q are constant. Therefore, A ∝ 1/v But A is linearly related to x, Hence v = k/(x+constant)

23	**Answer: A**
	Current in circuit, $I = P_{supply}/V_{supply} = 2400/240 = 10$ A $P_{kettle} = P_{supply} - P_{loss} = 2400 - (10^2)(0.5+0.5)$ $= 2300$ W Potential difference across kettle = 240 – (10)(0.5+0.5) = 230 V

24	**Answer: B**
	 Effective resistance between X and Y = 4.0 Ω Effective resistance between A and B = ½ (8.0) = 4.0 Ω By potential divider rule, potential difference between A and B = 20 × 4.0 /(6.0+4.0) = 8.0 V Therefore potential difference between X and Y = ½ (8.0) = 4.0 V

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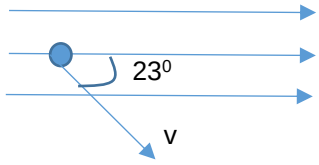
25	**Answer: A**

Conventional current direction due to electron going downwards at P

From Fleming's Left Hand Rule, electromagnetic force, F on electron is into the plane



B field (0.084 T)

F will always be perpendicular to the component of velocity normal to the B field. Hence electron will move in circular motion. At the same time, the component of velocity parallel to the B field remains constant. Hence, the electron will move in a helix.

$F = Bqv \sin\theta$

$v = \frac{7.3 \times 10^{-16}}{(0.084)(1.6 \times 10^{-19}) \sin 23^0}$

$= 1.4 \times 10^5 \text{ ms}^{-1}$.

26	**Answer: C**

Magnetic flux, $\phi = BA$ (where A is the area exposed to perpendicular B-field)
At 4s, Q and R are entirely within the field while coil P has length of 4.0 m within.
$\phi_P = 8B$; $\phi_Q = 6B$; $\phi_R = 12B$ (largest)

Magnetic flux linkage, $\Phi = N\phi$
$\Phi_P = 8B$; $\Phi_Q = 18B$(largest); $\Phi_R = 12B$

At 4s, coils Q and R would be experiencing maximum flux linkage. Hence no change in flux linkage => no induced e.m.f. and no induced current. Only coil P has changing flux linkage, induced e.m.f. and current.

27	**Answer: A**

The brightness depends on the power delivered to the bulb. The peak power is $p = \frac{V^2}{R}$, which does not depend on the frequency f of the alternating voltage.

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28	**Answer: B**
	Based on the uncertainty principle $\Delta x \Delta p \geq h$, $\Delta p = m\Delta v = 9.11\times10^{-31}\ (0.38 \times 3.0\times10^{8}) = 1\times10^{-22}$ kg m s^{-1} Min $\Delta x = 6.63\times10^{-34}/10^{-22} = 6\times10^{-12}$ m

29	**Answer: D**
	Activity $A = A_0 \exp(-\lambda t)$, where A_0 is the activity at t = 0. The decay constant is given by $\lambda = \frac{\ln 2}{t_{1/2}}$. A larger half-life yields a smaller λ. Hence, $\lambda_C > \lambda_N$. Taking natural log, $\ln A = -\lambda t + \ln A_0$. The graph of ln A vs t for each nuclide is a straight line with negative gradient ($-\lambda$). Initially, because of its short half-life, the activity of nuclide C dominates. So the initial part of the graph should be very close to that due to nuclide C alone, with gradient $-\lambda_C$. Later, nuclide C have mostly decayed, so nuclide N starts to dominate. The later part of the graph should be close to that due to nuclide N alone, with gradient $-\lambda_N$. Remembering that $\lambda_C > \lambda_N$, the graph should have less negative gradient (a gentler downward slope) in the later part than in the earlier part.

30	**Answer: B**
	The fact that most of the alpha particles pass straight through suggested that the atom is made up of mostly empty space with mass concentrated in the nucleus. The fact that a small proportion of alpha particles are deflected through large angles suggest that the nucleus is positively charged.

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JC2 PRELIMINARY YEAR EXAMINATIONS 2023
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME							
CIVICS GROUP	**2**	**2**	**-**			REGISTRATION NUMBER	

PHYSICS

9749/01

Multiple Choice Questions

22nd September 2023

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
The use of an approved scientific calculator is expected where appropriate.
Answer **all** questions.

There are **thirty** questions in this section.
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.

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

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Data

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

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
temperature,	$T\ /\ \text{K} = T\ /\ °\text{C} + 273.15$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\ \omega \sqrt{(x_0^2 - x^2)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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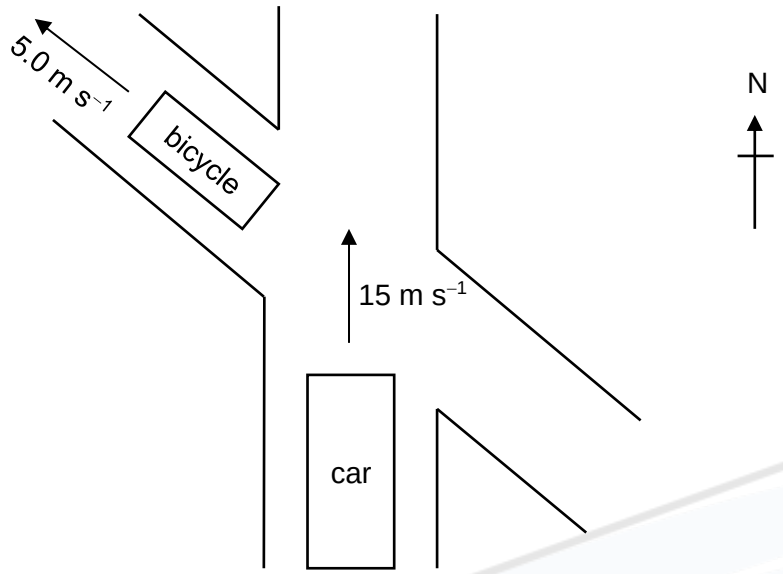
Section A – Multiple Choice Questions

1 A car and a bicycle are equal distances from a crossroads. The car is travelling north with a speed of 15 m s^{-1}.

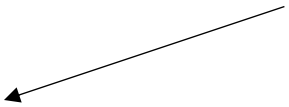
The bicycle is travelling northwest with a speed of 5.0 m s^{-1}.



At this instant, which arrow represents the velocity of the bicycle relative to the car?

A

B



C

D

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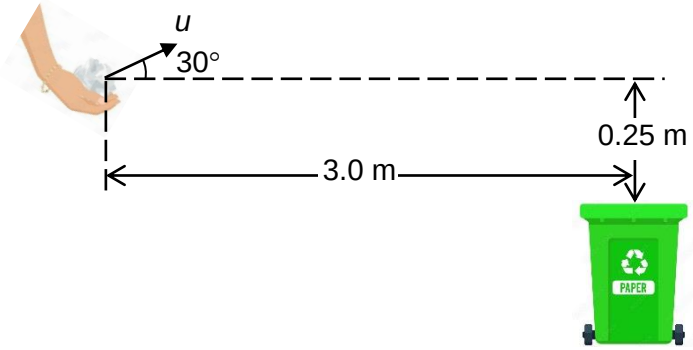
2 A student attempts a long distance shot with a crushed paper ball as shown in the diagram below (not to scale).

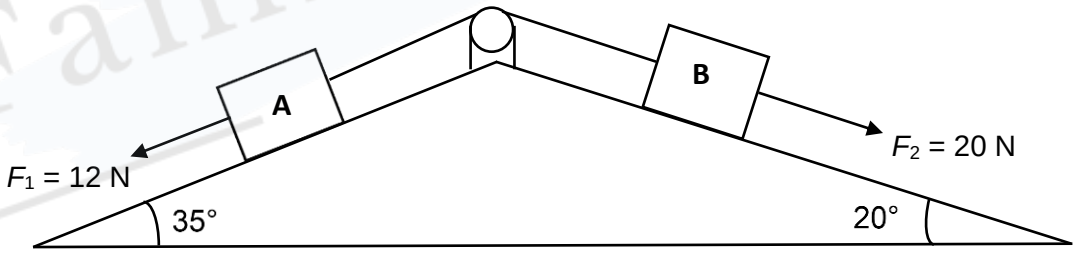


The horizontal distance between the centre of mass of the ball and the centre of the trash bin is 3.0 m, while the vertical distance between them is 0.25 m. The ball is shot at an angle of 30° above the horizontal, with an initial speed u.

Which value should u be, in order for the crushed paper ball to enter the trash bin?

A 5.4 m s^{-1} **B** 6.3 m s^{-1} **C** 30 m s^{-1} **D** 40 m s^{-1}

3 Two blocks, A and B, connected by a massless rope over a smooth pulley, are on a smooth incline plane with angles of inclination as shown in the diagram. The masses of blocks A and B are 2.0 kg and 5.0 kg respectively. The two blocks are acted upon by two external forces, F_1 and F_2, respectively as shown in the diagram with F_1 = 12 N and F_2 = 20 N.



What is the tension in the rope?

A 21 N

B 27 N

C 39 N

D 42 N

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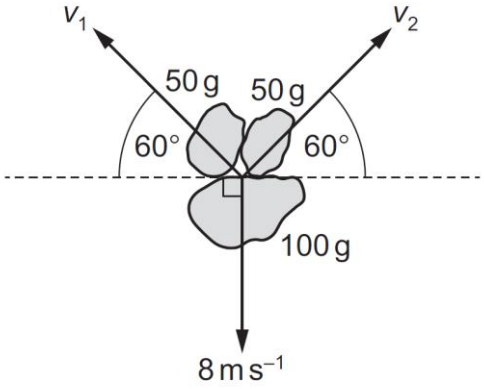
4 A stationary firework explodes into three pieces. The masses and the velocities of the three pieces immediately after the explosion are shown.



What is the speed v_1?

A 4.0 m s^{-1}

B 9.2 m s^{-1}

C 14 m s^{-1}

D 16 m s^{-1}

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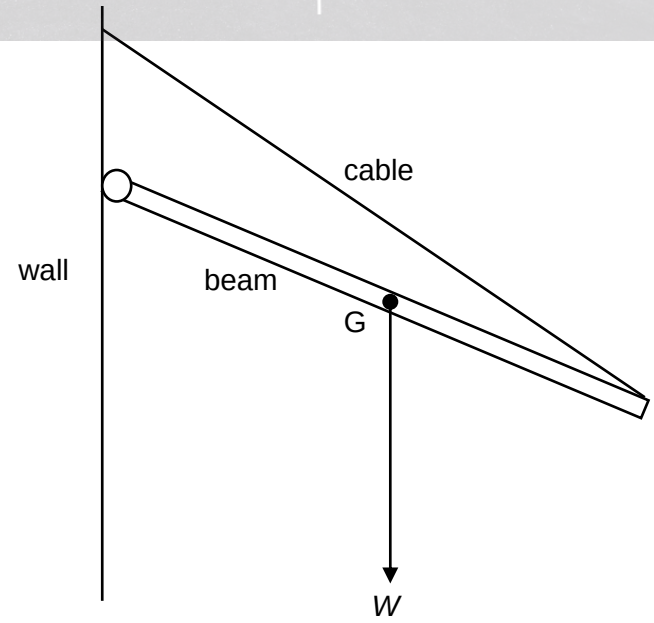
5 A uniform beam is freely hinged to a wall. It is held by a cable at the other end.



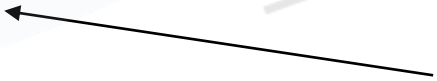
.

Its weight *W* acts through the centre of gravity G.

What is the direction of the force by the hinge on the beam?

A

B



C

D

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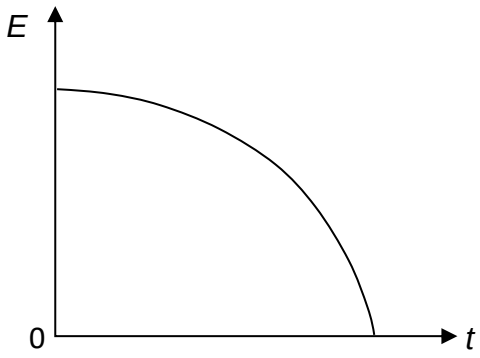
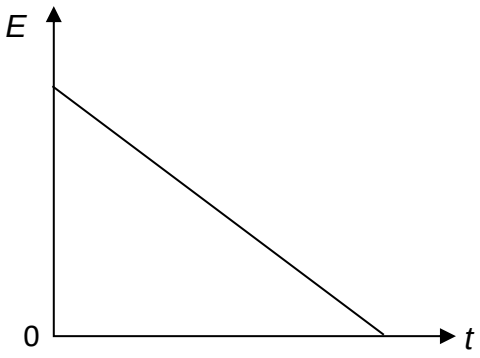
6 An object falls freely from rest. After time *t*, its displacement from origin is *s*.

Which graph(s) shows the correct relationship of how gravitational potential energy *E* of the ball varies?

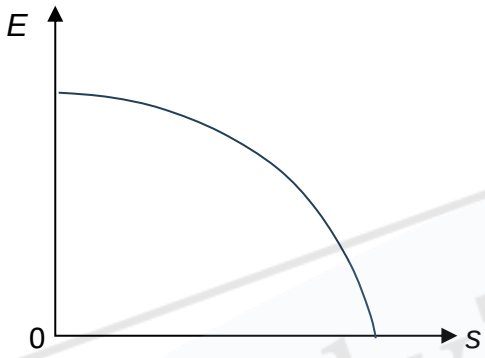
(i)



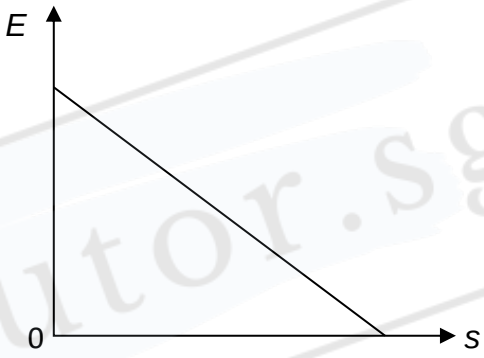
(ii)



(iii)



(iv)



A (i) and (iii) only
B (i) and (iv) only
C (ii) and (iii) only
D (ii) and (iv) only

7 A 1000 kg car travels along a road at with a constant acceleration of 0.50 m s^{-2}. At a speed of 20 m s^{-1}, its power output is 40 kW. The total resistive force on the car is proportional to the square of its speed.

What power will be required to travel at a constant speed of 25 m s^{-1}?

A 1.8 kW **B** 47 kW **C** 59 kW **D** 72 kW

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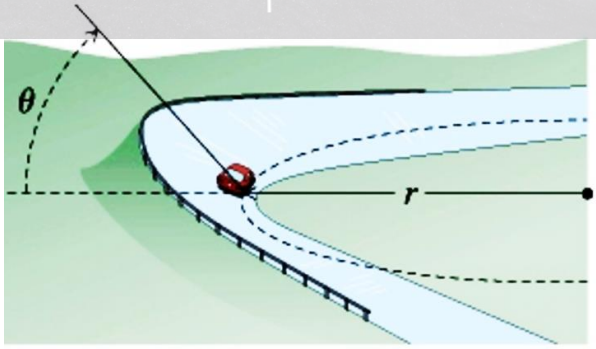
8 A car is driven round an icy road banked at an angle θ of 25° and a radius r of 50 m as shown.



The frictional force between the tyres and the road is negligible.

What is the speed that the car can travel at while maintaining the circular radius?

A 2.6 m s^{-1}

B 7.3 m s^{-1}

C 15.1 m s^{-1}

D 21.9 m s^{-1}

9 An object of 3.5 kg is fixed to one end of a light rod which rotates freely in a vertical circle. The length of the rod is 7.7 m.

When θ is 30°, the speed of the object is 25.0 m s^{-1}. Assume that there is no energy loss to the surrounding.

Which of the following describes the force in the rod when the object is at the top of the circular motion?

A 94 N in compression

B 94 N in tension

C 121 N in compression

D 121 N in tension

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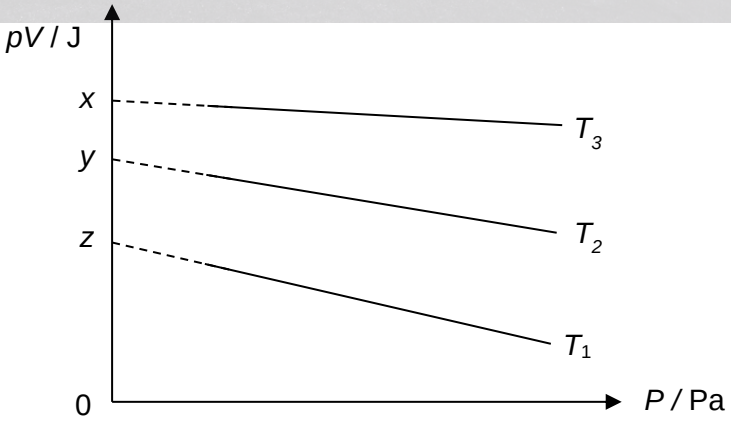
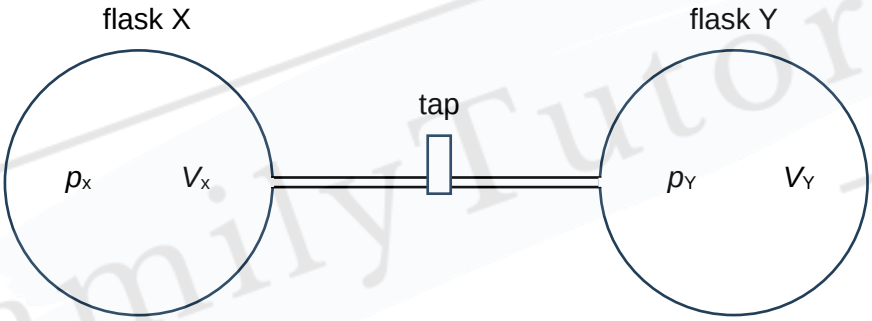
10 The given graph shows the isotherms obtained from a sample of real gas. The temperature T_1 is the ice-point (273.15 K) and T_2 is the boiling point of water at standard pressure.



What is the thermodynamic temperature T_3 in kelvin?

A $273.15\dfrac{(x-y)}{(y-z)}$ **B** $273.15\dfrac{x}{z}$ **C** $273.15+100\dfrac{x}{z}$ **D** $273.15+100\dfrac{(x-y)}{(y-z)}$

11 Some ideal gas is contained in two flasks X and Y. The flasks are connected by a tube of negligible volume that is fitted with a tap, as shown.



With the tap closed, the pressure and volume of the gas in the flask X are p_x and V_x respectively. In flask Y, the gas has pressure p_Y and volume V_Y. The temperature of the gas in both flasks is T.

The tap is opened. After some time, the temperature of the gas returns to T at pressure P and volume V.

Which expression relates the pressures and the volumes before and after opening the tap once the temperature has returned to T?

A $pV=(p_x-p_y)\times(V_x-V_y)$

B $pV=\dfrac{1}{2}(p_x+p_y)\times\dfrac{1}{2}(V_x+V_y)$

C $pV=p_xV_x+p_yV_y$

D $pV=(p_x+p_y)\times(V_x+V_y)$

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12 The density of argon at a pressure of 1.00×10^5 Pa and at a temperature of 300 K is 1.60 kg m^{-3}.

There are 4.35×10^{30} molecules of argon in a container.

What is the root mean square speed of argon molecules at this temperature?

A 216 m s^{-1}

B 250 m s^{-1}

C 306 m s^{-1}

D 433 m s^{-1}

13 An experiment was carried out to determine the specific latent heat of fusion of an unknown solid. Two power settings were used.

The power rating of the heater P and the time t to melt 3.0 kg of the solid were recorded in the table below.

P / W	t / min
650	2.0
1200	1.0

What is the specific latent heat of fusion of the solid?

A 22 kJ kg^{-1} **B** 24 kJ kg^{-1} **C** 25 kJ kg^{-1} **D** 26 kJ kg^{-1}

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14 The contents of a refrigerator are at a constant temperature, and the surroundings of the refrigerator are at a higher temperature. Because of this, thermal energy flows into the refrigerator from outside, and is removed at the same rate by cooling mechanism.

The first law of thermodynamics may be applied to the contents of the refrigerator. This law is represented by $\Delta U = Q + W$ where ΔU is the increase of internal energy of the contents of the refrigerator, Q is the net heating of the contents and W is the mechanical work done on the contents.

For the refrigerator contents, which of the following quantities ΔU, Q and W is/are zero?

A ΔU only

B Q only

C W only

D each of ΔU, Q and W

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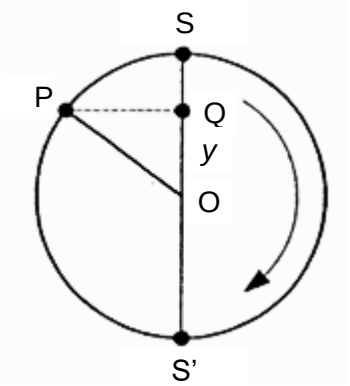
15 The given diagram shows a particle rotating clockwise in a horizontal circle of radius r with a constant angular velocity ω. At time t, the particle is at P. At $t = 0$, the particle is at S. The projection of P on the diameter through SS' is represented by Q. With respect to the origin O, the displacement, linear velocity and linear acceleration of Q in the direction OS are y, v and a respectively.



Which set of expressions is correct?

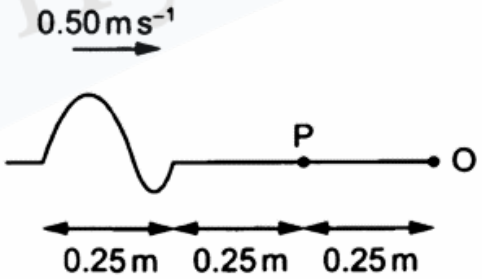
A $y = r\cos\omega t\,;\, v = -r\omega\sin\omega t\,;\, a = r\omega^2\cos\omega t$

B $y = r\cos\omega t\,;\, v = -r\omega\sin\omega t\,;\, a = -r\omega^2\cos\omega t$

C $y = r\cos\omega t\,;\, v = -r\omega\cos\omega t\,;\, a = r\omega^2\sin\omega t$

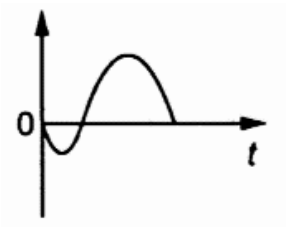
D $y = r\sin\omega t\,;\, v = -r\omega\cos\omega t\,;\, a = r\omega^2\sin\omega t$

16 A wave pulse of length 0.25 m is shown at the time $t = 0$. It moves along a string, fixed at O, at 0.50 m s^{-1}. There is a phase change of π rad upon reflection.

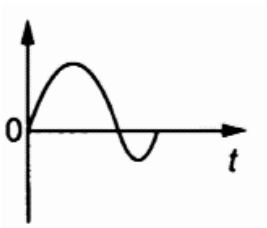


Which graph best represents the displacement of point P with time for the period $t = 1.5$ s to 2.0 s?

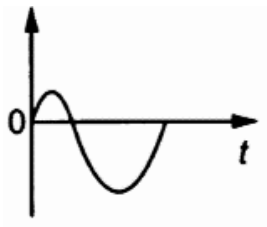
A



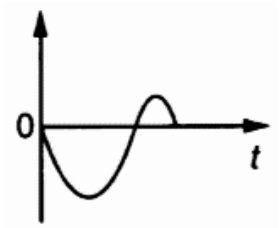
B



C



D



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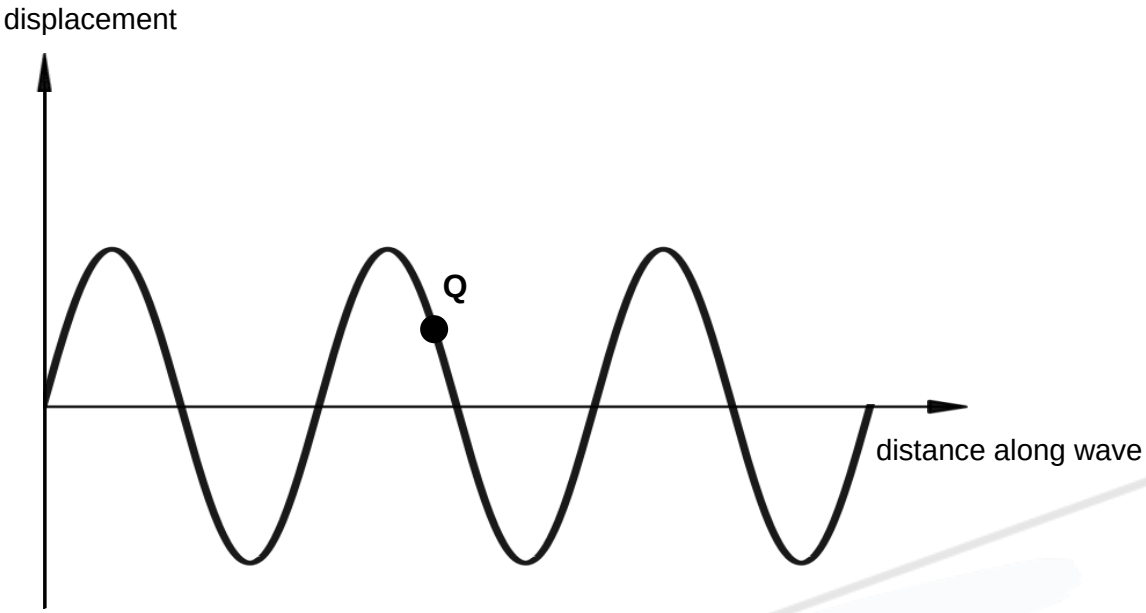
17 The graph shows the shape at a particular instant of part of a transverse wave. Point Q is displaced upwards but is moving downwards. Point P is $\frac{7}{4}$ of a wavelength away from point Q.

The wave moves leftwards and travels from P to Q.



Which of the following statements about the displacement and direction of velocity of P is correct?

A P is displaced upwards and moving upwards.

B P is displaced upwards and moving downwards.

C P is displaced downwards and moving downwards.

D P is displaced downwards and moving upwards.

18 Two coherent sources that are in phase with each other emit waves of wavelength 5.0 m. At a point 135.0 m from one source and 147.5 m from the other, the intensities due to the two sources individually are, respectively, I and $4I$.

What is the resultant intensity at that point?

A I **B** $3I$ **C** $5I$ **D** $9I$

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19 The diffraction pattern is formed when a single slit of width 0.60 mm is illuminated with monochromatic light of wavelength 550 nm. The width of the central maximum is *w* and the peak intensity is I_o.

The slit width is then doubled.

Given that the angle of diffraction is small, which row correctly shows the new width of the central maximum and the peak intensity?

	width of central maximum	peak intensity
A	½ *w*	$2\,I_o$
B	½ *w*	$4\,I_o$
C	2 *w*	$\frac{1}{2}\,I_o$
D	2 *w*	$\frac{1}{4}\,I_o$

20 Fringes of separation *y* are observed in a plane 1.00 m from a Young's double slit illuminated by yellow light of wavelength 600 nm.

At what distance from the slits would fringes of the same separation *y* be observed when using blue light of wavelength 400 nm?

A 0.33 m

B 0.67 m

C 0.75 m

D 1.50 m

21 An oil-drop of mass *m,* carrying a charge *q*, is in the region between two horizontal plates. When the potential difference between the upper and lower plates is *V*, the drop is stationary. The potential difference is then increased to 2*V*.

What is the initial upward acceleration of the oil-drop?

A *g* **B** 2*g* **C** $\frac{qV}{m}$ **D** $\frac{2qV}{m}$

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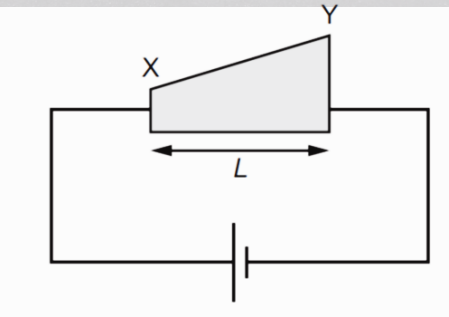
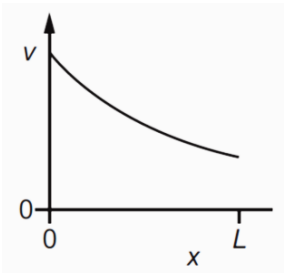
22 A wedge-shape metal conductor of length *L*, varying width and uniform thickness is connected to a cell, as shown.

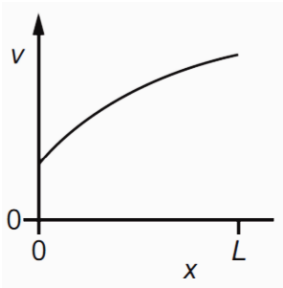


Which graph best shows how the average drift velocity *v* of the electrons in the conductor varies with distance *x* from end X?

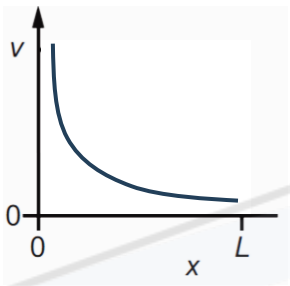
A



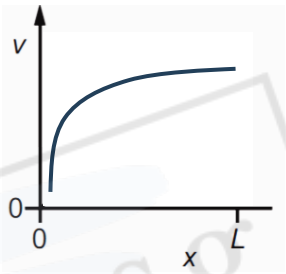
B



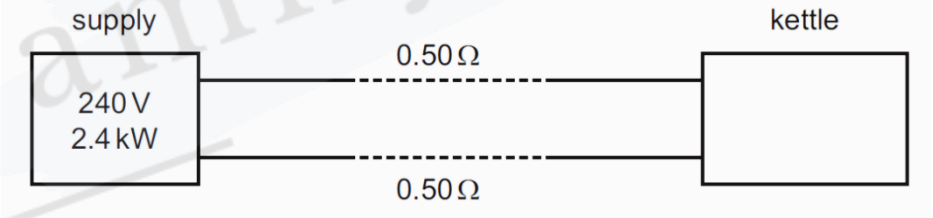
C



D



23 The power output of an electrical supply is 2.4 kW at a potential difference (p.d.) of 240 V. The two wires between the supply and a kettle each have a resistance of 0.50 Ω, as shown.



What is the power supplied to the kettle and the p.d. across the kettle?

	power / kW	p.d. / V
A	2.3	230
B	2.3	235
C	2.4	230
D	2.4	235

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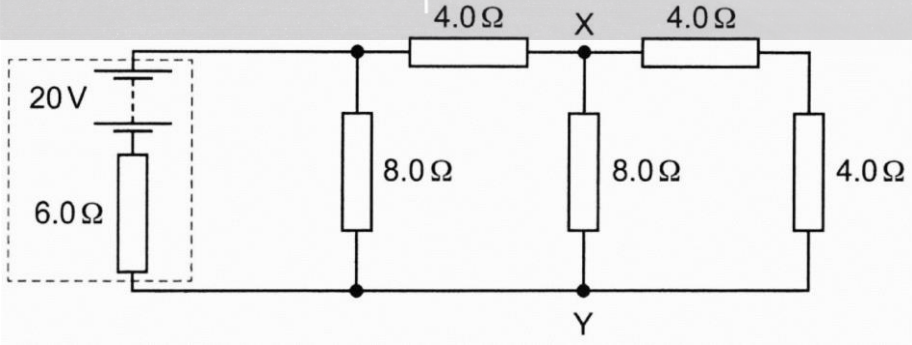
24 A battery of e.m.f. 20 V and internal resistance 6.0 Ω is connected to a network of resistors.



What is the potential difference between junctions X and Y?

A 2.0 V **B** 4.0 V **C** 6.0 V **D** 8.0 V

25 The force on an electron is 7.3×10^{-16} N when moving at an angle of 23° to a uniform magnetic field of magnetic field strength of 0.084 T.

What is the speed of the electron and what is the shape of the path of the electron?

A 1.4×10^{5} m s^{-1} in a helix

B 1.4×10^{5} m s^{-1} in a spiral

C 2.1×10^{4} m s^{-1} in a helix

D 2.1×10^{4} m s^{-1} in a spiral

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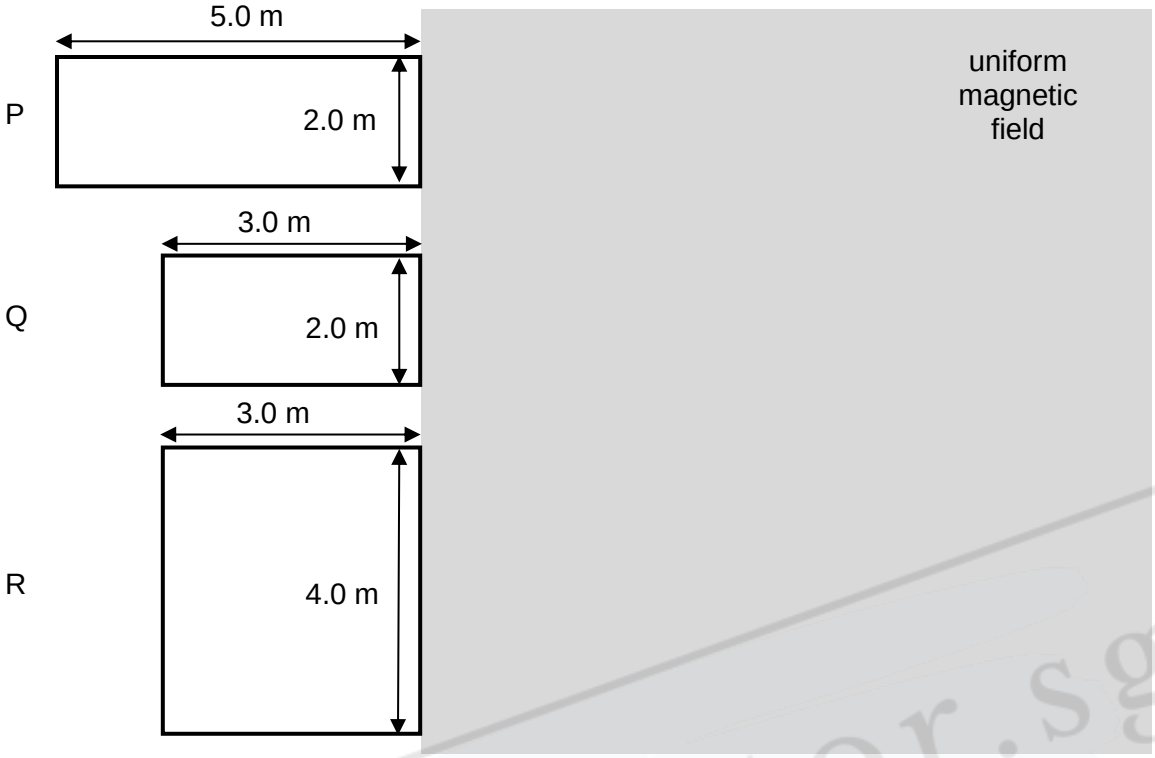
26 Three conducting coils P, Q, and R of the same material just enter a region of uniform magnetic field at t = 0 with constant velocity of 1.0 m s^{-1}.

Coils P, Q and R have 1, 3 and 1 number of turn(s) respectively.



After 4.0 s, which row shows the coils with the largest magnetic flux, magnetic flux linkage and induced current?

	largest magnetic flux	largest magnetic flux linkage	largest induced current
A	Q	R	P
B	P	Q	R
C	R	Q	P
D	Q	P	Q

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27 An alternating potential difference, with peak value V and frequency f, is applied across a light bulb of resistance R. The bulb lights up.

Which of the following changes would result in the maximum increase in the brightness of the bulb?

	V	f	R
A	doubles	doubles	halves
B	halves	doubles	doubles
C	doubles	increases by 4 times	doubles
D	halves	increases by 8 times	halves

28 An electron moves along the x-axis. The speed of the electron is measured with an uncertainty of 0.38*c*.

What is the smallest uncertainty in position of the electron?

A 10^{-22} m

B 10^{-12} m

C 10^{8} m

D 10^{10} m

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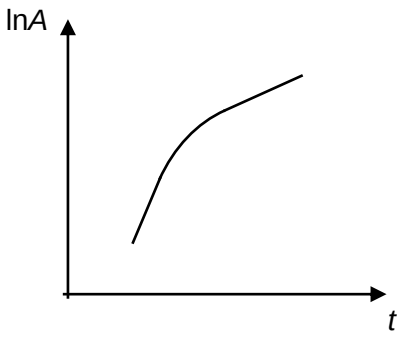
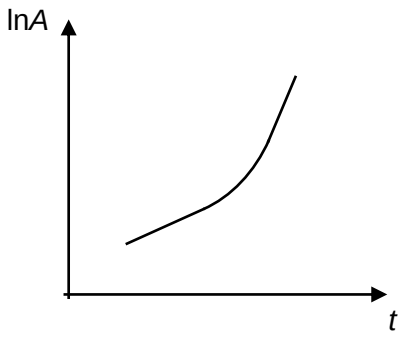
29 Nuclide C has a half-life of 5 years, while nuclide N has a half-life of 90 years. The activity *A* of a mixture of C and N is measured.

Which graph best represents the variation with time *t* of the natural logarithm of *A*?

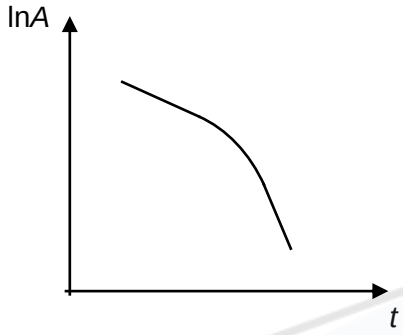
A



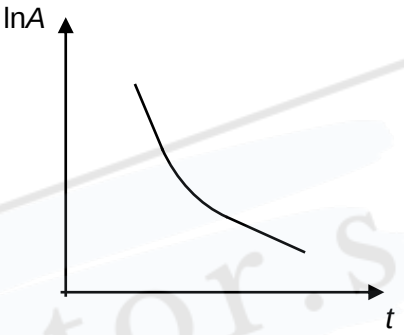
C



B



D



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30 What did the Rutherford scattering experiment reveal about the atomic structure?

A Electrons are distributed uniformly throughout the atom.

B The nucleus is charged and contains most of the atom's mass.

C Electrons move in discrete energy levels around the nucleus.

D The atom is composed of protons, neutrons, and electrons.

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Paper 2 – Structured

Qns	Answer	Marks
1(a)(i)	Precision is determined by the range in the values. Range of Set A = 1.55 – 1.43 = 0.12 cm Range of Set B = 1.58 – 1.42 = 0.16 cm Range of Set C = 1.56 – 1.45 = 0.11 cm Therefore, Set C is more precise as the range of values are smaller than the other two sets.	M1 for all correct values A1
1(a)(ii)	Accuracy is determined by the closeness of the measured value to the true value. Average values for Set A = $\frac{1.52+1.49+1.43+1.52+1.55}{5} = 1.502 = 1.50$ Average values for Set B = $\frac{1.42+1.45+1.43+1.51+1.58}{5} = 1.478 = 1.48$ Average values for Set C = $\frac{1.45+1.56+1.47+1.53+1.46}{5} = 1.494 = 1.49$ Therefore, Set A is more accurate as the average values are closer to the true value of the diameter.	M1 for all correct values A1

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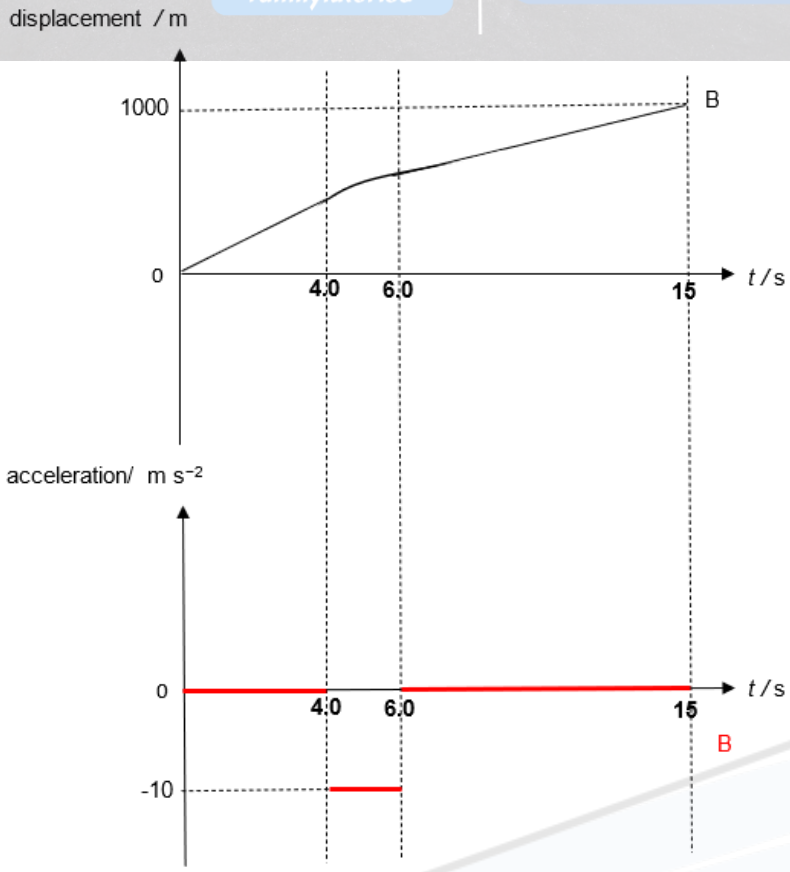
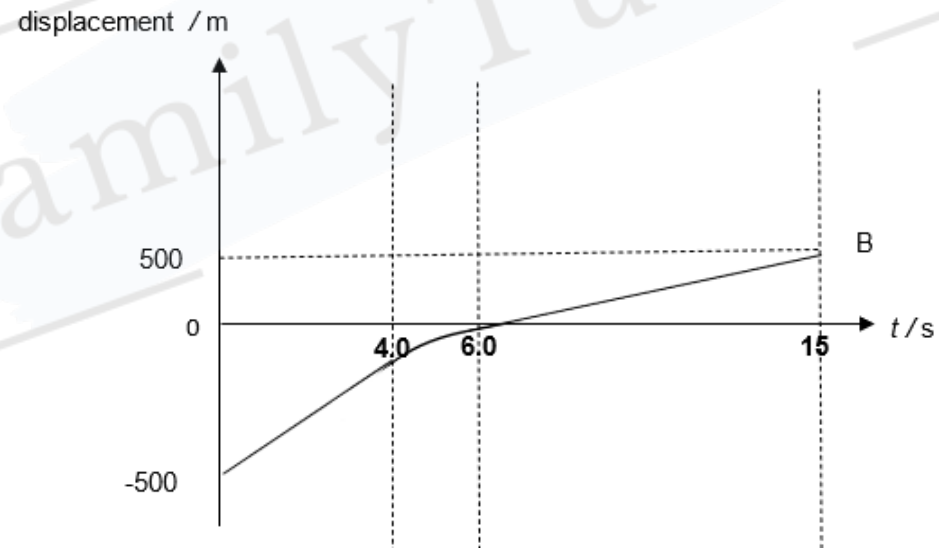
Qns	Answer	Marks
1(b)(i)		B1
		B1
	Alternative *s-t* graph 	
	For *s-t* graph: 1m – for correct sketch of graph for car B and correct displacement value Also, gradient of the line for first 4.0s must be greater than the gradient of the line for the last 9.0s **For a-*t* graph:** 1m – for correct sketch of graph for car B and correct acceleration value	

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Qns	Answer	Marks
1(b)(ii)	Minimum distance occurs when both cars have the same speed (v = 60 m s^{-1}).	B1
	Distance covered by Car A during the 6.0 s = $\left[\frac{1}{2}\times(25+60)\times 6.0\right]$ = 255 m	C1 for both correct answer
	Distance covered by Car B during the 6.0 s : $(80\times 4.0)+\left[\frac{1}{2}\times(80+60)\times 2.0\right]$ = 460 m	
	Minimum distance = (500 + 255) - 460 = 295 m	A1

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Qns	Answer	Marks
2(a)	No resultant force (in any direction) No resultant moment (about any point)	B1 B1
2(b)	Let the length of the rod be L. Take moment about the wall hinge. Sum of clockwise moment = Sum of anticlockwise moment $80\left(\frac{1}{2}L\sin 60^o\right) = T\left(L\sin 50^o\right)$ T = 45.2 N Let the vertical force at hinge be R_y. Let the horizontal force at hinge be R_x. No resultant force in vertical direction: $R_y + T\cos(180^o - 60^o - 50^o) = W$ $R_y + (45.2)\cos 70^o = 80$ R_y = 64.5 N No resultant force in horizotal direction: $R_x = T\sin(180^o - 60^o - 50^o)$ $R_x = (45.2)\sin 70^o$ R_x = 42.5 N Force by hinge on rod $R = \sqrt{R_x^{\,2} + R_y^{\,2}}$ $R = \sqrt{42.5^2 + 64.5^2}$ = 77.2 N Let θ be the angle of R from the wall $\tan\theta = \frac{R_x}{R_y}$ $\tan\theta = \frac{42.5}{64.5}$ $\theta = 33.4^o$ from wall	M1 A1 C1 A1 A1

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Qns	Answer	Marks
3a	Let speed of X before hitting Y be v_i	
	Gain in KE = Loss in GPE	B0
	$\frac{1}{2}mv_i^2 = mgh_i$	M0
	$v_i = \sqrt{2gh_i} = \sqrt{2\times 9.81\times 1.50\sin 40°}$	A1
	$v_i = 4.35$ m s^{-1}	
3bi	Let speed of X after hitting Y be v_f	
	Loss in KE = Gain in GPE	
	$\frac{1}{2}mv_f^2 = mgh_f$	
	$v_f = \sqrt{2gh_f} = \sqrt{2\times 9.81\times 0.80\sin 40°}$	
	$v_f = 3.18$ m s^{-1}	M1
	EITHER	
	Since collision is elastic,	
	Relative speed of approach = relative speed of separation	
	$v_i = v_y - v_f$	M1
	$4.35 = v_y - (-3.18)$	
	$v_y = 1.17$ m s^{-1}	A1
	OR	
	By conservation of linear momentum,	
	$m_X u_X = m_X v_X + m_Y v_Y$	
	$30(4.35+3.18) = m_Y v_Y \quad \cdots(1)$	(either eqn correctly written)
	By conservation of energy	M1
	Loss in KE of X = Gain in KE of Y	
	$\frac{1}{2}m_X u_X^2 - \frac{1}{2}m_X v_X^2 = \frac{1}{2}m_Y v_Y^2$	
	$30(4.35^2 - 3.18^2) = m_Y v_Y^2 \quad \cdots(2)$	
	Taking (2) ÷ (1)	
	$v_Y = 1.17$ m s^{-1}	A1

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Qns	Answer	Marks
3bii	Gain in KE of Y = Loss in GPE of X	B1
	$\frac{1}{2}m_Y v_y^{\ 2} = m_X g\Delta h$ $m_Y = \frac{2m_X g\Delta h}{v_y^{\ 2}}$ $m_Y = \frac{2(0.030)(9.81)\sin 40°(1.50-0.80))}{1.17^2}$ $m_Y = 0.192$ kg $m_Y = 190$ g	M1 A0
	OR From (b)(i) Using the law of conservation of momentum in (1) and energy in (2) $30^2(4.35+3.18)^2 = m_Y^{\ 2}v_Y^{\ 2}$ $\cdots(1)^2$ $30(4.35^2 - 3.18^2) = m_Y v_Y^{\ 2}$ $\cdots(2)$ Taking $(1)^2 \div (2)$ $m_Y = 193$ g = 190 g (2 s.f.)	B1 M1 A0
3ci	The collision is inelastic because the relative speed of approach is non-zero but the relative speed of separation is zero, which means that they are not equal.	A1
3cii	By conservation of linear momentum, $m_X v_i = (m_X + m_Y)v'$ $v' = \frac{m_X v_i}{m_X + m_Y}$ $v' = \frac{(0.030)(4.35)}{0.030+0.190}$ $v' = 0.5932$ m s^{-1} $v' = 0.59$ m s^{-1}	M1 A0

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Qns	Answer	Marks
3ciii	Loss in KE = Gain in GPE + work done against friction	B1
	$\frac{1}{2}(m_X + m_Y)(v')^2 = (m_X + m_Y)gd\sin 50° + fd$	
	$\frac{1}{2}(m_X + m_Y)(v')^2 = ((m_X + m_Y)g\sin 50° + f)d$	
	$d = \frac{\frac{1}{2}(0.030 + 0.190)(0.59^2)}{(0.030 + 0.190) \times 9.81 \times \sin 50° + 2.2}$	M1
	$d = 0.0099$ m	A1
	OR	
	Resultant force along the slope = friction + component of weight	
	$ma = 2.2 + mg\sin 50°$	
	$a = \frac{2.2}{0.220} + (9.81)\sin 50°$	
	$a = 17.51\ \text{m s}^{-2}$	(M1)
	where a is directed downslope.	
	Using $v^2 = u^2 + 2as$, where s is the distance travelled up the slope, d.	(C1)
	$0 = (0.59)^2 - 2(17.51)d$	
	$d = 0.0099$ m	(A1)

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Qns	Answer	Marks
4a	Electric force per unit positive charge on a small stationary test charge at that point.	 B1
4bi	Considering the distance between the nearest two equipotential lines around point A (4V and 0V) d = 3.5 cm $E = \Delta V/d = (4–0)/(3.5\times10^{-2})$ $F = eE = 1.6 \times 10^{-19} \times (4–0)/(3.5\times10^{-2})$ $= 1.8 \times 10^{-17}$ N	 M1 A1
4bii	From point B to C, $\Delta V = –6 –4 = –10$V Change in $E_P = e\Delta V = –1.6 \times 10^{-19}$ (–10) $= 1.6 \times 10^{-18}$ J (Gain) By Principle of Conservation of Energy, Loss in Kinetic energy = Gain in Electric Potential Energy ½ mu^2 – ½ $mv^2 = 9.6 \times 10^{-19}$ ½ $(9.11 \times 10^{-31})(5.3 \times 10^6)^2$ – ½ $(9.11 \times 10^{-31})v^2 = 1.6 \times 10^{-18}$ $v = 5.0 \times 10^6$ m s^{-1}	 C1 C1 A1
c	The change in potential from P to Q can be determined by estimating the area under the graph, 1 square : (0.5×10^3) V $m^{-1} \times 10^{-2}$ m = 5 V 18 squares : 18 × 5 = 90 V Change in potential energy = $1.6 \times 10^{-19} \times 90 = 1.44 \times 10^{-7}$ J	 C1 C1 A1

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Qns	Answer	Marks
5(a)	$R_{diode} = \frac{V}{I} = \frac{0.56}{6.0\times10^{-3}} = 93\ \Omega$	A1
5(b)	$E = V_{diode} + V_{R3}$ $1.2 = 0.56 + (6.0\times10^{-3})R_3$ $R_3 = 110\ \Omega$	C1 A1
5(c)	$I = \frac{E}{R_1 + R_2}$ $= \frac{1.2}{50 + 200}$ $= 4.8\times10^{-3}\ \text{A}$	C1 A1
5(d)	$I_{total} = 6.0\times10^{-3} + 4.8\times10^{-3} = 1.1\times10^{-2}\ \text{A}$ $P = I_{total}E = (1.1\times10^{-2})(1.2)$ $P = 1.3\times10^{-2}\ \text{W}$	C1 A1
5(e)	$\frac{x}{1.0} = \frac{50}{250}$ $x = 0.20\ \text{m}$	C1 A1

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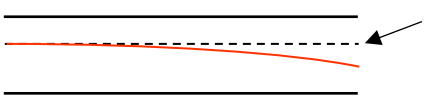
Qns	Answer	Marks
6(a)(i)	The magnetic force is downwards (by FLHR, B points into the paper and current is to the left) in the region between the plates, hence the electric force must be upwards. Since the particles are negatively charged, the electric field must be downwards (opposite to the electric force). Hence, P is positive. (Plate Q is grounded, hence is at 0 V.)	B1 B1
6(a)(ii)	To move undeflected, the net force must be zero. $F_E = F_B$ $qE = qvB$ $v = \frac{E}{B}$	M1 A0
6(a)(iii)	 $v > \frac{E}{B} \Rightarrow qvB > qE$, or $F_B > F_E$. Since the magnetic force F_B points downwards, the particles will be deflected downwards. (Note that the path is not parabolic.)	B1 B1
6(b)(i)	The magnetic force is always perpendicular to the velocity. Hence, it does no work on the particles. The kinetic energy, hence the speed, of the particle remain constant.	B1 B1
6(b)(ii)	The magnetic force provides the centripetal force. $qvB = m\frac{v^2}{r} \Rightarrow \frac{q}{m} = \frac{v}{Br}$ With $v = \frac{E}{B}$, $\frac{q}{m} = \frac{E}{B^2 r}$	M1 M1 A0

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Qns	Answer	Marks
7(a)	t = 1.2 s $E = \frac{d(N\phi)}{dt} = NA\frac{dB}{dt} = \frac{560 \times \pi \times 0.045^2 \times 0.250}{1.2}$ = 0.74 V or 0.742 V (accept 2 s.f. or 3 s.f.)	C1 A1
7(b)	Sheet cuts magnetic flux / experiences a changing magnetic flux (linkage) and causes induced e.m.f. in sheet (induced) e.m.f. causes (induced eddy) currents (in sheet) **Option 1:** Currents (in sheet is in a magnetic field which) cause resistive force **Option 2:** Currents (in sheet) dissipate (thermal) energy. (Thermal energy comes from energy of oscillations) **Option 3:** Currents (in sheet) produce a magnetic field around sheet which is in opposite direction to the external magnetic field and the sheet is repelled (current cannot pass all the way around the sheet / path of current is broken / not a complete/closed loop) **Option 1:** Smaller currents in Y OR smaller resistive force in Y **Option 2:** Larger currents in X OR larger resistive force in X, so **dashed line is X**	B1 B1 B1 B1

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<table>
<tr><th>Qns</th><th>Answer</th><th>Marks</th></tr>
<tr><td>8(a)(i)</td><td>Label V between 400-700 nm on the horizontal axis.</td><td>B1</td></tr>
<tr><td>8(a)(ii)</td><td>Wavelengths corresponding to red light would have the greatest intensity within the spectrum of visible light.</td><td>B1</td></tr>
<tr><td>8(b)(i)</td><td>
<table>
<tr><th>T / K</th><th>λ_{max} / nm</th><th>$T \times \lambda_{max}$</th></tr>
<tr><td>600</td><td>4830</td><td>2898000</td></tr>
<tr><td>700</td><td>4140</td><td>2898000</td></tr>
<tr><td>800</td><td>3610</td><td>2888000</td></tr>
<tr><td>900</td><td>3210</td><td>2889000</td></tr>
<tr><td>1000</td><td>2900</td><td>2900000</td></tr>
<tr><td>1100</td><td>2630</td><td>2893000</td></tr>
</table>
Since the product $T \times \lambda_{max}$ for different temperatures are the same when rounded to 2 s.f., it is a constant.
$\text{constant} = (T \times \lambda_{max})_{average} = 2.9 \times 10^6$ K nm
Note: Unit for constant is required in A level examination.
</td><td>B1
B1
B1</td></tr>
<tr><td>8(b)(ii)</td><td>$T \times \lambda_{max} = 2.89 \times 10^6$
$\lambda_{max} = \dfrac{2.89 \times 10^6}{1200}$
$= 2.41 \times 10^3$ nm $= 2.41 \times 10^{-6}$ m</td><td>M1
A1</td></tr>
</table>

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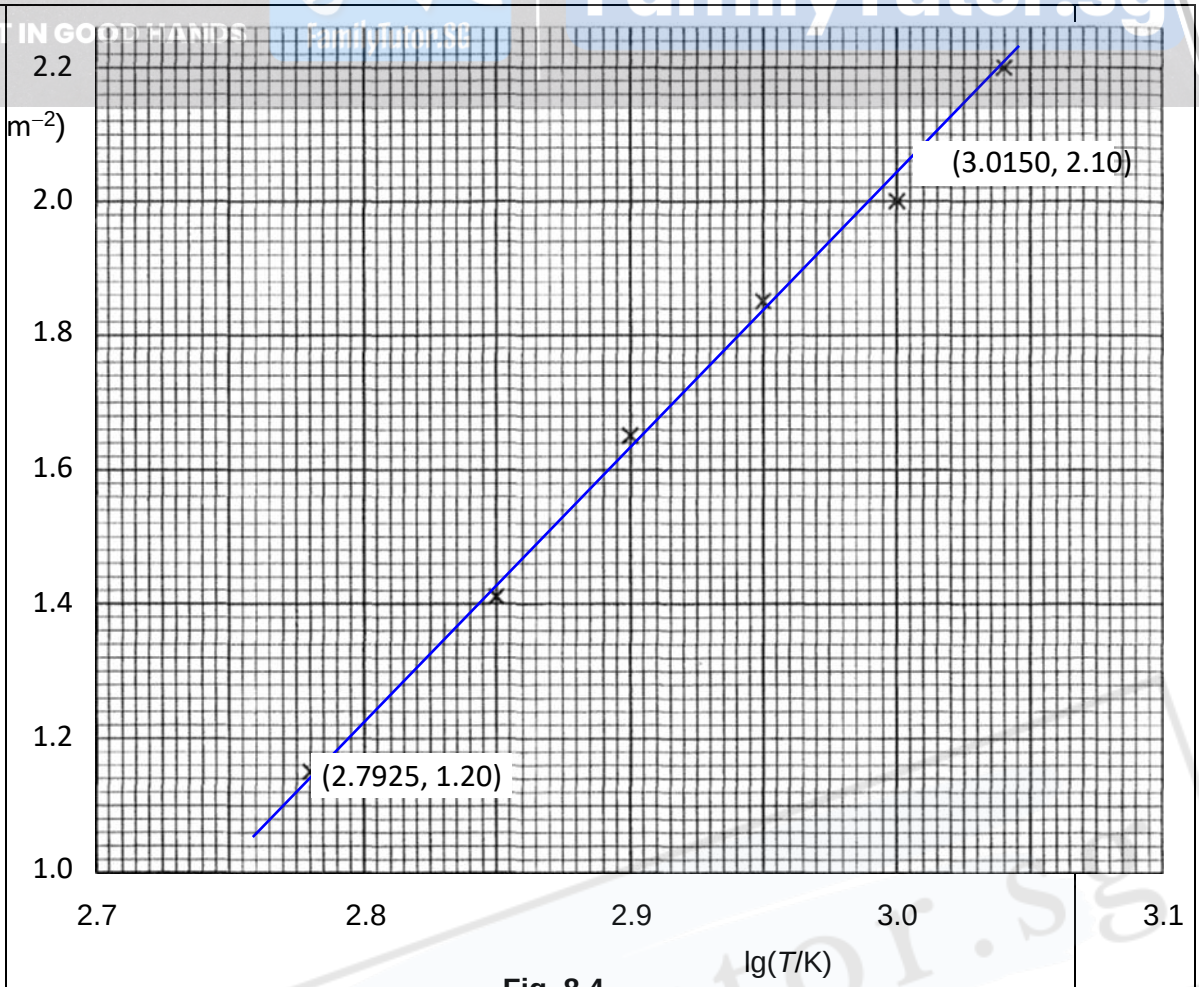
8(c)(i)	 **Fig. 8.4**	
	$I_{tot} = cT^n$ $\lg I_{tot} = n\lg T + \lg c$ Hence, n is the gradient of the lgI_{tot} against lg$T$ graph. gradient $= \dfrac{2.10 - 1.20}{3.0150 - 2.7925} = 4.045$ $n = 4.045$	**M1** **M1** **A1**
8(c)(ii)	$I_{tot} = cT^n$ $71 = c(900)^{4.045}$ $c = 7.97 \times 10^{-11}$ I_{tot} at 1200 K $= 7.97 \times 10^{-11} \times 1200^{4.045} = 227$ W m^{-2}	**M1** **M1** **A1**
8(d)	The curve should be similar to the curves for the other temperatures. It should start from the origin and peak at 2410 nm. It should be above the 1100 K curve (except intersecting at the origin). Graph has to be smooth. Note: Peak should be more pointed than that for 1100 K.	**B1** **B1** **B1**

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8(e)(i)	Either wavelength λ_{max} (wavelength at maximum intensity) or I_{tot} (total intensity)	**B1**
	Determine the temperature using $T = \frac{\text{constant}}{\lambda_{max}}$ or $I_{tot} = cT^n$	**B1**
8(e)(ii)	advantage: No physical contact is needed to make the measurement.	**B1**
	disadvantage: (any of the followings)	**B1**
	The intensity varies smoothly with wavelength. It is difficult to measure λ_{max} to high precision.	
	Low intensity with low temperature, difficult to measure.	
	Presence of background radiation.	

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JC2 PRELIMINARY EXAMINATIONS 2023
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	

CIVICS GROUP	**2**	**2**	**-**			REGISTRATION NUMBER	

PHYSICS
Structured Questions

9749/02

14th September 2023

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
The use of an approved scientific calculator is expected where appropriate.
Answer **all** questions.

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 paper clips, highlighters, glue or correction fluid.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Q1	/9
Q2	/7
Q3	/11
Q4	/9
Q5	/9
Q6	/9
Q7	/6
Q8	/20
s.f.	
P2 Total	/80

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Data

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

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
temperature,	$T\ /\ \text{K} = T\ /\ °\text{C} + 273.15$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\ \omega \sqrt{(x_0^2 - x^2)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 (a) The diameter of a marble is measured using a vernier calliper and three sets of measurements are obtained as shown in Table 1.1. The true value of the diameter of the marble is 1.52 cm.

Table 1.1

	diameter of marble / cm				
Set A	1.52	1.49	1.43	1.52	1.55
Set B	1.42	1.45	1.43	1.51	1.58
Set C	1.45	1.56	1.47	1.53	1.46

(i) State and explain which set of measurements is the most precise. [2]

……

……

……

(ii) State and explain which set of measurements is the most accurate. [2]

……

……

……

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(b) Two cars A and B are travelling on a straight level road. Car A is 500 m ahead of Car B at t = 0 s. The velocity-time graph for cars A and B in the first 15 s are shown in Fig. 1.2 below.

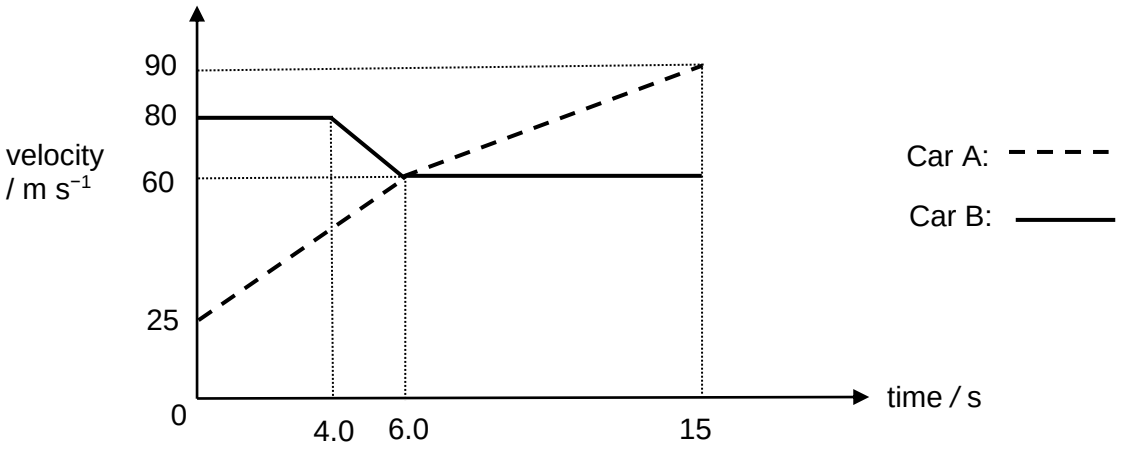

Fig. 1.2

(i) Sketch the corresponding displacement-time graph and acceleration-time graph of **car B** in the graphs provided in Fig. 1.3.

For the displacement-time graph, label the displacement at 15 s on the axis.
For the acceleration-time graph, label all accelerations on the axis.

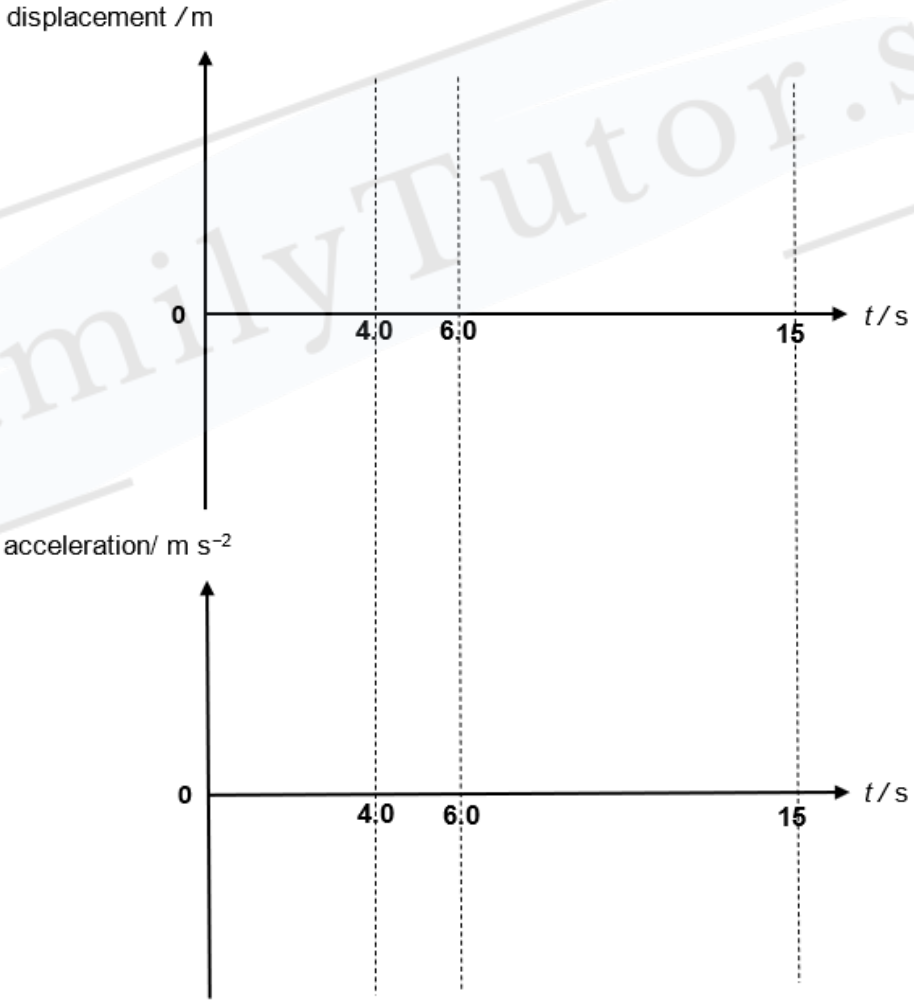

Fig. 1.3

[2]

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(ii) Find the minimum distance between the two cars within the first 15 s.

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distance = …… m [3]

[Total: 9]

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2 **(a)** State the two conditions necessary for the equilibrium of a body which is acted upon by a number of forces.

1. ……

……

2. ……

…… [2]

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(b) A uniform rod of weight 80 N is supported by a wall hinge at one end and a cable at the other end, as shown in Fig. 2.1. It makes an angle of 60° with the wall and 50° with the cable. Determine the tension in the cable and the force *R* on the rod by the wall hinge.

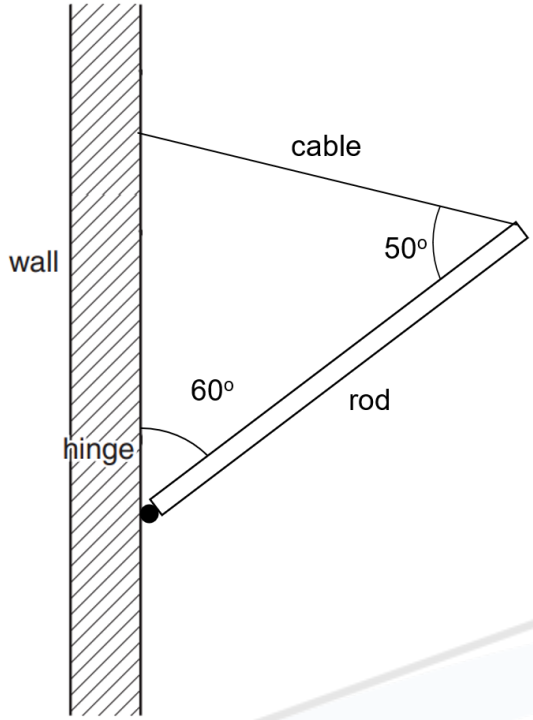

Fig. 2.1

tension = …… N

magnitude of force *R* = …….. N

direction of force *R* from the wall surface = ……..…….…… [5]

[Total: 7]

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3 A small magnet X of mass 30 g is released from rest on the top of a smooth slope of length 1.50 m inclined at 40° as shown in Fig. 3.1. Another small magnet Y was placed at rest on a smooth horizontal surface a long distance away from the slope.

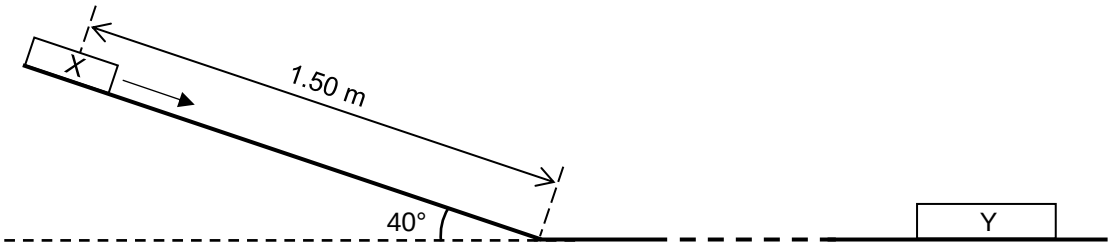

Fig. 3.1

(a) Calculate the speed of magnet X as it reaches the bottom of the slope after being released.

speed of X = …….…….. m s^{-1} [1]

(b) The two magnets X and Y were positioned with **like** poles facing each other.

Magnet X reaches a point of closest approach with magnet Y before changing direction and going towards the slope. It stopped 0.80 m up the slope. Assume that the collision is elastic.

(i) Calculate the final speed of magnet Y.

speed of Y = ……..…….…… m s^{-1} [3]

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(ii) Show that the mass of magnet Y is 190 g. [2]

(c) The two magnets are now aligned with **unlike** poles facing each other. X is released from rest at the top of the frictionless slope. As it touches Y, they stick and move off together.

(i) Explain why such a collision is always inelastic.

.....

..... [1]

(ii) Show that the speed of X and Y after the collision is 0.59 m s^{-1}. [1]

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(iii) After the collision, X and Y travelled up a rough slope inclined at 50° to the horizontal as shown in Fig. 3.2. The slope exerts a constant frictional force of 2.2 N on the magnets.

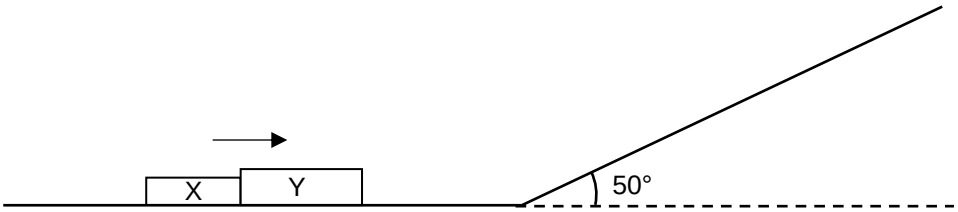

Fig. 3.2

The magnets travelled a distance *d* up the rough slope before coming to a stop.

Calculate the distance *d*.

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d = ... m [3]

[Total: 11]

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4 **(a)** Define *electric field strength*.

.....

.....[1]

(b) Fig. 4.1 is a **full scale** diagram that shows a series of equipotential lines around a few point charges.

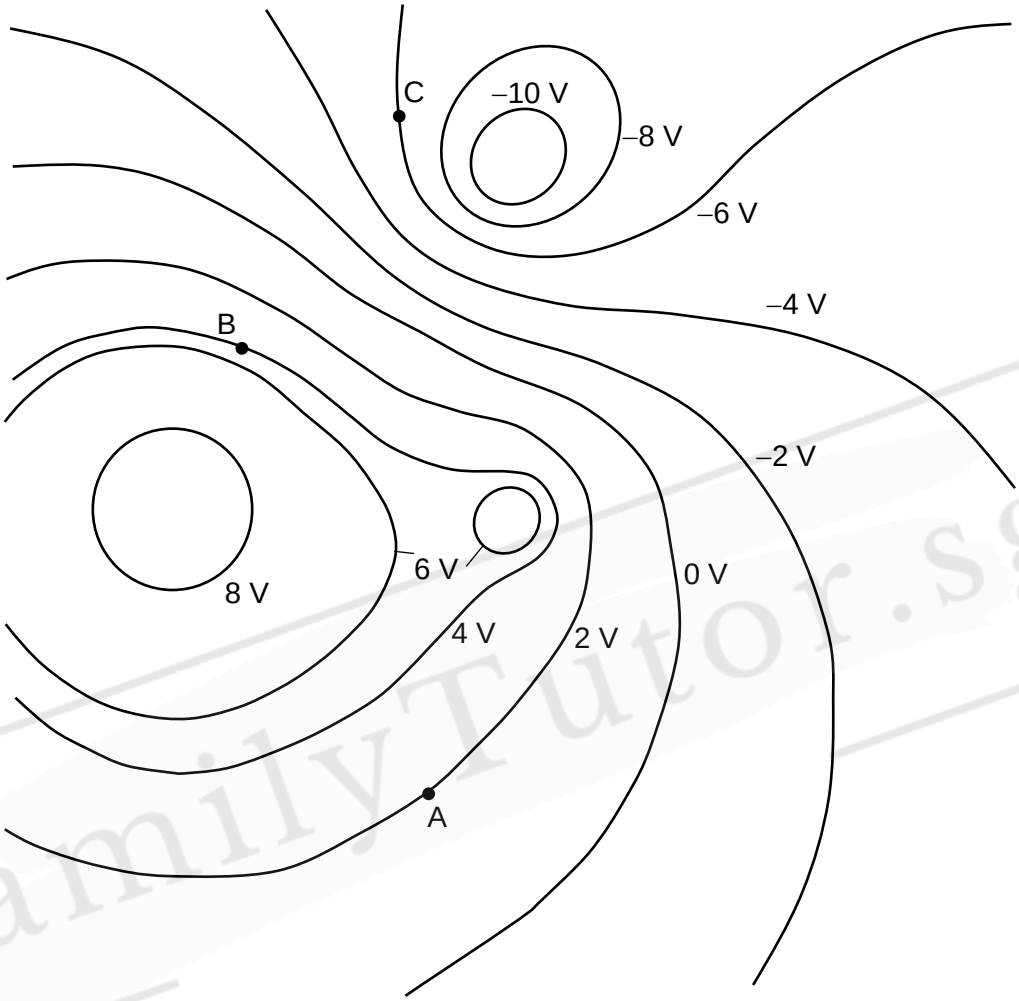

Fig. 4.1

(i) Determine the magnitude of the electric force experienced by an electron placed at point A.

electric force = ... N [2]

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(ii) Another electron is projected from point B to point C with an initial speed of 5.3×10^6 m s^{-1}.

Calculate the final speed of the electron at point C.

final speed = …….. m s^{-1} [3]

(c) Electrons are emitted from a cathode P and accelerated towards an anode Q. The distance PQ is 8.0 cm.

The variation with distance *d* from P along PQ of the magnitude of the electric field strength *E* is shown in Fig. 4.2.

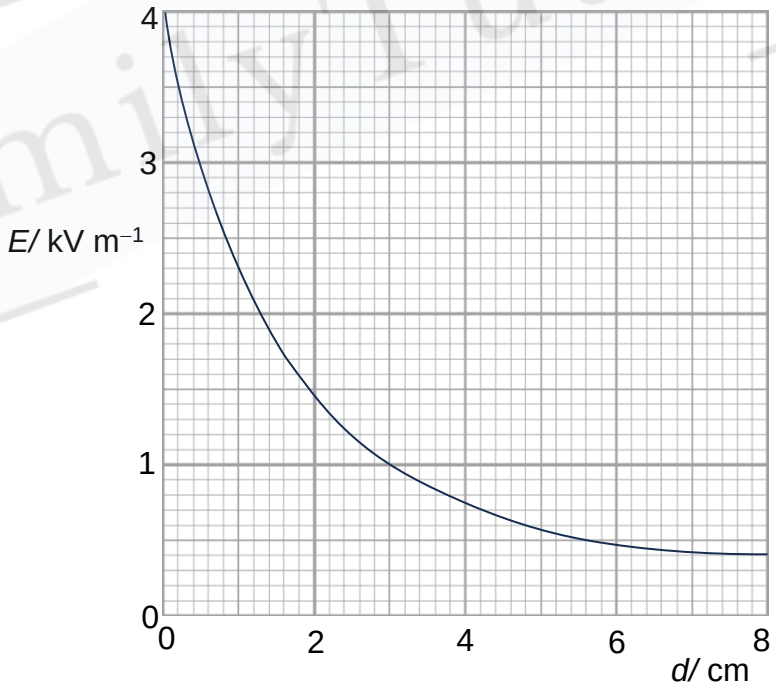

Fig. 4.2

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Estimate the change in electric potential energy experienced by an electron as it accelerates from P to Q.

change in potential energy = ... J [3]

[Total: 9]

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5 A cell of e.m.f. 1.2 V and negligible internal resistance is connected to three resistors and a semiconductor diode, as shown in Fig. 5.1.

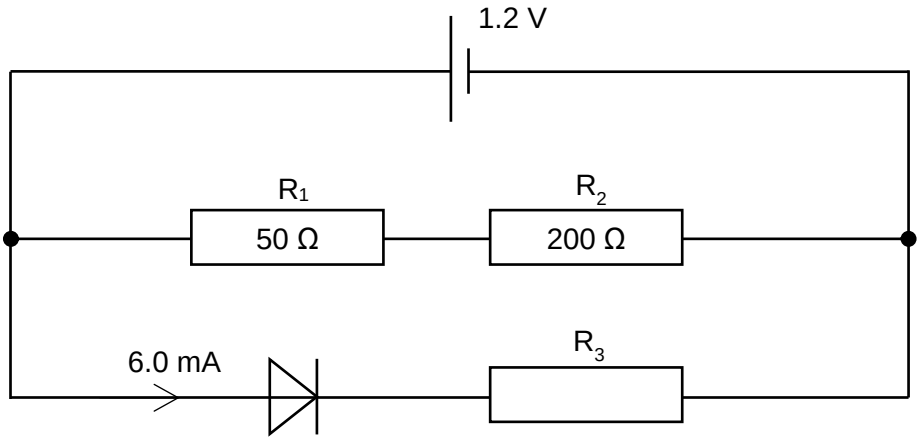

Fig. 5.1

The I-V characteristic of the semiconductor diode is shown in Fig. 5.2.

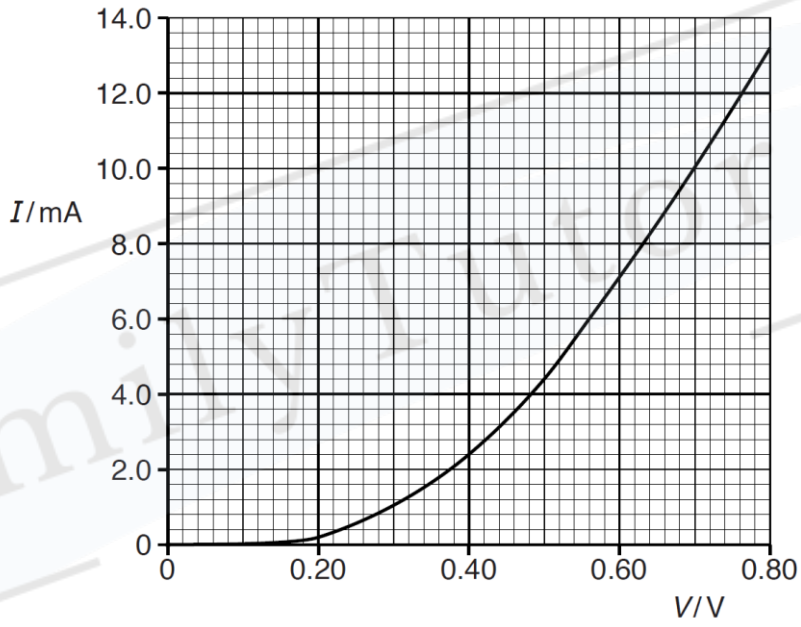

Fig. 5.2

The current in the diode is 6.0 mA.

(a) Use Fig. 5.2 to determine the resistance of the diode for a current of 6.0 mA.

resistance = ... Ω [1]

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(b) Determine the resistance of R_3.

resistance = ... Ω [2]

(c) Determine the current in R_1.

current = ... A [2]

(d) Determine the total power dissipated in the circuit.

total power = ... W [2]

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(e) A 1.0 m metal wire is added to the circuit as shown in Fig. 5.3.

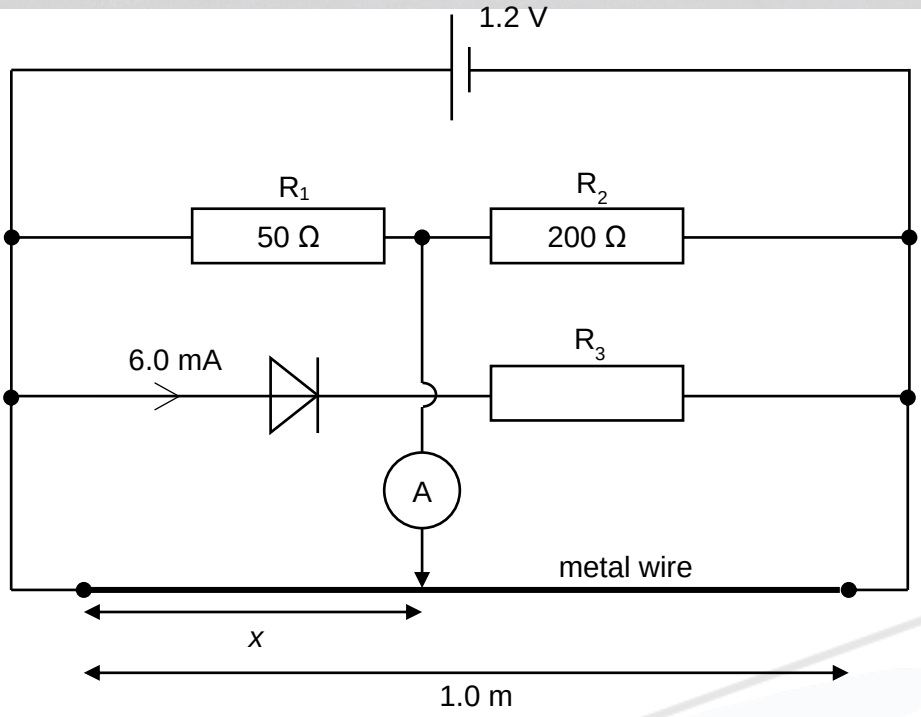

Fig. 5.3

Determine length *x* such that there is no current flowing through the ammeter.

x = ... m [2]

[Total: 9]

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6 Two oppositely charged parallel metal plates P and Q are placed in vacuum. The electric field strength E is uniform in the region between the plates, and is zero outside this region. Uniform magnetic flux density B into the plane of the paper also exists in the region between the plates, as well as in the adjacent area, as shown in Fig. 6.1.

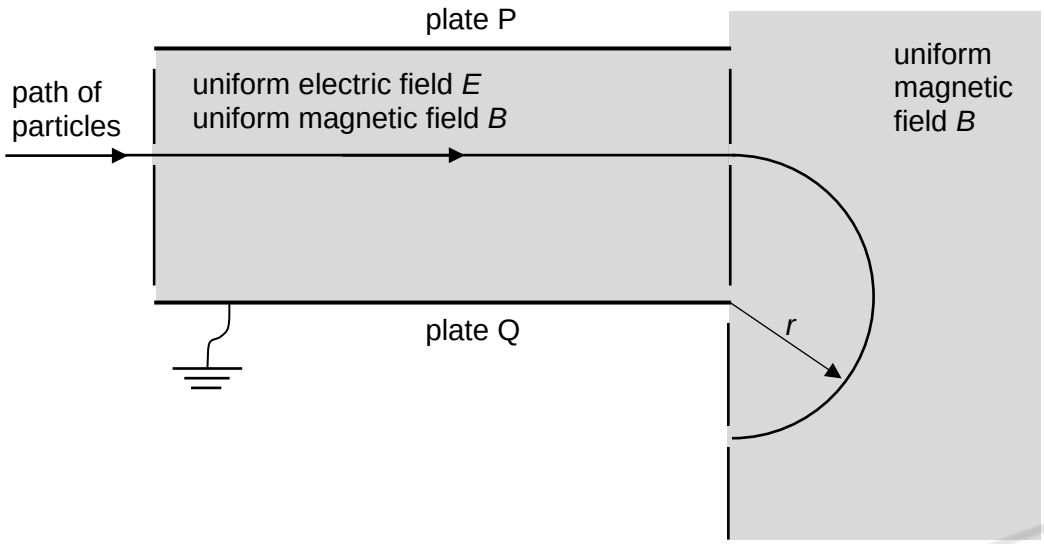

Fig. 6.1

A beam of negatively charged particles moving in the direction perpendicular to the electric field enters the region between the plates.

(a) **(i)** Some of the particles move in a straight line undeflected in the region between the plates.

State and explain the polarity, positive or negative, of plate P.

……

……

……

…… [2]

(ii) Show that the speed v of these particles satisfies

$$v = \frac{E}{B}$$

[1]

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(iii) Some of the particles move with an initial speed $v > \frac{E}{B}$.

On Fig. 6.1, sketch the path between the plates of these particles.

Explain your answer.

……

……

…… [2]

(b) After leaving the parallel plates, the undeflected particles enter a region with only the uniform magnetic flux density B, in which they follow a circular trajectory of radius r.

(i) Explain why the speed of the particles remains constant along the circular trajectory.

……

……

…… [2]

(ii) Show that, for the particles that follow the circular path of radius r, the charge-to-mass ratio is given by

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

[2]

[Total: 9]

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7 (a) A solenoid of diameter 9.0 cm and 560 turns is placed in a uniform magnetic field as shown in Fig. 7.1.

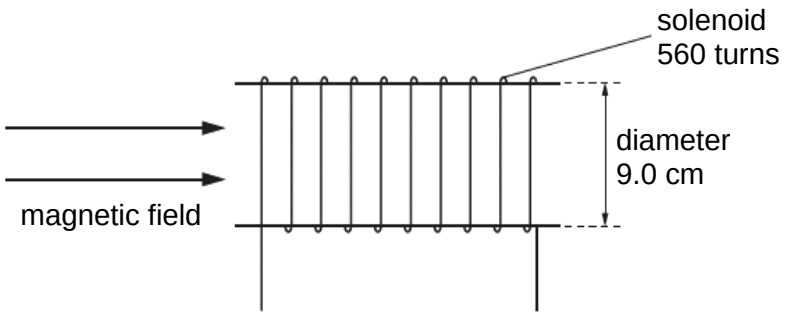

Fig. 7.1

The variation with time *t* of the magnetic flux density is shown in Fig. 7.2.

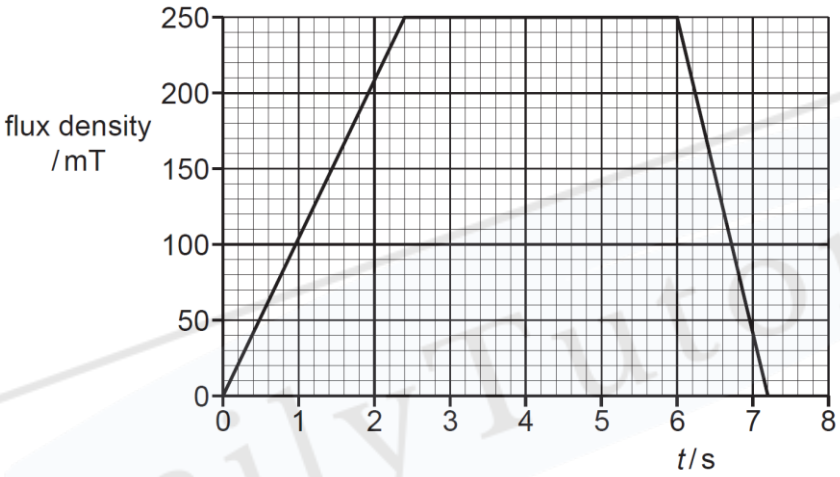

Fig. 7.2

Calculate the maximum magnitude of the induced electromotive force (e.m.f.) in the solenoid.

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

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(b) A thin copper sheet X is supported on a rigid rod so that it hangs between the poles of a magnet as shown in Fig. 7.3.

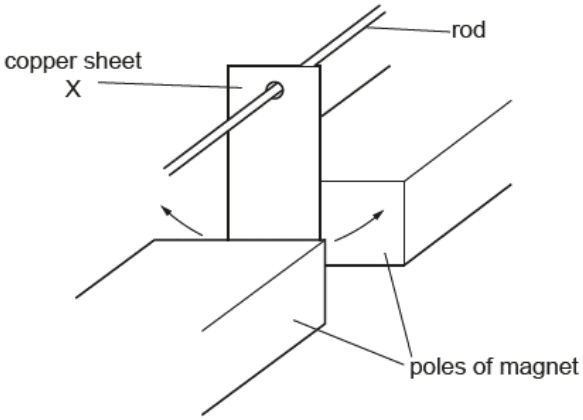

Fig. 7.3

Sheet X is displaced to one side and then released so that it oscillates. A motion sensor is used to record the displacement of X.

A second thin copper sheet Y replaces sheet X. Sheet Y has the same overall dimensions as X but is cut into the shape shown in Fig 7.4.

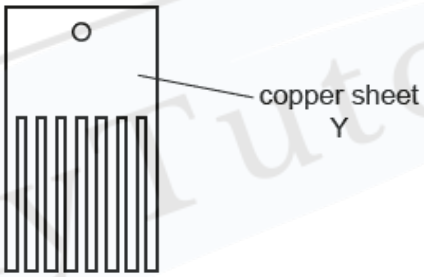

Fig. 7.4

The motion sensor is again used to record the displacement.

The graph in Fig. 7.5 shows the variation with time *t* of the displacement *s* of each copper sheet.

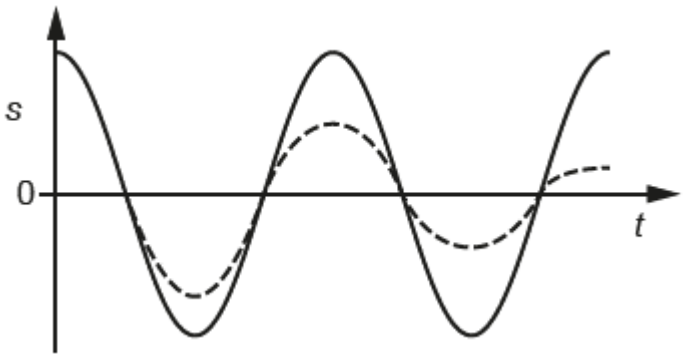

Fig. 7.5

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(ii) Deduce which copper sheet is represented by the dashed line. Explain your answer using the principles of electromagnetic induction.

……

……

……

……

……

……[4]

[Total: 6]

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8 An object that is at a higher temperature than its surroundings loses thermal energy by emitting electromagnetic radiation.

For loss of thermal energy as electromagnetic radiation, the intensity I_λ of the emitted radiation of wavelength λ varies with wavelength λ as shown in Fig. 8.1.

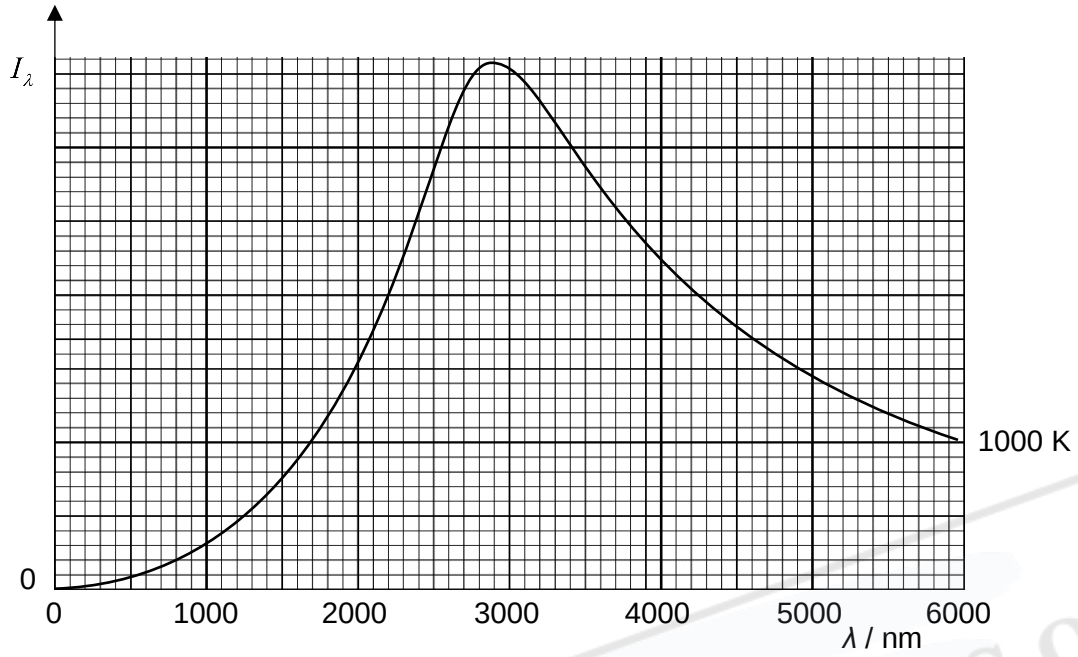

Fig. 8.1

Fig. 8.1 shows the variation of I_λ with λ for the body when it is at 1000 K.

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The distribution of intensity is different at different temperatures. This is illustrated in Fig. 8.2.

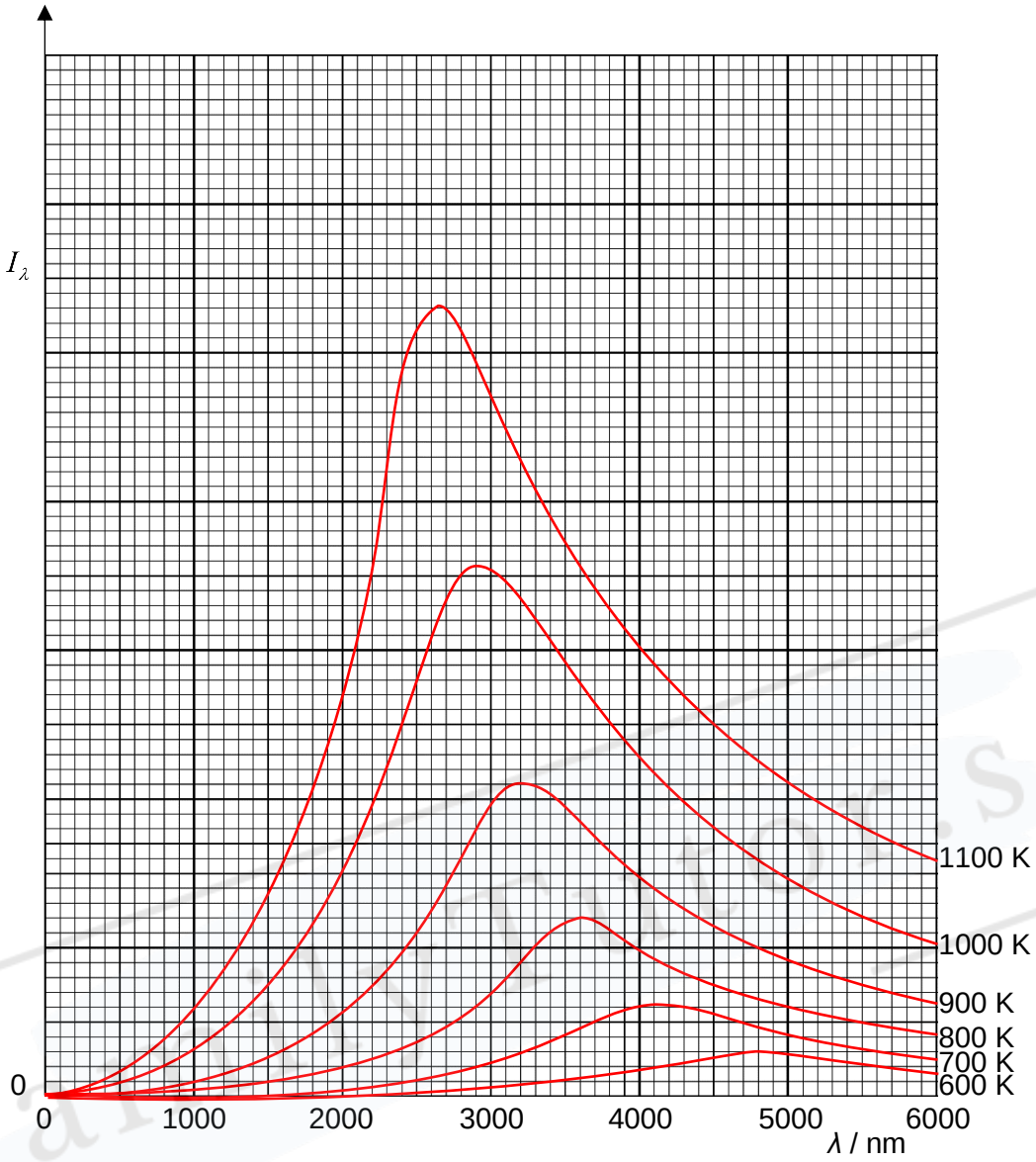

Fig. 8.2

(a) **(i)** On the horizontal axis of Fig. 8.2, indicate with the letter V a wavelength that is in the visible region of the electromagnetic spectrum. [1]

(ii) Hence suggest why, at a temperature of 1100K, the object would glow with a red colour.

.....

..... [1]

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(b) At any temperature T, the graph of Fig. 8.2 shows a peak corresponding to a wavelength λ_{max} and an intensity I_{max}. Data for T and λ_{max} are shown in Table 8.3.

Table 8.3

T / K	λ_{max} / nm
600	4830
700	4140
800	3610
900	3210
1000	2900
1100	2630

(i) Without drawing a graph, show that

$$T \times \lambda_{max} = \text{constant},$$

and determine the constant.

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constant = ... [3]

(ii) Hence, determine the wavelength for the maximum intensity at a temperature T of 1200 K.

wavelength = ... m [2]

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(c) The total intensity of emitted radiation from a particular body at temperature T is I_{tot}. Fig. 8.4 shows the values of lg(T/K) plotted against the corresponding values of lg(I_{tot}/W m^{-2}).

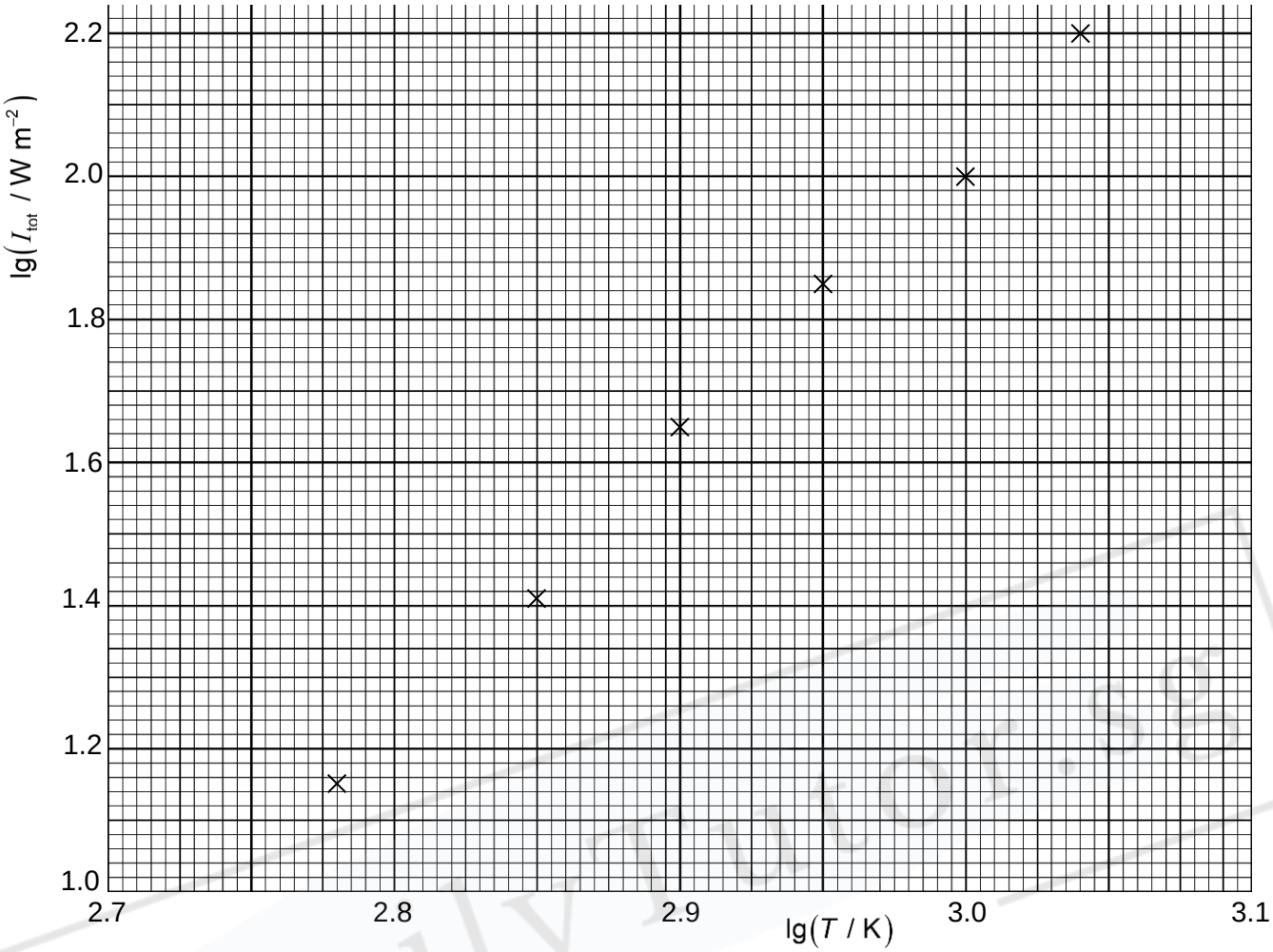

Fig. 8.4

It is known that I_{tot} varies with T according to the relation

$$I_{tot} = cT^n,$$

where c and n are constants.

(i) Use Fig. 8.4 to determine a value for n.

n = ... [3]

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(ii) For this body at $T = 900$ K, I_{tot} is found to be 71 W m^{-2}.

Use these data and your answer to (c)(i) to determine I_{tot} for the body at a temperature of 1200 K.

$I_{tot} =$ ..... W m^{-2} [3]

(d) Using your answer to **(b)(ii),** sketch on Fig. 8.2, the variation with wavelength λ of intensity I_λ for a temperature of 1200 K. [3]

(e) The radiation emitted by a hot body may be used as a means of determining the temperature of the body.

(i) Suggest and explain a property of the radiation that could be used for this purpose.

.....

.....

..... [2]

(ii) Suggest one advantage and one disadvantage of this method for measuring temperature.

advantage: .....

.....

disadvantage: .....

..... [2]

[Total: 20]

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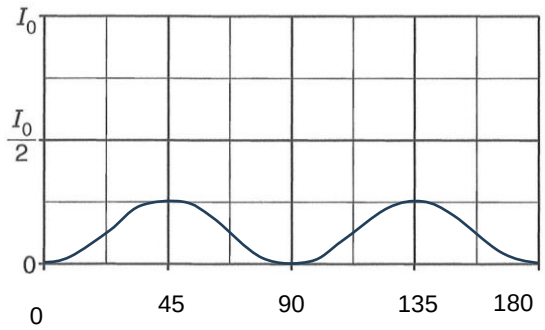
Paper 3 – Longer Structured

Qns	Answer	Marks
1a	 Correct positions of max and min intensities, and gradient at 0° and 180° should be approx zero [B1] Max intensity of $I_o/4$ [B1] Working: $I_o = I_o \cos^2\theta \cos^2(90-\theta)$ $= I_o \cos^2\theta \sin^2\theta$ $= I_o/4 \sin^2 2\theta$ [note: $\sin 2\theta = 2\sin\theta \cos\theta$]	
1bi	$d = 10\times10^{-6} \div 7$ $= 1.43 \times 10^{-6}$ m	**M1** **A1**
1bii	For number of images on each side, $\sin\theta = 45°$ $n_{max} = d \sin 45°/\lambda$ $= 1.43 \times 10^{-6} \times \sin 45°/ 600\times10^{-9}$ $= 1.68$ ≈ 1 Total number of images = 1 + 1 + 1 = 3	**C1** **A1**
1biii	For the first order maxima, $d \sin\theta = \lambda$. Most of the line spacing in the grating is uniform such that the rays converge at α to give a bright image. Some of the line spacing is smaller than the standard spacing, giving rise to some part of the image being formed at a larger angle between α and β.	**B1** **B1**

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1ci	The stationary wave is formed when the incident wave is reflected at the sea wall such that the incident and reflected waves are of the same type, amplitude, frequency, wavelength and speed the incident and reflected wave travelling in opposite directions then overlap and superpose.	**B1** **B1**
1cii	For the increase in amplitude at wall, the incident and reflected waves must have amplitudes of the same sign / crest meets with crest. OR Constructive interference The reflected wave must have the same phase as the incident wave, hence no phase change occurred during reflection.	**M1** **A1**
1ciii	$1.75\lambda = 0.78$ $\lambda = 0.78/1.75$ $v = f\lambda$ $= 720 \times 0.78/1.75$ $= 321$	**C1** **A1**

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Qns	Answer	Marks
2(ai)	The increase in internal energy of a system is the sum of external work done on the system and the heat supplied to the system.	B1 B1
2(aii)	When roasting, heat is supplied to the potato, thus Q_{to} is positive. W_{on} is negligible since there is little change in volume of the potato) / W_{on} is positive since cooked potato becomes smaller in volume Therefore, $\Delta U_{increase}$ is positive. OR W_{on} is negative but magnitude of Q is larger than magnitude of W Therefore, $\Delta U_{increase}$ is positive. $\Delta U = \Delta KE + \Delta PE$ ΔPE is negligible as there is no change in state of the potato, therefore, ΔKE is positive. **OR** ΔPE is positive as water from the potato is changed to gaseous state but ΔKE is also positive. Since KE is directly proportional to (thermodynamic) temperature, the temperature of the potato increases.	B1 B1 B1
2(b)(i)	$\Delta U = Q + W$ Constant volume, therefore W = 0 J $\Delta U = Q$ $= -55$ J	B1 A1
2(b)(ii)	Process A to B takes place at constant temperature, therefore $U_A = U_B \Rightarrow \Delta U_{AB} = 0$ For cyclic process, $\Delta U_{ABCA} = 0$ $\Delta U_{AB} + \Delta U_{BC} + \Delta U_{CA} = 0$ $\Delta U_{CA} = 55$ Process C to A is an adiabatic process, therefore $Q_{to} = 0$ J $\Delta U_{CA} = W_{on} = 55$ $W_{by} = -55$	B1 B1 A1

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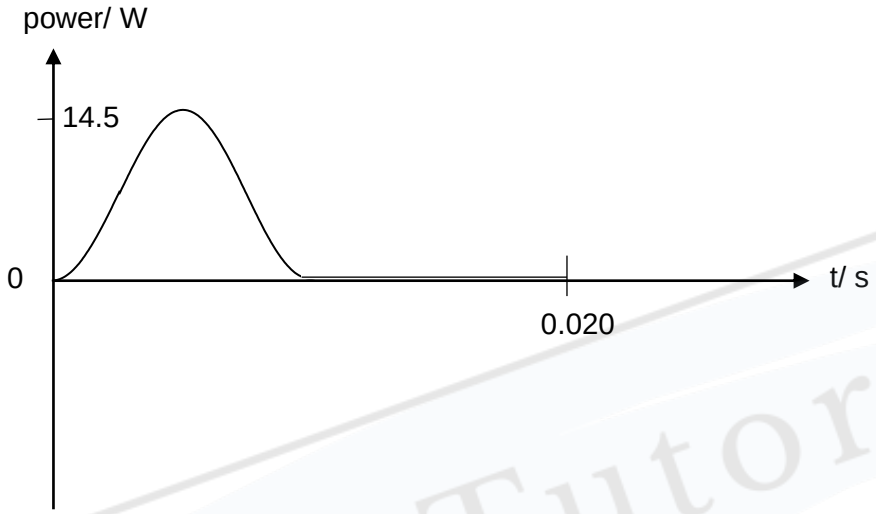
Qns	Answer	Marks
3(a)	r.m.s. value of an alternating current is the value of a steady direct current that will dissipate thermal energy at the same average rate as the a.c. in a given resistor	A1
3(b)	peak voltage = $6.0\sqrt{2}$ peak voltage = 8.5 V	A1
3(c)	$k = \omega = 2\pi f = 2\pi(50) = 310$ Unit: radian per second, rad s^{-1} (or s^{-1})	A1 A1
3(d)	8.5 V	A1
3(e)	zero because either no current in circuit (and V = IR) or all p.d. across diode	A1
3(f)	 $P_{max} = \frac{V_o^2}{R} = \frac{8.5^2}{5.0} = 14.5$ W $T = \frac{1}{f} = \frac{1}{50} = 0.020$ s Shape and showing one complete cycle Labelling max power as 14.5 W Labelling period as 0.020 s	 M1 A1 A1

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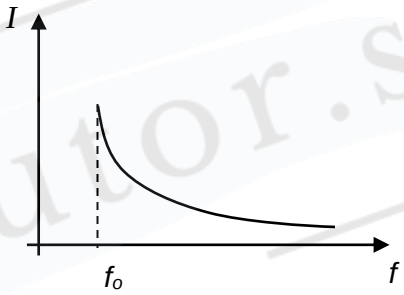
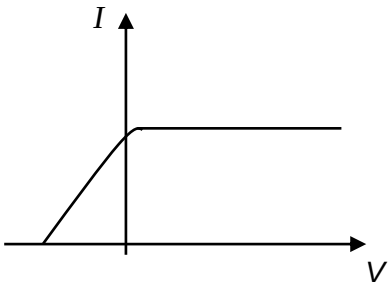
Qns	Answer	Marks
4(a)(i)	A beam of white light consists of photons of all wavelengths (λ) in the visible spectrum. The photons interact with electrons in the gas atoms OR The photons will be absorbed by the electrons **(Option 1)** Photon energy causes electron to move to higher energy level (or to be excited) The photon energy (of certain wavelengths ($E = hf = hc/\lambda$)) is equal to the energy difference between the energy levels of the gas atoms When electrons de-excite, photons are re-emitted in all directions **(Option 2)** This results in fewer photons of these wavelengths/photons with much less intensity in the direction of the incident light/original direction of travel. Hence, there will be dark lines corresponding to these wavelengths in the diffraction pattern.	**B1** **B1** **B1** **B1** **B1**
4(a)(ii)	Transitions –3.40eV to –0.85eV and –3.40eV to –1.51eV	**B1**
4(b)(i)	f increases, so energy carried by each photon (= hf) increases. P is constant, so the total incident energy per unit time is constant. Hence, the number of photons per unit time must decrease. The number of photoelectrons must also decrease.  $\text{quantum yield} = \frac{\text{no. of photoelectrons emitted}}{\text{no. of incident photon}}$ is a fixed value for a given wavelength and type of metal. Correct shape – **B1** Indication of f_o – **B1**	
4(b)(ii)	Negative potential diffrence slows down the electrons, so fewer electrons can reach the collector, photocurrent decreases, to 0 if electrons with max KE cannot reach collector. Positive potential difference accelerates the electrons towards the collector, so all electrons reach the collector, saturation current is reached.  	**B1**

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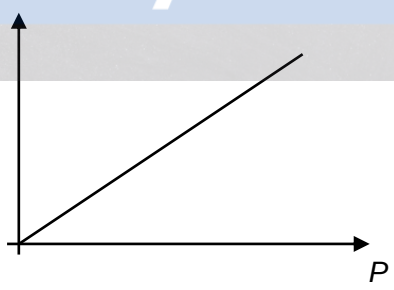
4(b)(iii)	With energy per photon (= h*f*) constant, the number of incident photons increases linearly with power. Hence, the number of photoelectrons also increases linearly with power. 	**B1**
4(c)(i)	no. of electrons $= 6^{10} = 6.05 \times 10^{7}$	**B1**
4(c)(ii)	no. of electrons per unit time from 10th dynode $= \dfrac{9.2 \times 10^{-6}}{1.6 \times 10^{-19}} = 5.75 \times 10^{13}$ no. of electrons per unit time from cathode $= \dfrac{5.75 \times 10^{13}}{6.05 \times 10^{7}} = 9.50 \times 10^{5}$	**M1** **A1**
4(c)(iii)	no. of incident photons per unit time $= 9.50 \times 10^{5} \times 3 = 2.85 \times 10^{6}$ power of incident light $= n\dfrac{hc}{\lambda}$ $= 2.85 \times 10^{6} \times \dfrac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{361 \times 10^{-9}} = 1.57 \times 10^{-12}$ W	**M1** **A1**
4(c)(iv)	kinetic energy of an electron $= qV = 1.6 \times 10^{-19} \times 50 = 8.0 \times 10^{-18}$ J $E = \dfrac{p^2}{2m} = 8.0 \times 10^{-18}$ J $\Rightarrow p = \sqrt{2mE} = \sqrt{2 \times 9.11 \times 10^{-31} \times 8.0 \times 10^{-18}} = 3.82 \times 10^{-24}$ N s $\lambda = \dfrac{h}{p} = \dfrac{6.63 \times 10^{-34}}{3.82 \times 10^{-24}} = 1.74 \times 10^{-10}$ m	**M1** **M1** **A1**

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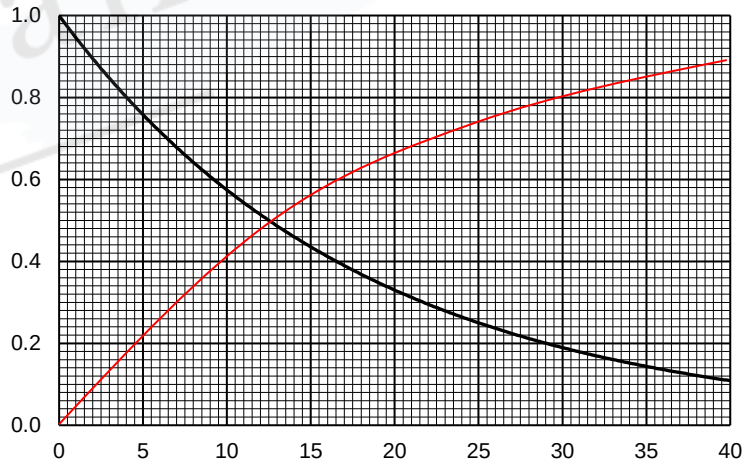
Qns	Answer	Marks
5ai	Binding energy of Mo $= 95 \times 8.09 = 768.55$ MeV Binding energy of La $= 139 \times 7.92 = 1100.88$ MeV Energy released = Binding energy of Mo + Binding energy of La – Binding energy of U Therefore 182 = 768.55 + 1100.88 - Binding energy of U Binding energy of U = 1687.43 MeV = 1690 MeV	C1 (either one) M1 A1
5aii	Binding energy = $\Delta m\, c^2$ $\Delta m = \dfrac{1687.43\times10^{6}\times1.6\times10^{-19}}{\left(3.0\times10^{8}\right)^{2}}$ $= 3.00\times10^{-27}$ kg	C1 A1
5bi	${}^{42}_{19}\mathrm{K} \rightarrow {}^{42}_{20}\mathrm{Ca} + {}^{0}_{-1}e + \bar{\nu}$ Also accept: “neutrino”, “anti-neutrino” and ν	A1
5bii	From Fig. 5.2, time taken for number of nuclei to drop from N_0 to 0.25 N_0 is 25 hours. $2t_{1/2} = 25$ $t_{1/2} = 12.5$ hours	A1
5biii	 Graph of Ca is a reflection of the graph for K in the N =0.5 N_0 line. Graphs will intersect at N = 0.5 N_0	P1
5biv	When N (Ca) = 4 N (K), N (K) = 0.2 N_0 From the graph, this occurs when t = 29 hours	M1 A1

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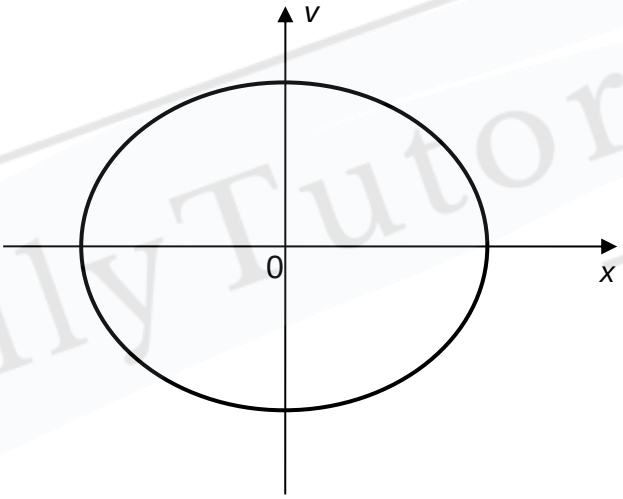
Qns	Answer	Marks
6(a)	acceleration proportional to displacement (from a fixed point)	B1
	either acceleration and displacement in opposite directions or acceleration always directed towards a fixed point	B1
6(b)(i)	g and r are constant so a is proportional to x	B1
	negative sign shows a and x are in opposite directions	B1
6(b)(ii)	$\omega^2 = \frac{g}{r}$ and $\omega = \frac{2\pi}{T}$	M1
	$\left(\frac{2\pi}{T}\right)^2 = \frac{9.81}{0.28}$	M1
	T = 1.06 s	A0
6(b)(iii)	$x = x_o \sin \omega t$	
	$1.5 = 2.0 \sin\left(\frac{2\pi}{1.1} t\right)$	M1
	$t = 0.15$ s (or 0.143 s)	A1
6(b)(iv)	Correct shape  	B1
	Correct maximum velocities	B1
	Label units of v	B1
	$v_o = \omega x_o$ $v_o = \left(\frac{2\pi}{T}\right) x_o$ $v_o = \left(\frac{2\pi}{1.1}\right)(0.020) = 0.11 \text{ m s}^{-1}$ (or 0.118 m s^{-1})	
6(b)(v)	Total energy = max KE	B1
	$= \frac{1}{2}(0.100)(0.11)^2$	C1
	$= 0.61$ mJ (or 0.69 mJ)	A1

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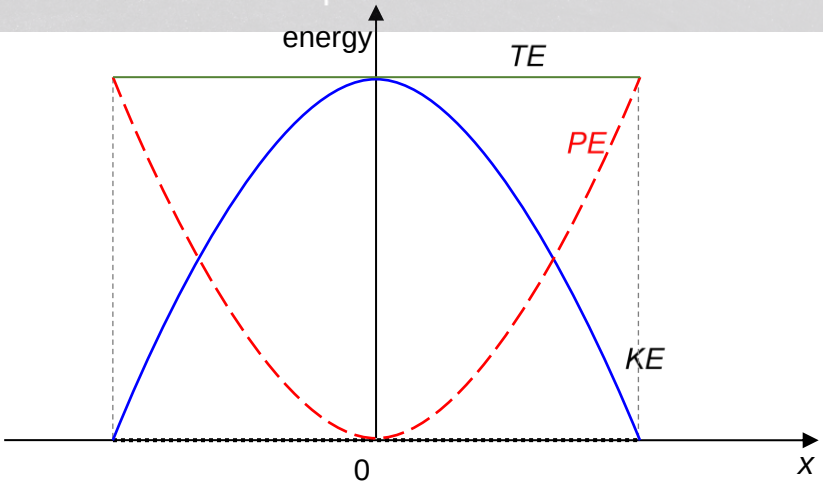
6(b)(vi)	Correct shape of TE, KE and PE  Label TE value and unit on axis	**B1** **B1**

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6(b)(vii)	**METHOD 1:** $N_{28}T_{28} = N_{29}T_{29}$ $N_{28}\sqrt{r_{28}} = N_{29}\sqrt{r_{28}}$ AND $(N+1)\sqrt{28} = N\sqrt{29}$ $N = 56.5$ $t = (56.5)(1.1)$ or $t = (56.5)(1.06)$ $= 62$ s or $= 60$ s	C1 C1 C1 A1
	METHOD 2: $N_{28}T_{28} = N_{29}T_{29}$ $N\sqrt{28} = (N-1)\sqrt{29}$ $N = 57.5$ $t = (57.5)(2\pi\sqrt{\frac{0.29}{9.81}})$ $= 62$ s	C1 C1 C1 A1
	METHOD 3: $\Delta\phi = 2\pi$ $\phi - \phi' = 2\pi$ $\omega t - \omega' t = 2\pi$ $\left(\frac{2\pi}{T}\right)t - \left(\frac{2\pi}{T'}\right)t = 2\pi$ $\left(\frac{2\pi}{1.1}\right)t - \left(\frac{2\pi}{1.08}\right)t = 2\pi$ OR $\left(\frac{2\pi}{1.06}\right)t - \left(\frac{2\pi}{1.08}\right)t = 2\pi$ $t = 59$ s or $t = 57$ s	C1 C1 C1 A1

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METHOD 4:

$\Delta\phi = 2\pi$
$\phi - \phi' = 2\pi$ **C1**
$\omega t - \omega' t = 2\pi$

$\left(\sqrt{\frac{g}{r}}\right)t - \left(\sqrt{\frac{g}{r'}}\right)t = 2\pi$ **C1**

$\left(\sqrt{\frac{9.81}{0.28}}\right)t - \left(\sqrt{\frac{9.81}{0.29}}\right)t = 2\pi$ **C1**

$t = 61\text{ s}$ **A1**

METHOD 5:

$\Delta T = 1.08 - 1.06 = 0.02\text{ s}$ **C1**

$\frac{1.06}{0.02} = 53$ **C1**

$t = 53 \times 1.06$ **C1**

$t = 56\text{ s}$ **A1**

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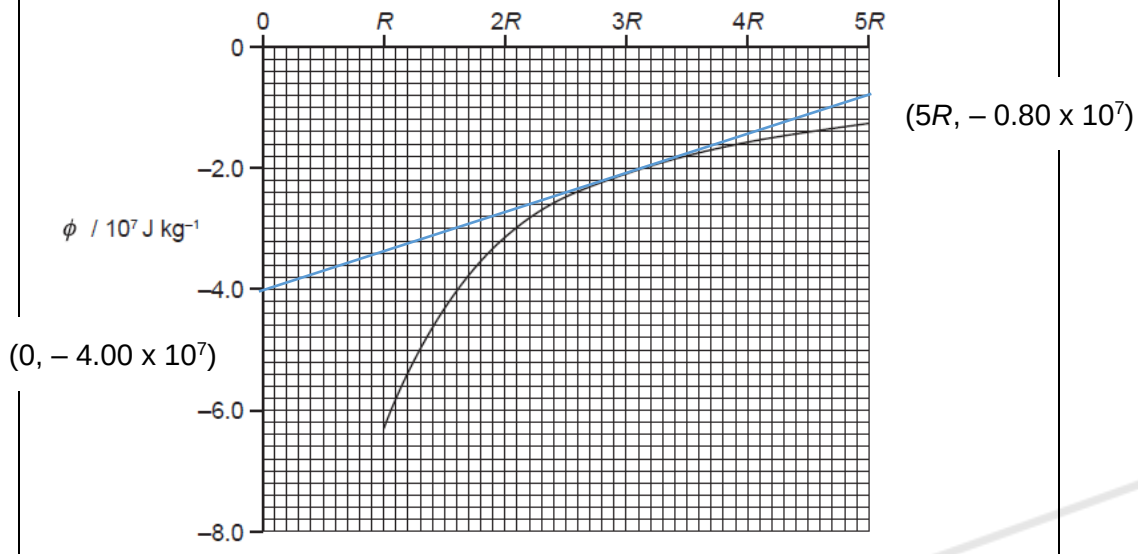
Qns	Answer	Marks
7 (a)	work done per unit mass in bringing a small test mass from infinity to that point	B1 B1
7(b)(i)	gravitational field strength of the electric field at a point is numerically equal to the potential gradient at that point.  field strength = $\frac{-0.80\times10^{7}-(-4.00\times10^{7})}{5R-0}$ $= \frac{3.2\times10^{7}}{5(6.4\times10^{6})}$ = 1.0 N kg^{-1} (accept 0.9 to 1.2 N kg^{-1})	C1 A1
7(b)(ii)1	Point A. Since the total energy A intersects the potential energy graph at x = 2R, the space capsule would only possess gravitational potential energy and have zero kinetic energy.	A1 M1
7(b)(ii)2	Point(s) B, C, D. Total energy is greater than GPE. KE is not zero	A1 M1 M1
7(b)(ii)3	Point D. As the total energy D value is equal to zero, the space capsule would have enough energy to travel to infinity where the potential energy is zero.	A1 M1
7(b)(ii)4	Point B. For circular motion, $TE = -\frac{GMm}{2r} = = \frac{1}{2}\left(-\frac{GMm}{r}\right) = \frac{1}{2}(GPE)$	A1 M1

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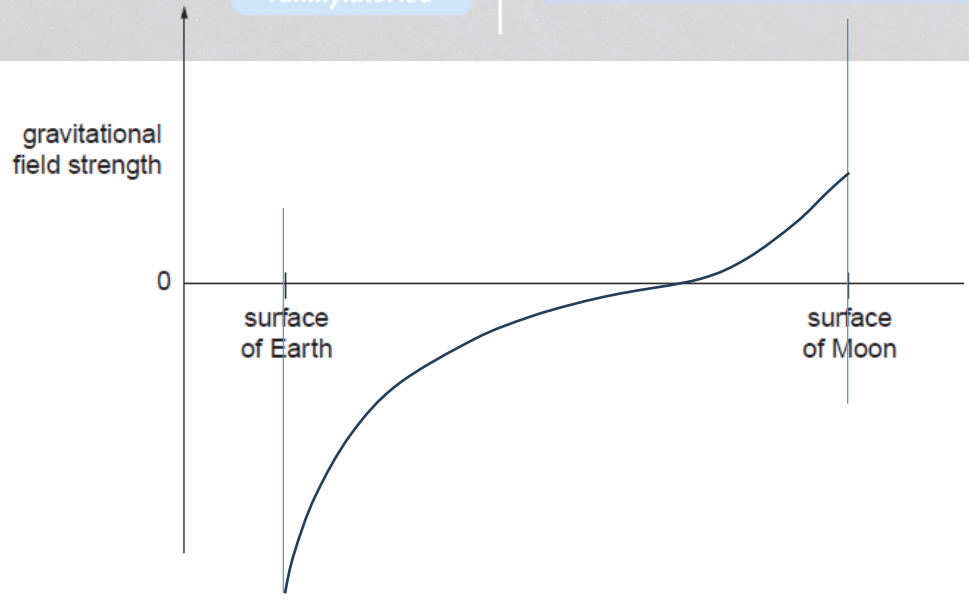
7(c)(i)	 Shape g = 0 *at least* ⅔ distance to Moon $\lvert g_E \rvert > \lvert g_M \rvert$ at surface	**M1** **B1** **B1**
7(c)(ii)	Minimum energy = m ΔΦ = (4.0)[–1.3 – (–62.3)] x 10^6 = 2.44 x 10^8 J	**C1** **C1** **A1**

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PHYSICS
Longer Structured Questions

9749/03

19th September 2023

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
The use of an approved scientific calculator is expected where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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 paper clips, highlighters, glue or correction fluid.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
Q1	/14
Q2	/10
Q3	/9
Q4	/17
Q5	/10
Section B	
Q6	/20
Q7	/20
s.f.	
P3 Total	/80

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Data

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

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
temperature,	$T\ /\ \text{K} = T\ /\ °\text{C} + 273.15$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\ \omega \sqrt{(x_0^2 - x^2)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

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

1 (a) Three sheets of polaroids P, Q and R are placed close to one another. Polaroids P and R have their polarising axes fixed and perpendicular to each other.

The incoming beam of intensity I_o is polarised parallel to the polarising axis of P before reaching P.

Polaroid Q is rotated about the axis of the light beam, as shown in Fig. 1.1. The plane of Polaroid Q remains parallel to that of P and R.

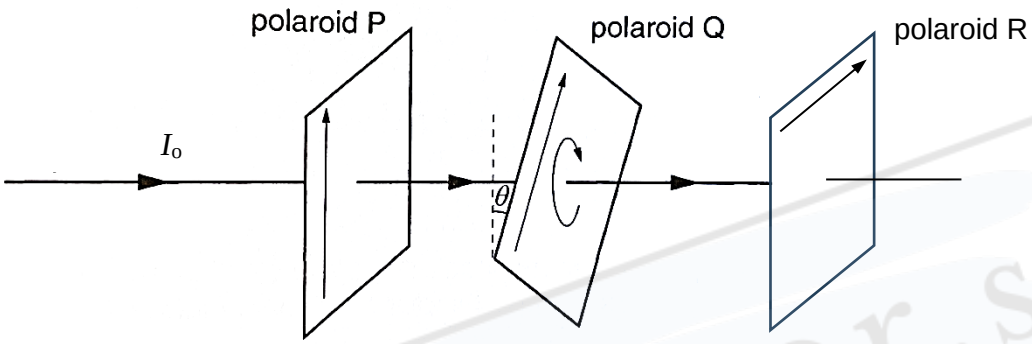

Fig. 1.1

Complete Fig. 1.2 to show the variation of the angle of rotation with intensity of the light transmitted after passing Polaroid R.

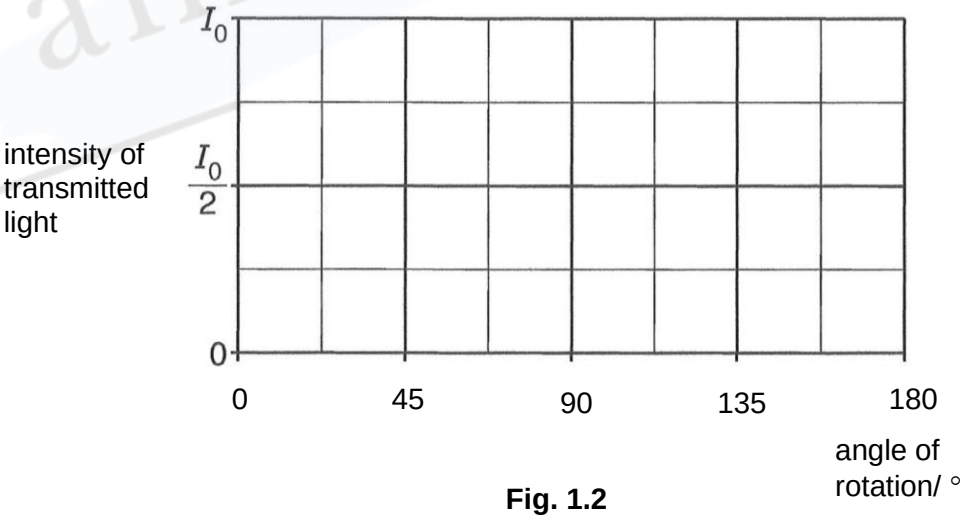

Fig. 1.2

[2]

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(b) A parallel beam of wavelength 600 nm is incident normally on a diffraction grating.

Fig. 1.3 shows part of the diffraction grating used.

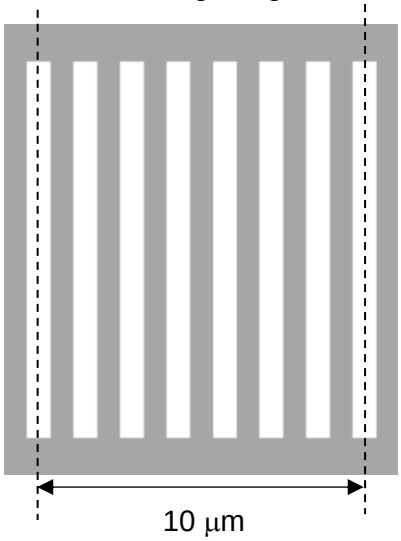

Fig. 1.3

(i) Determine the distance between adjacent slits on the grating.

distance = ... m [2]

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(ii) Fig 1.4 shows how the parallel beam of light that was incident on the diffraction grating.

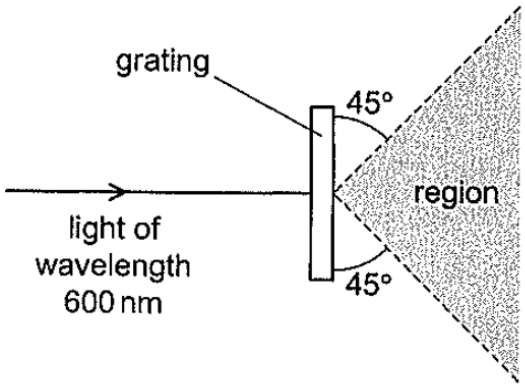

Fig. 1.4

Calculate the total number of images that emerge from the grating within the shaded 90° region shown in Fig. 1.4.

total number of images = …… [2]

(iii) In a mass production of diffraction gratings with slit separation *d*, a monochromatic laser light with a fixed wavelength λ was used to check for the quality of the diffraction gratings produced. In a certain test, a few defective pieces were found.

In a good product, the first order maximum occurs at an angle of α from the zeroth order maximum. In a defective product, the first order maximum is not a single sharp point but a band of light extending from angle α to β, where β is larger than α. The band of light is brightest at an angle of α and reduces towards the angle of β.

Describe what could be the fault in the manufacturing of the grating to result in this observation.

……..

……..

……..

……..

…….. [2]

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(c) On an initially calm day out at sea, water waves of constant speed approach a sea wall and a stationary wave is formed.

(i) State how the stationary wave is formed.

……..

……..

……..

…….. [2]

(ii) When the waves hit the wall, an increase in amplitude of the wave was observed at the sea wall.

State and explain if the water waves experienced a phase change when hitting the wall to result in the increase in amplitude.

……

……

……

…….. [2]

(iii) In Fig. 1.5, fine sand is spread along the length of a tube fitted with a piston. A small loudspeaker which emits sound of 720 Hz is placed at the opened end and the length of the air column was varied by adjusting the position of the piston.

When the air column is 0.78 m, the sand in the tube forms the pattern as shown.

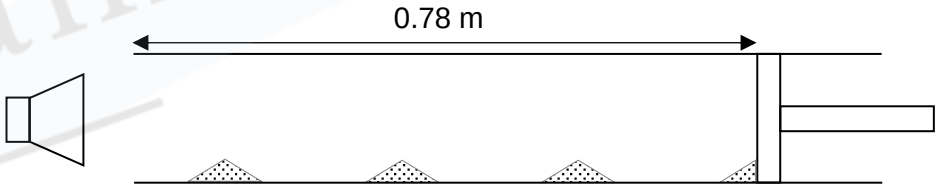

Fig. 1.5

Calculate the speed of sound travelling through the air column.

speed of sound = …… m s^{-1} [2]

[Total: 14]

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

……

……

……[2]

(ii) Use first law of thermodynamics to explain how roasting of potatoes causes its temperature to rise.

……

……

……

……

……

……

……[3]

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

Process A to B takes place at constant temperature of 310 K. Process B to C takes place at constant volume and during this process, 55 J of heat leaves the system. The temperature at C is 280 K. Process C to A takes place with no heat exchange.

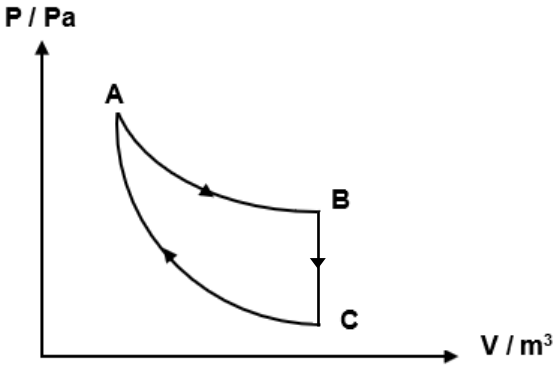

Fig. 2.1

(i) Calculate the change in internal energy of the gas during the process B to C.

change in internal energy = …… J [2]

(ii) Determine the work done by the gas during the process C to A.
Explain your working clearly.

work done by the gas = …… J [3]

[Total: 10]

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3 An alternating supply of frequency 50 Hz and having an output of 6.0 V r.m.s. is to be rectified so as to provide direct current for a resistor R. The circuit of Fig. 3.1 is used.

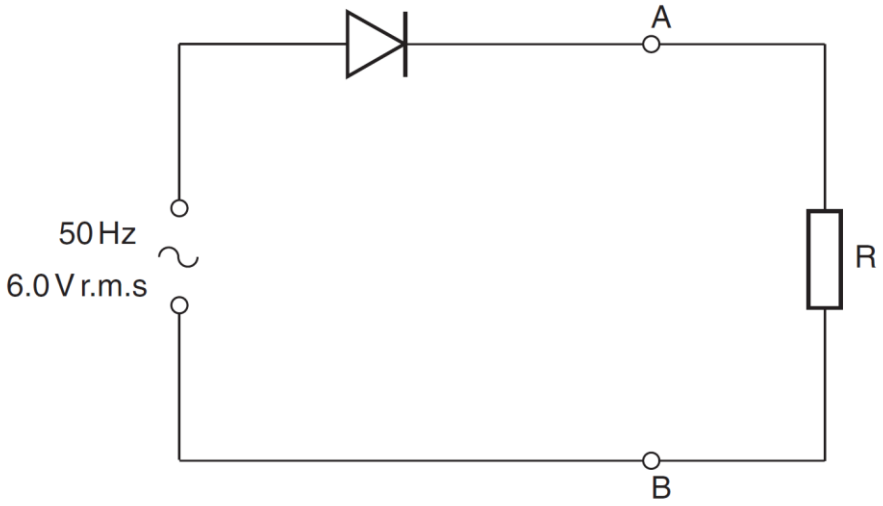

Fig. 3.1

The diode is ideal.

The output potential difference V of the alternating power supply is represented by

$$V = V_o \sin(kt)$$

where V_o is the maximum potential difference in volts and t is the time in seconds.

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

……

……

……[1]

(b) Determine the value of V_o

V_o = …… V [1]

(c) Determine the value and unit of k.

value of k = …… unit …… [2]

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(d) Determine the maximum potential difference across the diode during one cycle.

potential difference = …… V [1]

(e) State the potential difference across A and B when the diode has maximum potential difference across it. Give a reason for your answer.

……

…… [1]

(f) R has a resistance of 5.0 Ω .

In Fig. 3.2, sketch the variation with time of the power dissipated in R for **one** period of the alternating supply.

Fig. 3.2

[3]

[Total: 9]

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4 **(a)** A beam of white light passes through a cloud of gas. The spectrum of the light emerging from the gas is viewed using a diffraction grating.

(i) Explain why the spectrum observed contains a number of dark lines.

……

……

……

……

……

…… [4]

(ii) Some of the electron energy levels of the atoms in the cloud of the gas are represented in Fig. 4.1.

Fig. 4.1 (not to scale)

The photons of light have energies ranging from 1.60 eV to 2.60 eV.

On Fig. 4.1, draw arrows to show the electron transitions between energy levels that could give rise to dark lines in the absorption spectrum.

[1]

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(b) A metal surface with a threshold frequency f_o is placed in an evacuated tube and illuminated with monochromatic light. The photoelectrons emitted are collected at an adjacent electrode of the same metal. The photoelectric current I depends on the frequency f of the incident light, and potential difference V between collector and emitter, and the incident power P.

In Fig. 4.2 to 4.4, sketch graphs to show the variation of I with

(i) f, while V and P remain constant.

Fig. 4.2

[2]

(ii) V, while f and P remain constant.

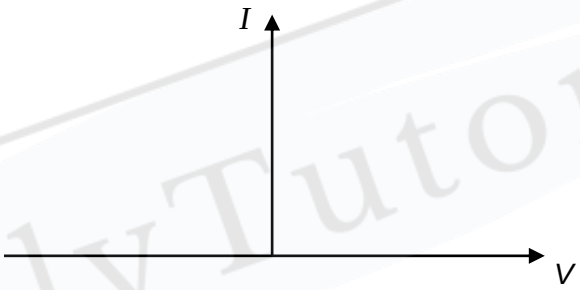

Fig. 4.3

[1]

(iii) P, while f and V remain constant.

Fig. 4.4

[1]

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(c) A very weak beam of light ray may be detected using a device known as a photo-multiplier, as shown in Fig. 4.5.

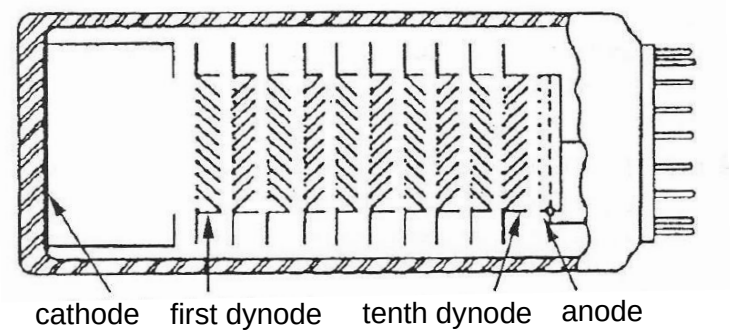

Fig. 4.5

The incident light causes photoelectrons to be emitted from the cathode. These photoelectrons are accelerated and strike a target electrode, called the first dynode. For each electron incident, six leave the dynode. These six are accelerated to the second dynode, which emits 36 electrons, which are all accelerated to the third dynode, and so on. The photomultiplier contains a series of ten dynodes in all.

(i) Calculate the number of electrons emitted by the tenth dynode for each electron striking the first dynode.

no. of electrons = …….. [1]

(ii) The electrons emitted from the tenth dynode are collected and constitute a current of 9.2 μA.

Determine the rate at which the photoelectrons are being emitted from the cathode.

rate = …….. s^{-1} [2]

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(iii) The incident light has a wavelength of 361 nm. At this wavelength, one in three of the incident photons causes an emission of photoelectron from the cathode.

Determine the power of the incident light.

power = …….. W [2]

(iv) The electrons emitted by a dynode have negligible initial energy, and are accelerated through a potential difference of 50 V before striking the next dynode.

Determine the de Broglie wavelength of these electrons right before they strike the next dynode.

wavelength = …….. m [3]

[Total: 17]

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5 **(a)** When a neutron is captured by a Uranium-235 nucleus, the outcome may be represented by the nuclear equation shown below.

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{95}_{42}\mathrm{Mo} + {}^{139}_{57}\mathrm{La} + 2\,{}^{1}_{0}\mathrm{n} + 7\,{}^{0}_{-1}\mathrm{e}$$

The energy released in the nuclear reaction above is 182 MeV. Fig. 5.1 shows how the binding energy per nucleon varies with mass number *A*.

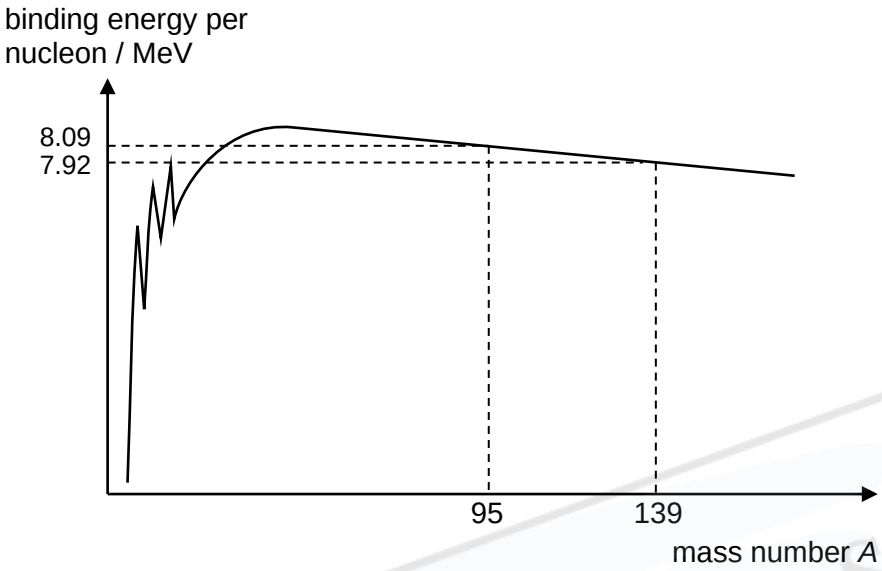

Fig. 5.1

(i) Determine the binding energy, in MeV, of a nucleus of Uranium-235.

binding energy = ... MeV [3]

(ii) Calculate the mass defect, in kg, of a nucleus of Uranium-235.

mass defect = ... kg [2]

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(b) The nuclide Potassium-42 $\left({}^{42}_{19}\text{K}\right)$ undergoes radioactive decay to become Calcium-42 $\left({}^{42}_{20}\text{Ca}\right)$. A radioactive sample contains N_0 atoms of Potassium-42 and no atoms of Calcium-42 at time $t = 0$. Fig. 5.2 shows the variation with time t of the ratio $\frac{N}{N_0}$ where N is the number of atoms of Potassium-42.

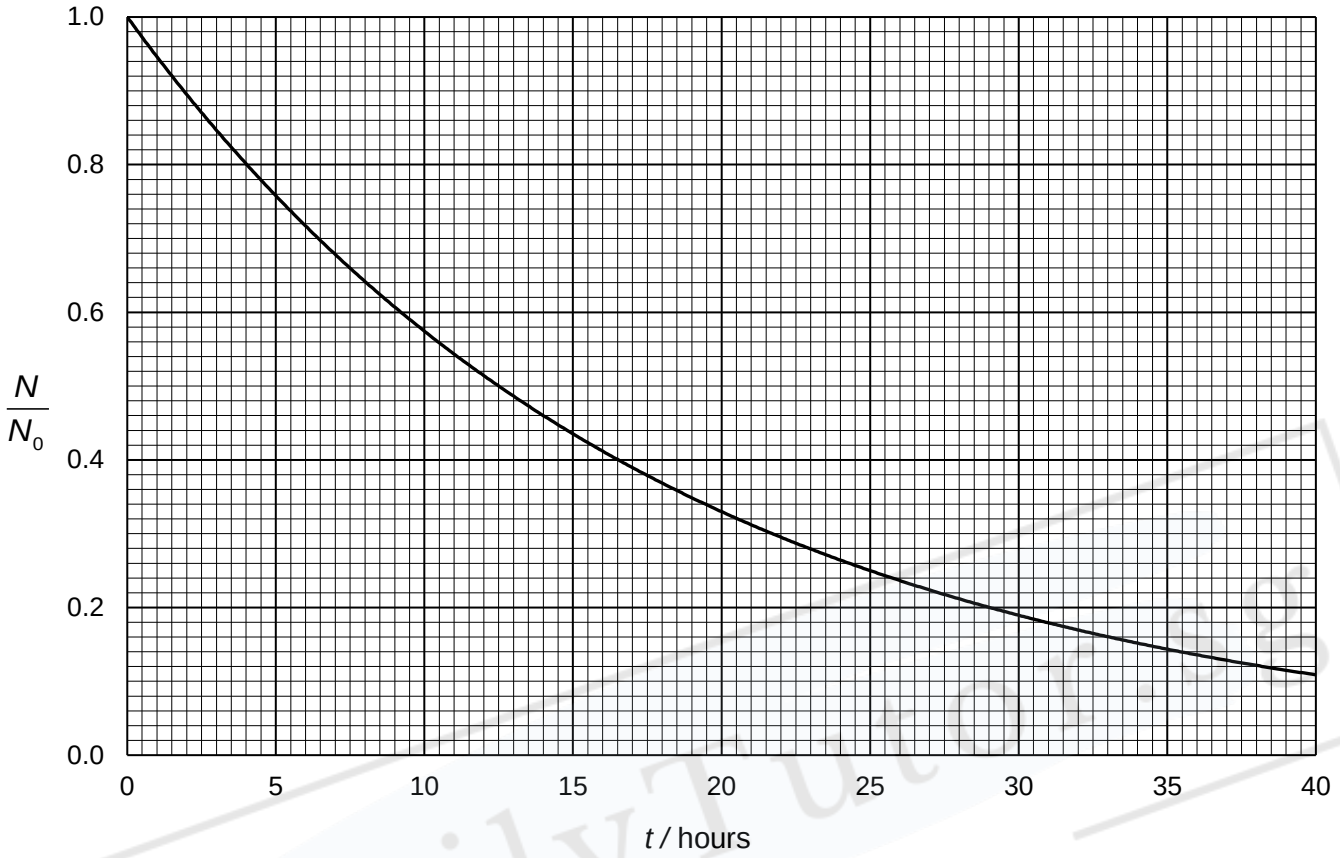

Fig. 5.2

(i) Write down the equation for the decay of Potassium-42 to Calcium-42. [1]

(ii) Use Fig. 5.2 to estimate the half-life of Potassium-42.

half-life = …….. hours [1]

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(iii) Calcium-42 is stable. Using the axes of Fig. 5.2, sketch a graph to show the variation with time t of the ratio of Calcium-42 atoms to N_0 in the sample. [1]

(iv) By reference to Fig. 5.2 or otherwise, determine the age of the radioactive sample when the ratio

$$\frac{\text{number of Calcium - 42 atoms}}{\text{number of Potassium - 42 atoms}}$$

is equal to 4.0.

age = ... hours [2]

[Total: 10]

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Section B

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

6 **(a)** State what is meant by *simple harmonic motion*.

……

……

…… [2]

(b) A small ball rests at point P on a curved track of radius r, as shown in Fig. 6.1.

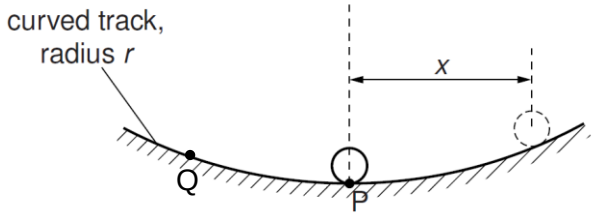

Fig. 6.1

The ball is moved a small distance of 2.0 cm to one side and is then released. The horizontal displacement x of the ball is related to its acceleration a towards P by the expression

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

where g is the acceleration of free fall.

(i) Explain how the equation above shows that the ball undergoes simple harmonic motion.

……

……

……

…… [2]

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

Show that the period T of the oscillation is 1.1 s. [2]

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(iii) Determine the time interval τ between the ball passing point P to point Q, where Q is 1.5 cm to the left of P.

τ = ... s [2]

(iv) On the axes of Fig. 6.2, sketch a graph to show the variation with displacement x of the velocity v.

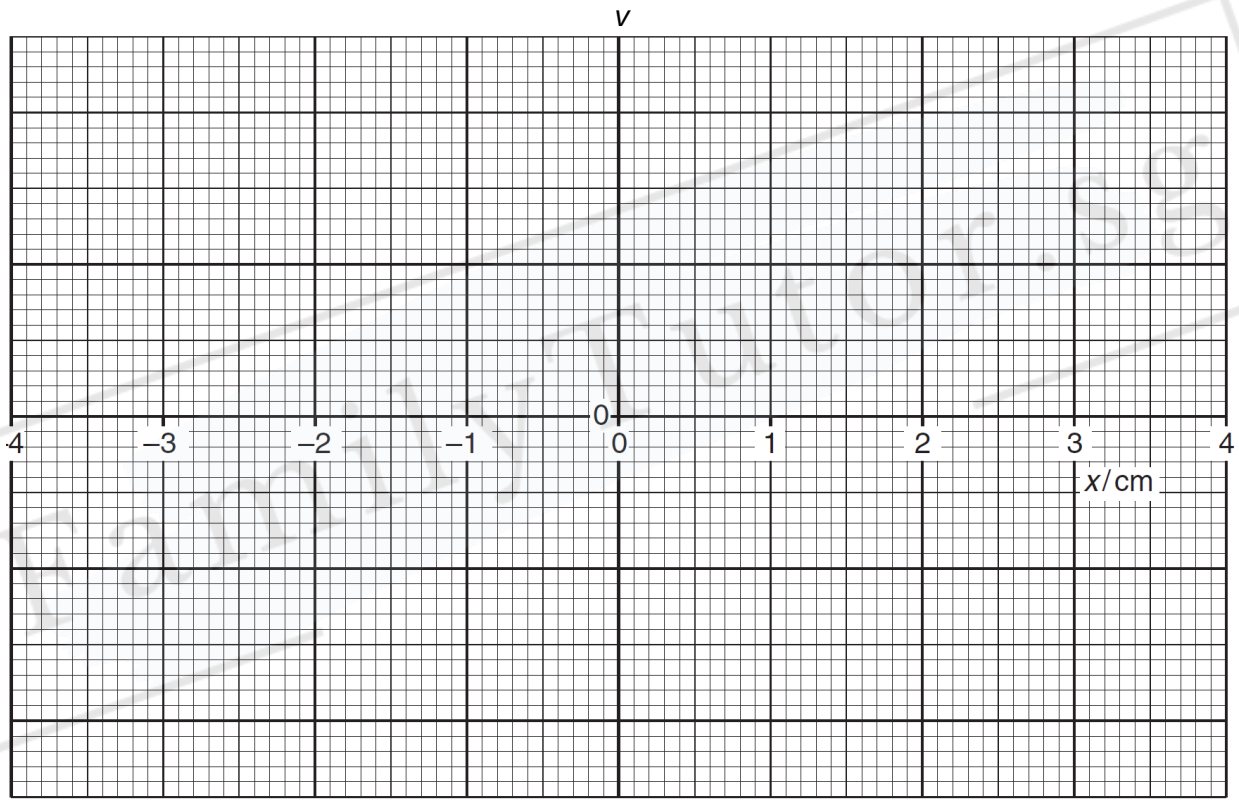

Fig. 6.2

[3]

(v) The mass of the ball is 0.10 kg. Calculate the total energy of the oscillation.

total energy = ... mJ [3]

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(vi) Hence, on the axes of Fig. 6.3, to show the variation with displacement x of

1. the total energy (label this TE)
2. the kinetic energy (label this KE)
3. the potential energy (label this PE)

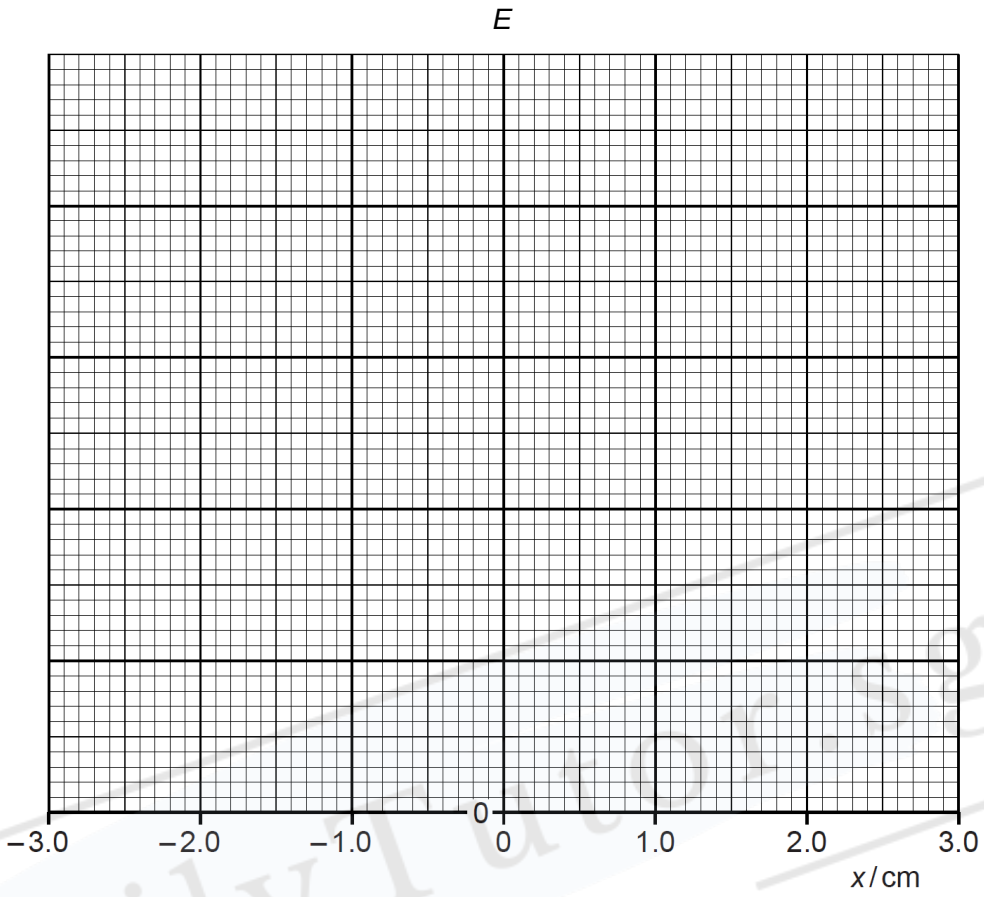

Fig. 6.3

[2]

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(vii) An additional track with a radius of 29 cm is placed beside the track with a radius of 28 cm. One ball is placed on each track and released as shown in Fig. 6.4 so that the balls start to move in phase.

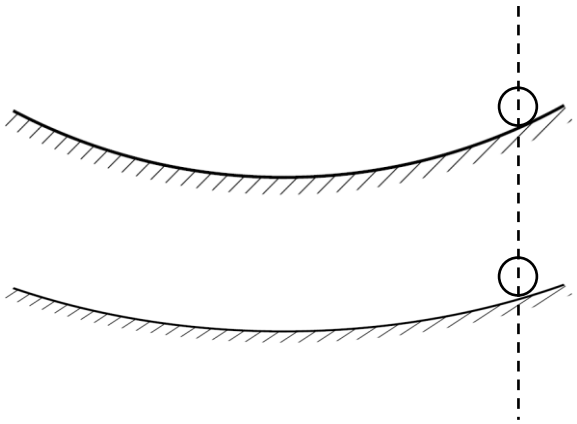

Fig. 6.4

The balls will start to move out of phase as they oscillate.

Determine the time it takes from the time of release till the next point in time when the balls are in phase again.

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time = ... s [4]

[Total: 20]

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7 **(a)** Define the *gravitational potential* at a point.

……

……

…… [2]

(b) The Earth may be considered to be an isolated sphere of radius R with its mass concentrated at its centre.

The variation of the gravitational potential ϕ with distance x from the centre of the Earth is shown in Fig. 7.1.

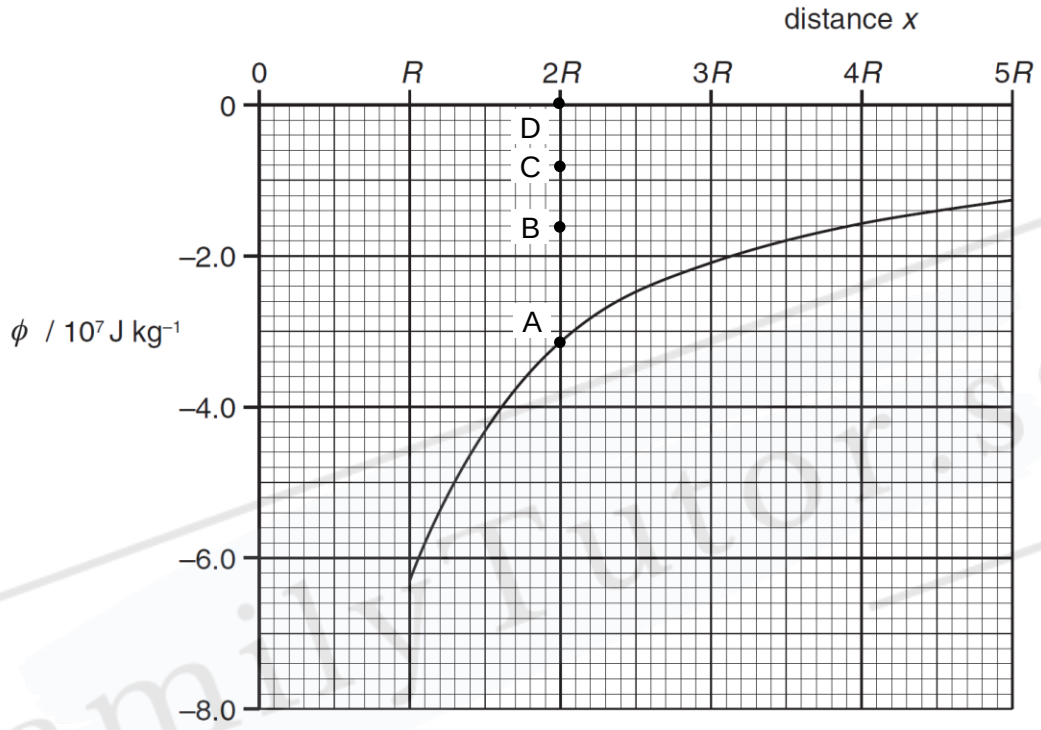

Fig. 7.1

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

(i) Using Fig. 7.1, determine the gravitational field strength at the point $2R$ above the surface of the Earth. Explain your working.

gravitational field strength = …… N kg^{-1} [3]

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(ii) At a certain distance $x = 2R$, the total energy of a space capsule (i.e. the sum of its gravitational potential energy and its kinetic energy) may be represented by one of the 4 points A, B, C and D.

Which point (or points) could represent the total energy of the space capsule

1. if it were momentarily at rest at the top of its trajectory,

2. if it were falling towards the Earth,

3. if it were moving away from the Earth, with sufficient energy to reach an infinite distance,

4. if it is moving in a circular orbit around Earth.

In each case, briefly explain how you arrived at your answer.

1. ……

……

…… [2]

2. ……

……

……

…… [3]

3. ……

……

…… [2]

4. ……

……

…… [2]

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(c) In practice, the Earth is not isolated and the gravitational field around Earth is affected by other celestial bodies such as the Moon.

Fig. 7.2, which is not to scale, shows how the gravitational potential between the surface of the Earth and the surface of the Moon varies along the line joining the centres. At the point P, the gravitational potential is a maximum.

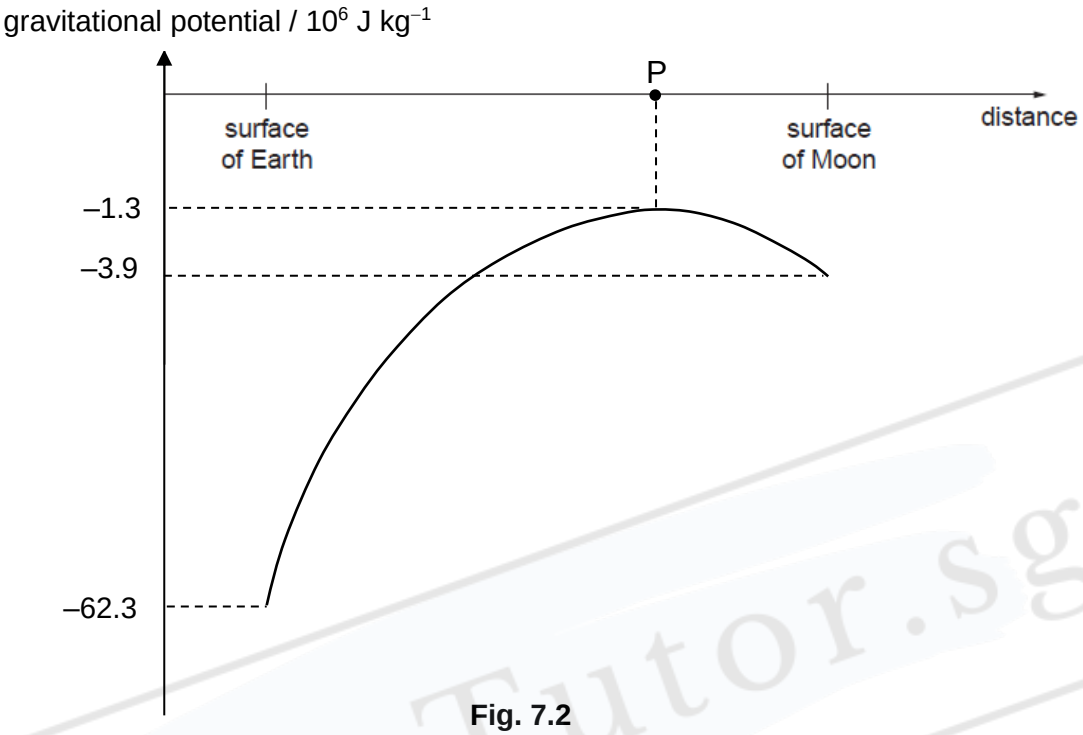

Fig. 7.2

(i) On the axes of Fig. 7.3, sketch a graph to show the variation of the gravitational field strength with distance between the surface of the Earth and the surface of the Moon.

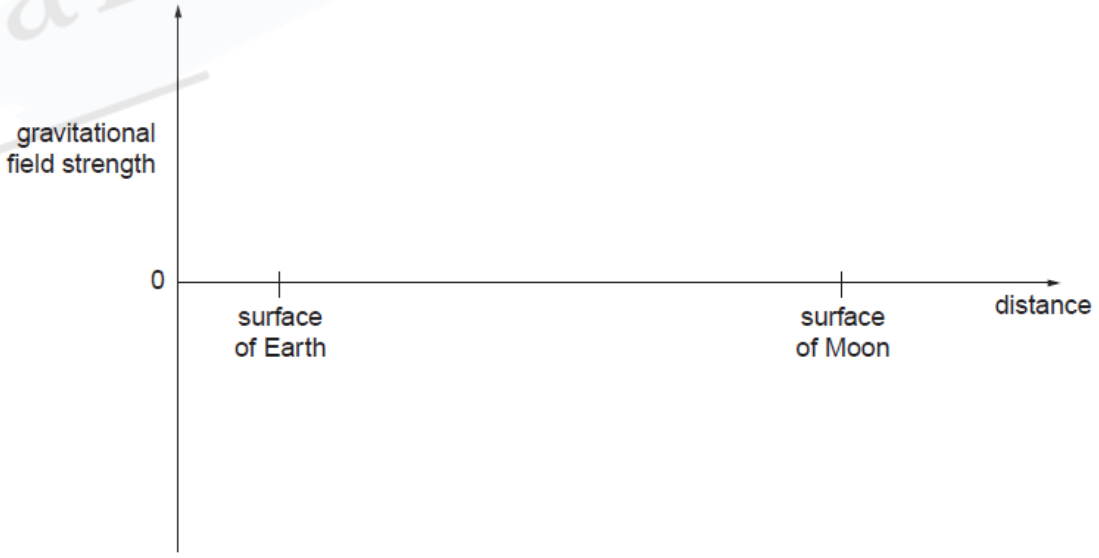

Fig. 7.3 [3]

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(ii) Using Fig. 7.2, find the minimum energy needed to send a 4.0 kg object from the surface of Earth to the surface of the Moon.

minimum energy = …….. J [3]

[Total: 20]

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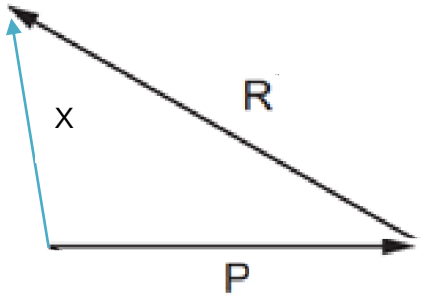
H2 Physics PU3 Preliminary Examination Paper 1 Answers

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

1	**A**	X = P – R = P + (–R) Hence vector R needs to change to the opposite direction before adding to P 
2	**C**	The object dropped from a great height will be experiencing a decreasing acceleration due to to increase in air resistance acting on it. As a result, the velocity will be increasing at a decreasing rate until it reaches a constant value.
3	**B**	$\Delta p = \text{impulse}$ $p_f - p_i = \text{area under F-t graph}$ $m(v_f - v_i) = 10(0.5) + 5(0.5)$ $3(v_f - 0.50) = 7.5$ $v_f = 3.0 \text{ m s}^{-1}$
4	**B**	Since no net external force acts on the system of 2 particles, final momentum = initial momentum Considering vertical momentum, $p_X \sin\theta + (-p_Y \sin\alpha) = 0$ $p_X \sin\theta = p_Y \sin\alpha$

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5	**D**	Let L be the distance from hip joint pivot to centre of mass. Applying principle of moment at the hip joint pivot, $TL\sin 8^o = WL\sin 70^o$ $T = W\dfrac{sin70^o}{sin8^o}$ $= 400 \times 6.752$ $= 2700$ N
6	**B**	Upthrust $= V\rho g = \left(2.0\times10^{-4}\right)(800)(9.81) = 1.6$ N The spring balance will read = 8.0 1.6 = 6.4 N
7	**B**	By conservation of energy, Loss in GPE = Gain in KE + W.D by resistive force (600)(80 – h)(9.81) = [½ (600)(12.0)^2 – 0] + (200)(1500) h = 22 m
8	**C**	The resultant of 160 N and 120 N should provide the horizontal centripetal force. Resultant force = (160^2 – 120^2) =105.8 N Resultant force = ma 105.8 = (120/9.81) a ® a = 8.65 ms^{-2}
9	**D**	g = $\frac{GM}{r^2}$ = $GM\frac{1}{r^2}$ The gradient is "GM", where M is the mass of the planet.
10	**D**	v = rw = r $\frac{2\pi}{T}$ $= (36000 + 6400) \times 10^3 \times \frac{2\pi}{24\times60\times60}$ = 3100 m s^{-1}
11	**C**	total kinetic energy = $\frac{3}{2}nRT = \frac{3}{2}pV = \frac{3}{2}(1.0\times10^{-5}\times0.010) = 1500\,J$ Total KE is the same for the same T.
12	**A**	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ ⇒ $c_{rms} = \sqrt{\frac{3kT}{m}}$ $\frac{c'_{rms}}{c_{rms}} = \sqrt{\frac{T'}{T}}$ ⇒ $\frac{0.8c_{rms}}{c_{rms}} = \sqrt{\frac{T'}{295}}$ T' = 188.8 K = 84.4 °C

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13	**A**	Total heat supplied by the potatoes = heat for calorimeter + heat for water = $C($ + $mc($ = 200*12 + (2000)*(4.18)*12 = 102720 J Hence heat supplied per gram of potato = *Q/m* = 102720/75 =1369.6 J per gram
14	**B**	a_{max} = $\omega^2 x_o$ ------- (1) where x_o = 0.30 cm $\omega = \frac{2\pi}{T_{shm}}$ -------- (2) T_{shm} = twice the period of E_k – t graph [Remember this!] = 2 × 0.20 s = 0.4 s $a_{max} = (\frac{2\pi}{0.40})^2(0.30 \times 10^{-2}) = 0.74\ m\ s^{-2}$
15	**A**	With increased damping, the initial amplitudes are the same, the maximum amplitude is reduced and resonance occurs at a frequency slightly lower than natural frequency.
16	**B**	Using Malus' Law, $I_p = I_o \cos^2($ = 2.0 ($\cos^2 60^o$) = 0.5 W m^{-2}
17	**D**	The wave is reflected from the surface of the water and then interferes with the incident wave to form the stationary wave.
18	**C**	$x = \frac{\lambda D}{a} \Rightarrow \lambda = \frac{ax}{D} = \frac{(0.1 \times 10^{-3})(8.0 \times 10^{-3})}{2.0} = 4.0 \times 10^{-7}\ m$ At the second order dark fringe, the path difference will be 1.5 times of the wavelength, $6.0 \times 10^{-7}\ m$
19	**D**	At point A, the resultant electric field is pointing towards the left. At points B and C, the resultant electric field is pointing towards the right.

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		At point D, the electric field due to $+4Q$ is pointing towards the right and that due to $-Q$ is pointing towards the left. Considering the magnitude of $\frac{Q}{r^2}$ for both charges at point D, it is possible for the resultant electric field to be zero.
20	**C**	The electric force on the positive charge is pointing in the direction of the E-field. So the external force exerted to move the charge is pointing in the opposite direction to the E-field. Work done by external force, $W = F\,s\cos\theta = qEs\cos 0°$ $= (2.6 \cdot 10^{-8})(3.0 \cdot 10^{5})(4.0 \cdot 10^{-3})$ $= +3.1 \cdot 10^{-5}$ J
21	**C**	E=Pt=40x3=120 J
22	**A**	Characteristics of (1) NTC: when the temperature is high, the resistance of a thermistor decreases. (2) LDR: when light intensity is high, the resistance of the LDR decreases For lamp to glow more brightly, LDR must have lower resistance (to increase the overall supply current) and NTC with a higher resistance (so that more current will pass through lamp in the parallel branch). To achieve this, the light intensity on the LDR must increase while the NTC temperature must decrease.
23	**A**	The point charge's velocity is parallel to resultant magnetic flux density at the centre of the two wires. Thus magnetic force is zero.
24	**D**	The change in C will result in an increase in magnetic field hence, an increase in the balancing force required. With a larger moment, a larger mass of the rider had to be used to rebalance.
25	**B**	$\left\|\varepsilon\right\| = \left\|\frac{\Delta BAN}{\Delta t}\right\|$ $= \left\|\frac{(0-0.15)\times 0.050\times 0.080\times 40}{3.0}\right\|$ $= 0.0080$ V
26	**B**	On the secondary side, $I_{S\,rms} = \frac{\langle P\rangle}{V_{S\,rms}} = \frac{12}{6.5} = 1.8462\ A$ There using $\frac{I_P}{I_S} = \frac{N_S}{N_P}$ $$I_{P\,rms} = \frac{40}{1000}\times 1.8462 = 0.0738 = 0.074\ A$$

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27	**C**	Option A : Incorrect. If the frequency of light is sufficiently high, even at extremely low intensities there will be emission of photoeelectrons. Option B : Incorrect. From Einstein's photoelectric effect equation, the relationship between frequency and stopping potential is not directly proportional. Option D: Increasing the intensity of the incident photons will not change the energy of each photon, it just increases the no. of photons per unit time incident on the metal. Hence, the energy of the photoelectrons emitted will not change as the interaction between each photon and electron remains the same.
28	**B**	K_{max} = 0 eV occurs when λ = 300 nm. Therefore, the threshold wavelength is 300 nm. By photoelectric equation, $\Phi = \frac{hc}{\lambda} - E_k\text{max}$ $= \frac{6.63\times10^{-34}(3.0\times10^{8})}{300\times10^{-9}} - 0$ $\Phi = 6.63\times10^{-19}$ J $= 4.14$ eV
29	**D**	Total BE before reaction = 7.59 (235) = 1783. 65 Mev Total BE after reaction = (8.26 x 121) + (8.52 x 113) = 1962 MeV Change in BE = +179 MeV, manifested as the energy released (products are more stable)
30	**C**	For sample X: $A = \lambda_A N$ For sample Y: $3A = \lambda_Y N$ $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ and since for half life we can combine the equations as follows:

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		$A = \frac{\ln 2}{t_{1/2(X)}} N$ $3A = \frac{\ln 2}{t_{1/2(Y)}} N$ $\frac{3A}{A} = \frac{\frac{\ln 2}{t_{1/2(Y)}} N}{\frac{\ln 2}{t_{1/2(X)}} N}$ $3 = \frac{t_{1/2(X)}}{t_{1/2(Y)}}$

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Qn		Answers	Marks
1	a	units of $v^2 = (\text{m s}^{-1})^2 = \text{m s}^{-2}$ units of $u^2 = (\text{m s}^{-1})^2 = \text{m s}^{-2}$ units of $2as = \text{m s}^{-2} \times \text{m} = \text{m s}^{-2}$ Since the units of all the terms are the same, the equation is homogenous. units of v^2, u^2, and $2as$ presentation and conclusion	 B1 B1
	b	$mass = (length \times width \times height) \times density$ $= (1.99 \times 1.95 \times 2.02) \times 1.24 = 9.7199 = 9.71\ g$ $By\ calculating\ percentage\ /\ fractional\ uncertainty: \frac{\Delta m}{m}$ $= \frac{\Delta l}{l} + \frac{\Delta w}{w} + \frac{\Delta h}{h} + \frac{\Delta \rho}{\rho} = 0.01 + 0.01 + 0.01 + \frac{0.05}{1.24}$ $= 0.070323 \Delta m = 0.070323 \times 9.7199 [* M1] = 0.68353$ $= 0.7\ g$ $mass = (9.7 \pm 0.7)\ g$ Alternatively, max-mean method: m_{max} = (1.99 x 1.01)(1.95 x 1.01)(2.02x1.01)(1.29) = 10.418 g $\Delta m = m_{max} - m_{mean} = 10.418 - 9.7199 = 0.7\ g$	C1 C1 C1 A1 (C1) (C1)

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2	**a**	Use of *mgh = ½ m v²* ***and*** *makes h subject* h = 14.7 or 15 m	 A1
	bi	Calculate the final vertical velocity at C (using v = 0 + at=9.81x1.6) v = 15.7 or 16 m s^{-1}	C1 A1
	bii	Straight line of positive gradient) Starting at 0 ms^{-1} and ends at 16 ms^{-1} at 1.6 s.	 A1
	biii	Use of pythagoras' theorem: resultant $v^2 = 15.7^2 + 17^2$ $v = 23$ or 23.1 m s^{-1}	M1
	c	slope: smaller change in vertical component of velocity/ smaller change in vertical component of momentum by Newton's second law, the force experienced = rate of change of momentum is less, so less risk of injury	M1 A1
3	**ai**	Archimedes' Principle states that the upthrust on a body completely or partially submerged in a fluid is equal in magnitude and opposite in direction to the weight of the fluid the body displaces.	B1
	aii	Pressure increases with depth in a fluid. When an object is submerged in a fluid, bottom is at a greater depth than at the top, hence, the pressure is greater at the bottom than at the top of the object. The difference in pressure results in a net upward force acting on the object, which is upthrust.	B1 B1
	b	$F_{net} = 0$ $m_{total}g = U + F_{resistive}$ $m_{submarine}g + m_{seawater}g = \rho g V_{submarine} + F_{resistive}$ $4800(9.81) + m_{seawater}(9.81) = (1030 \times 9.81 \times 5) + 1100$ $m_{seawater} = 462$ kg	 C1 C1 A1
	c	$P = P_o + \rho gh$ $= 1.01 \times 10^5 + (1030 \times 9.81 \times 200)$ $= 2.12 \times 10^6$ Pa	 A1

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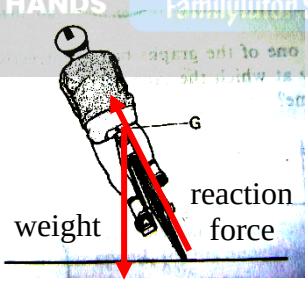
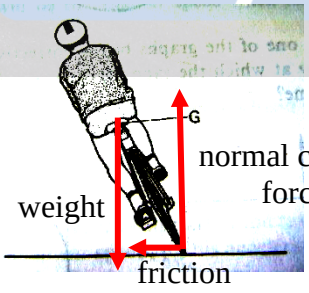
4 **(a)**





1 mark for correct direction of arrows B1
1 mark for similar length of arrows in vertical direction B1

(b) Since frictional force provides for the centripetal force,

$$f = \frac{mv^2}{R}$$

$$70 = \frac{(80)v^2}{55}$$

$$v = 6.9 \text{ m s}^{-1}$$ A1

(c) **(i)** For a surface which is banked, the horizontal component of the normal reaction is an additional source of the centripetal force. B1

Since Centripetal Force = $\frac{mv^2}{r}$, an increase in the centripetal force would allow the rider to turn the corner at a higher speed without slipping, provide the mass of cyclist and bicycle and radius of turn remain constant. B1

(ii) Considering forces acting on the rider/bicycle in the horizontal direction:

$$N \sin 20° + f \cos 20° = \frac{mv^2}{r}$$ ---------- (1) C1 C1

For the equilibrium in the vertical direction:

$$N\cos 20° = mg + f \sin 20°$$ ----------(2)

Solving (1) & (2),

$$\tan 20° \left(mg + f \sin 20° \right) = \frac{mv^2}{r} - f \cos 20°$$ A1

max velocity during turning v = 15.7 m s^{-1}

[Turn over

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5	**a**	The rocket experiences equal and opposite gravitational forces exerted by Earth and Moon. Hence there is zero net force as the forces cancel out.	B1
	b	1. Moon does not have an atmosphere hence there is no need to supply energy to do work against air resistance. 2. The gain in gravitational potential energy from Moon to P is much lower than that from Earth to P hence less kinetic energy is required for the rocket to move from Moon to P.	B1 B1
	c	At P, $F_E = F_M$ $\frac{GM_E m}{d_E^{\ 2}} = \frac{GM_M m}{d_M^{\ 2}}$ $M_M = \frac{\left(5.97\times10^{24}\right)\left(3.80\times10^{7}\right)^2}{\left(3.46\times10^{8}\right)^2}$ $= 7.20\times10^{22}\ \text{kg}$	C1 A1
	di	The gravitational potential at a point is the work done per unit mass in bringing a point mass from infinity to that point.	B1
	dii	$\phi_P = -\frac{GM_E}{d_E} - \frac{GM_M}{d_M}$ $= -\left(6.67\times10^{-11}\right)\left(\frac{5.97\times10^{24}}{3.46\times10^{8}} + \frac{7.20\times10^{22}}{3.80\times10^{7}}\right)$ $= -1.277\times10^{6}\ \text{J kg}^{-1}$ KE = Loss in GPE $= (7.5)\left[0 - \left(-1.277\times10^{16}\right)\right]$ $= 9.58\times10^{6}\ \text{J}$	C1 C1 A1

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6	**ai**	Total resistance of the 4 parallel resistors = $(1/2R + 1/2R)^{-1}$ = R. I = E/(R + r).	B1 A1
	aii	Power in the 4 parallel resistors = I^2 R, where I = E/(R+r) Power in the battery = IE $\frac{power\ in\ external\ resistors}{power\ by\ batter} = \frac{I^2R}{IE}$ or $\frac{I^2R}{I^2(R+r)}$ $= \frac{I\ R}{E}$ $= \frac{E\ R}{R+r}\ \frac{1}{E}$ $= \frac{R}{R+r}$	M1 A0
	aiii	Having 4 resistors in a network shown in Fig. 6.1, each resistor only dissipates ¼ of the power compared to a single resistor. Hence one of the resistors in Fig. 6.1 is less likely to exceed the power rating.	B1
	bi	There will be no deflection in the galvanometer when the p.d across JY = 1.5 V. Let the balance length (between J and Y) be *L*. Then $V_{JY} = \frac{L \times 1.50}{(1.50+0.50)} \times 4.0 = 1.5$ *L* = 0.500 m.	C1 A1
	bii	When 4.7 ∧ connected with the 1.5 V cell, the terminal p.d across the 4.7 ∧ is $V = \frac{4.7}{4.7+0.50} \times 1.5 = 1.356\ V$ There will null deflection when V_{JY} = 1.356 V. Then $V_{JY} = \frac{L' \times 1.50}{(1.50+0.50)} \times 4.0 = 1.356$ L' = 0.452 m. Alternative working: $L' = \frac{1.356}{3} \times 1.0 = 0.452\ m$	C1 C1 A1

[Turn over

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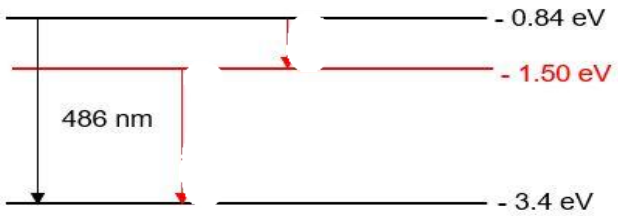
7	**a**	{Similarity} The discrete lines of both absorption and emission spectrum occur at same frequencies, {Difference} the absorption has dark lines against a continuous spectrum whereas the emission spectrum has coloured lines against a black background.	B1 B1
	bi	E = hf = $\frac{hc}{\lambda}$ = $\frac{(6.63\times10^{-34})\times(3.0\times10^{8})}{656\times10^{-9}\times(1.6\times10^{-19})}$ = 1.90 eV	 M1 A1
	bii	 Energy level labelled -1.50 eV and nearer to -0.84 eV	 A1
	c	0.92 eV Nothing happens to the lithium atom (ie. it stays in the -5.02 eV level) 0.92 – (5.02 – 4.53) = 0.43 eV Atom will be excited to the -4.53 eV level	A1 B1 A1 B1
	di	When the highly energetic electrons knock out the electrons in the inner shell of the atoms, leaving a vacancy. Electrons in the next higher energy levels transit down to the vacancy and X-ray photons are produced with energy equal to the energy difference between the 2 energy levels.	B1 B1
	dii	$eV = \frac{hc}{\lambda_o}$ $V = \frac{hc}{e\lambda_o} = \frac{(6.63\ x\ 10^{-34})(3.0\ x\ 10^{8})}{(1.6\ x\ 10^{-19})(1.2\times10^{-11})}$ $= 1.04\times10^{5}$ V = 104 kV	 C1 A1
	diii	Same characteristic wavelengths, lower threshold wavelength, higher intensity	A1

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		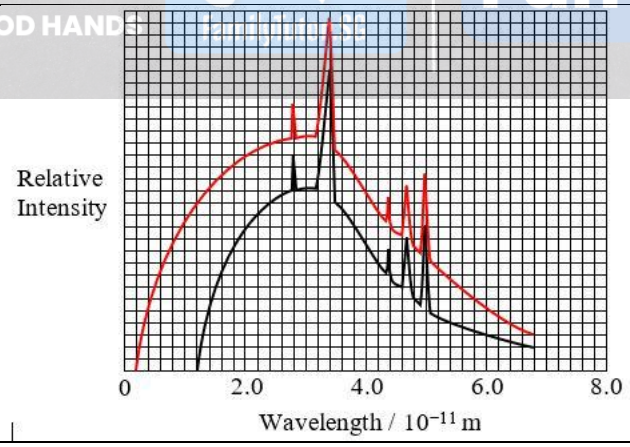	
8	**(a)**	There are <u>3 positively charged particles</u> <u>Applying Fleming's Left Hand Rule</u>, there are 3 lines curving to the left.	A1 M1
	(b)(i)	$r\alpha \frac{p}{q}$ Compared to other tracks, the <u>radius of the track in Fig. 8.3 is the smallest</u>. The <u>mass of electron is small</u>. Its momentum and the radius will be small. Hence the proposal is possible.	M1 A1
	(b)(ii)	The electron <u>loses energy</u> as it travels through the chamber. Its <u>momentum and hence its radius decreases</u>, resulting in a spiral.	B1 B1
	(c)(i)	Conservation of charge gives (Charge of K^-) + (proton charge) = Total charge after collision (-e) + (+e) = (+e) + (–e) + (+e) + q_4 ⇒ $q_4 = -e$	C1 A1
	(c)(ii)	$r\alpha \frac{p}{q}$ Particle 3 has the lowest momentum because r is smallest.	A1
	(d)(i)	It causes little or no ionization in the target atoms, so it leaves no track.	B1
	(d)(ii)	They are oppositely charged, as the paths curve in opposite directions, implying that the magnetic force points in opposite directions, OR, because they are formed from a neutral particle.	B1 B1
	(e)(i) 1. **(e)(i) 2.**		A1

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	438.05	-13.24	0.81	1317.12
p	0.00	0.00	0.00	150.13
sum	438.05	-13.24	0.81	1467.25

[Turn over

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		<table><tr><th>particle</th><th>p_x / 10^{-20} N s</th><th>p_y / 10^{-20} N s</th><th>p_z / 10^{-20} N s</th><th>E / 10^{-12} J</th></tr><tr><td>K^-</td><td>79.03</td><td>1.48</td><td>11.95</td><td>252.50</td></tr><tr><td>Ω^-</td><td>7.98</td><td>-0.60</td><td>2.07</td><td>33.38</td></tr><tr><td>Ω^+</td><td>2.02</td><td>-6.52</td><td>-1.21</td><td>30.51</td></tr><tr><td>P</td><td>80.46</td><td>6.85</td><td>-3.76</td><td>285.22</td></tr><tr><td>K^0</td><td>189.10</td><td>-8.69</td><td>-13.07</td><td>574.78</td></tr><tr><td>sum</td><td>358.59</td><td>-7.48</td><td>-4.02</td><td>1176.39</td></tr></table>	A1
	(e)(ii)1	p_x = (438.05 - 358.59) x 10^{-20} = +79.46 x 10^{-20} N s p_y = (-13.24 + 7.48) x 10^{-20} = -5.76 x 10^{-20} N s p_z = (0.81 + 4.02) x 10^{-20} = +4.83 x 10^{-20} N s E = (1467.25 - 1176.36) x 10^{-12} = 290.86 x 10^{-12} J	A1 A1 A1 A1
	(e)(ii)2	$m = \sqrt{\frac{E^2 - (p_x^2 + p_y^2 + p_z^2)c^2}{c^4}}$ $= \sqrt{\frac{(290.87\times10^{-12})^2 - ((79.46\times10^{-20})^2 + (5.77\times10^{-20})^2 + (4.83\times10^{-20})^2)c^2}{c^4}}$ = 1.835 x 10^{-27} kg	C1 A1

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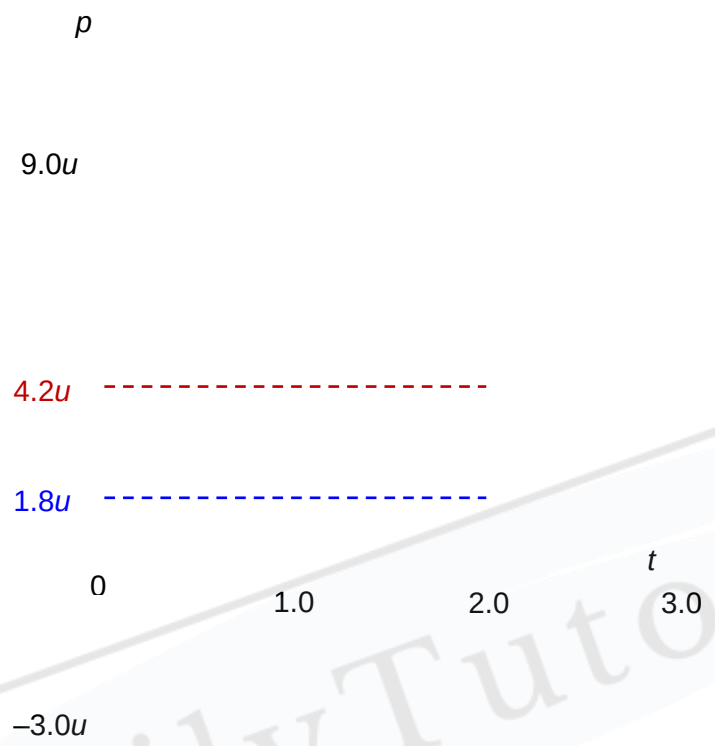
2023 MI PU3 H2 Physics Prelim Paper 3 Suggested Solution

1a(i)	No external forces act on the system of two objects. OR The two objects form a closed system.	B1
(ii)	Straight line from (1.0, -3.0u) to (2.0, 4.2u) Horizontal line at p = 4.2u from t = 2.0 to 3.0 s  	B1 B1
(iii)	Since the <u>total momentum before the collision is 6.0*u*</u>, the <u>total momentum</u> of the system <u>remains constant at 6.0*u* at all times</u>. So final p of object B = 6.0u – 1.8u =4.2u OR Since <u>p of object A decrease by 7.2u</u> after the collision, <u>p of particle B will increase by 7.2*mu.*</u> So final p of particle B = -3.0u + 7.2u = 4.2u	B1
1b	v_A = 1.8u / 9.0 = 0.2u v_B = 4.2u / 1.0 = 4.2u	

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	relative speed of approach$= u_A - u_B = u - (-3u) = 4u$ relative speed of separation$= v_B - v_A = 4.2u - 0.2u = 4u$ Since the relative speed of approach and the relative speed of separation are equal, the collision is elastic. OR kinetic energy, $E_k = \frac{1}{2}mv^2 = \frac{1}{2}\frac{(mv)^2}{m} = \frac{p^2}{2m}$ before collision: $E_{k,before} = \frac{p_{A,before}{}^2}{2m_A} + \frac{p_{B,before}{}^2}{2m_B} = \frac{(9.0u)^2}{2(9.0)} + \frac{(-3.0u)^2}{2(1.0)} = 9.0u^2$ after collision: $E_{k,after} = \frac{p_{A,after}{}^2}{2m_A} + \frac{p_{B,after}{}^2}{2m_B} = \frac{(1.8u)^2}{2(9.0)} + \frac{(4.2u)^2}{2(1.0)} = 9.0u^2$ Since the kinetic energy of the system before and after the collision remains the same, the collision is elastic.	M1 M1 A1 (M1) (M1) (A1)
1c(i)	$F = \frac{\Delta p}{\Delta t}$ $= \frac{(1.8u - 9.0u)}{(2.0 - 1.0)}$ = (-) 7.2u (accept + or – answer) Therefore, magnitude of F is 7.2u	M1 A0
(ii)	By Newton's second law, gradient of p vs t graph represents resultant force. During collision, gradient of graph of object A and object B have equal magnitude, showing that forces acting on A and B have equal magnitude. The gradients have opposite signs indicate that the two forces act in opposite directions. Hence the graphs are consistent with Newton's third law	 B1 B1
	Total:	10

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2a	Total volume of molecules is negligible compared with volume occupied by the gas	B1
2b	$pV = NkT$ $2.10 \times 10^5 \times 950 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times (280)$ $N = 5.16 \times 10^{22}$ volume of one molecule = $(4/3)\pi r^3$ ($= 1.41 \times 10^{-29}$ m^3) volume of all molecules = $5.16 \times 10^{22} \times 1.41 \times 10^{-29}$ $= 7.3 \times 10^{-7}$ m^3 $= 7 \times 10^{-7}$ m^3 (**1 s.f.**; as this is an estimation question the uncertainty of final answer cannot be more precise than that of the given data.) **OR** volume of one molecule = d^3 ($= 2.7 \times 10^{-29}$ m^3) volume of all molecules = $2.7 \times 10^{-29} \times 5.16 \times 10^{22}$ $= 7 \times 10^{-7}$ m^3 (**1 s.f.**; as this is an estimation question the uncertainty of final answer cannot be more precise than that of the given data.)	C1 C1 A1 (C1) (C1) (A1)
2c	Since volume of all atoms (1×10^{-6} m^3) is *3 orders of magnitude less* than volume occupied by the gas (950×10^{-6} m^3 H 1 x 10^{-3} m^3) OR 0.1% of volume occupied by the gas so assumption in (a) is justified.	B1
2d(i)	Internal energy depends on temperature. Since final temperature equal initial temperature so **no change in total internal energy**	B1 B1
2d(ii)	<u>For P → Q:</u> work done on gas = **0 J** and increase in internal energy, ⊗U = Q + W = +97.0 + 0 = **97.0 J** <u>For Q → R</u>: increase in internal energy, ⊗U = 0 -42.5 = **–42.5 J** <u>For R→P:</u> work done on gas, W = p ΔV = $2.10 \times 10^5 \times (1125 - 950) \times 10^{-6}$ = **36.8 J** since total change in internal energy is zero, $+97 + (-42.5) + \Delta U_{RP} = 0$ increase in internal energy, ΔU_{RP} = **–54.5 J** thermal energy supplied, Q = ΔU – W = −54.5 – 36.8 = **–91.3 J**	A1 A1 A1 A1 A1
	Total:	12

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3a	upthrust and weight	B1
3b	**upthrust greater than weight** so resultant force is **upwards**	B1
3c(i)	*A*, *g* and *ρ* all constant so *F* is proportional to *x* minus sign means *F* and *x* are in opposite directions	B1 B1
3c(ii)	$a = \frac{F}{m} = (-)\frac{Ag}{m}x$ compare with SHM defining equation $a = -\omega^2 x$ $\omega^2 = \frac{A\rho g}{m}$ $\omega = \sqrt{\frac{Ag}{m}}$	M1 M1 A0
3d(i)	Damping due to viscous forces	B1
3d(ii)	$-\omega^2 = gradient = \frac{2 \cdot 30}{0.020} = 115$ $(2\pi f)^2 = 115$ f = 1.71 = 1.7 Hz	C1 A1
3d(iii)	$E = \frac{1}{2}kx^2 = \frac{1}{2}mw^2x$ $initial\ E = \frac{1}{2}(O.57)(115)(0.020)^2 = 0.01311\ J$ $final\ E = \frac{1}{2}(0.57)(115)(0.016)^2$ = 0.0083904 J $\Delta E = Initial\ E - final\ E$ $= 4.7\ x\ 10^{-3} J$ OR accept if students use area under graph to final initial and final E read off first point (-0.02,2.3) gives initial E = 0.01311 J accept either: read off second point as (0.016, -1.8) gives final E = 0.008208, hence $\Delta E = 4.9\ x\ 10^{-3} J$ read off second point as (0.016, -1.84) gives final E = 0.0083904 hence $\Delta E = 4.9\ x\ 10^{-3} J$	C1 C1 A1
	Total:	12

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4a	Zero electric field strengths in sphere A(between x = 0 and x = 1.4 cm) and in sphere B (between x = 11.4 and x = 12.0 cm)	B1
4b	Since the field strength is zero at a point between the spheres OR the electric fields are in opposite directions, the charges on the spheres are of the same sign.	M1 A1
4c	At x = 0.08 m, the electric field strength due to sphere A cancels out the electric field strength due to sphere B. $E_A = E_B$ $\frac{Q_A}{4\pi\varepsilon_o (0.08)^2} = \frac{Q_B}{4\pi\varepsilon_o (0.04)^2}$ $\frac{Q_A}{Q_B} = \left(\frac{0.08}{0.04}\right)^2$ $= 4$ (Allow estimation from graph, 7.8 cm < x < 8.2 cm)	 B1 C1 A1
4d	 ● Correct field line direction (either all inwards or all outwards) and shape ● neutral point nearer to sphere B and any of the following: ● field lines more closely spaced for sphere B ● field lines perpendicularly from the spheres	 B1 B1 B1
4e	change in electric potential = area under graph between x = 1.4 cm and x = 3.0 cm Estimated area between x = 1.4 cm and x = 3.0 cm = ½ (0.8 x 10^{-2})(11.0 + 5.0)10^7 + ½ (0.8 x 10^{-2})(5.0 + 2.5)10^7 = 940 kV Or by counting squares under graph. Acceptable range for either method is between 850 kV and 1050 kV. Energy gained by proton = (940 x 10^3)(1.60 x 10^{-19}) = 1.5 x 10^{-13} J Accept (1.4 to 1.6) x 10^{-13} J	C1 C1 A1
	Total:	12

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5a(i)	$(E = BE_{products} - BE_{reactantan\,t\,s})$ E = (BE per nucleon of C) x 12 – 3 x (BE per nuceon of He x 4) $E = [12 \times (7.680) - 3 \times (4 \times 7.074)]$ =7.272 MeV	C1 A1
5a(ii)	$P = \frac{E_{total}}{t}$ $= \frac{\text{number of reactions} \times E_{\text{each reaction}}}{t}$ $\frac{\text{number of reactions}}{t} = \frac{P}{E_{\text{each reaction}}} = \frac{2.75 \times 10^{26}}{7.272 \times 10^{6}\left(1.6 \times 10^{-19}\right)}$ $\left(= 2.3635 \times 10^{38}\ \text{s}^{-1}\right)$ $\frac{n}{t} = \frac{number\ of\ reactions}{t} \times 3 = (2.3635 \times 10^{38})(3)$ $\frac{n}{t} = 7.09 \times 10^{38}\ helium\ nuclei\ per\ second$	C1 C1 A1
5b(i)	*714X* *−10e*	B1 B1
5b(ii)1.	Observation 1: electrons/®-particles (emitted from the nucleus) have a (continuous) range of/ different (kinetic) energies OR Observation 2: electrons/®-particles and daughter nuclei X are not in opposite directions	B1
5b(iii)2.	Explanation for observation 1: Since the energy released in each decay is **same/fixed** by the principle of conservation of energy there must be **neutrinos** (emitted) to **take varying amounts of the** (same total) **energy** (released in the decay) so that electrons can take different/range of kinetic energy OR Explanation for observation 1: By conservation of momentum there must be **neutrinos** (emitted) such that the sum of momentum of neutrino and electron is in the opposite direction of the daughter nuclei X direction of neutrinos varies so electrons can be emitted in varying directions	 B1 B1, (B1) (B1)
5c(i)	tangent drawn and gradient calculation attempted activity = 1.3×10^6 Bq (accept answer within $\pm 0.2 \times 10^6$ Bq)	B1 A1
5c(ii)	$A = \lambda N$ $\lambda = (1.3 \times 10^6)/(3.05 \times 10^{10})$ $= 4.3 \times 10^{-5}\ \text{s}^{-1}$ ($\approx 4 \times 10^{-5}\ \text{s}^{-1}$)	B1 M1 A0
	Total:	14

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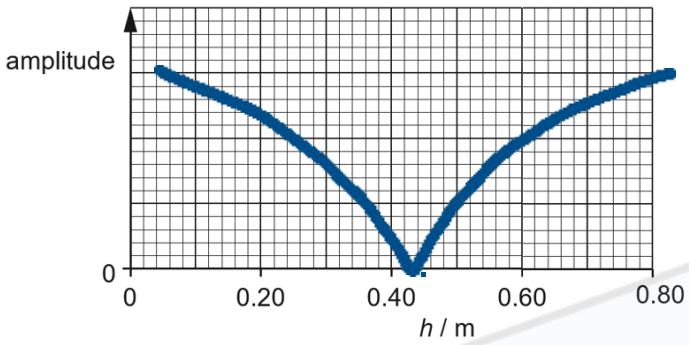
6a	distance moved by wavefront/energy during one cycle/oscillation/period (of source)	B1
6b	$T = 2.0 \times 2.5$ (= 5.0 ms) $f = 1 / (5.0 \times 10^{-3})$ = 200 Hz	 A1
6c(i)	(incident) **wave reflects at end/top of tube** (incident) **wave and reflected wave interfere/superpose** to produce stationary wave	B1 B1
6c(ii)	line has maximum value of amplitude at $h = 0$ and $h = 0.80$ m only line has minimum/zero value of amplitude at $h = 0.40$ m only  	B1 B1
6c(iii)1.	vertical/along length of tube/along axis of tube	B1
6c(iii)2.	phase difference = 0°	A1
6c(iv)	$\lambda = 2 \times 0.80 = 1.6$ m	A1
6d(i)	path difference = $8.0 + (20.8^2 - 8.0^2)^{0.5} - 20.8$ = 6.4 m	M1 A0
6d(ii)	• **path difference = 4λ** waves (meet at C) in phase • **constructive interference** (of waves) occurs	B1 B1
6d(iii)	$v = 200 \times 1.6$ = 320 m s^{-1} $\Delta t = 6.4 / 320$ **or** $27.2 / 320 - 20.8 / 320$ = 0.020 s	 C1 A1
6d(iv)	$3\lambda = 6.4$ $\lambda = 2.1$ m	C1 A1
6e(i)	Use Malus' law, Intensity $I = I_o \cos^2 \theta$ Intensity $I = I_o \cos^2 \theta = I_o \cos^2 45°$ $= I_o/2$	 C1 A1

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	And orientation to the vertical is 45°	
6e(ii)	Intensity $I = (I_o \cos^2 45°) \cos^2 45°$	C1
	$= I_o/4$ and orientation to the vertical is 0° (i.e. emergent beam is polarised vertically)	A1
	Total:	20

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7a(i)	Faraday's Law of Electromagnetic Induction states that the induced e.m.f is directly proportional to the rate of change of magnetic flux linkage.	B1
7a(ii)	A (primary) **coil** is installed **in the charging plate** and a another (secondary) **coil in the device**. A **changing magnetic flux** is produced in the (primary) **coil of the charging plate**, due to the alternating current from the power source. By Faraday's law, an **emf** will be **induced** in the (secondary) **coil of the device** which will charge the device.	B1 B1 B1
7a(iii)	Advantage: (any valid suggestion) ● No connecting wires required between device and charging plate, so less risk of electrical shock. ● Can fully enclose the charging parts to make it water-proof. Disadvantage: (any valid suggestion) ● Coils of wires are required to be installed inside the device, hence more bulky/costly. ● Less efficient than wired connection due to resistive heating (Lenz's law). ● Longer charging time. ● Device will need to stay with the charging plate and is not mobile when charging.	B1 B1
7b(i)	$2\pi f = 377 f = \frac{377}{2\pi} = 60.0\ Hz$	C1 A1
7b(ii)	$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{340}{\sqrt{2}}$ $= 240\ V$	C1 A1
7b(iii)	It means that this alternating supply voltage will provide the same average/mean power (or rate of heat dissipation) as an equivalent steady direct voltage of 240 V.	B1
7c(i)	$\varepsilon = BLv = (0.54)(0.100)(2.3) = 0.1242 = 0.124\ V$	C1 A1
7c(ii)	end C	B1
7c(iii)	$I = \frac{\varepsilon}{R} = \frac{0.1242}{0.83}$ $= 0.1496 = 0.150\ A$	C1 A1
7c(iv)	By Fleming's LHR, since current flows from A to B and magnetic field is into the plane, so force on rod AB is **towards right**.	M1 A1
7c(v)	$F = BIL = (0.54)(0.1496)(0.100)$ $= 8.08 \times 10^{-3}\ N$ $a = \frac{F}{m} = \frac{8.08 \times 10^{-3}}{0.034}$ $= 0.238\ m\ s^{-2}$ [A1]	C1 A1
	Total:	20

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TEST QUESTIONS AND ANSWER KEYS

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2023 Preliminary Examinations
Pre-University 3

H2 PHYSICS **9749/1**

Paper 1 Multiple Choice **21 September**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Do not turn over this page until you are told to do so.

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

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

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **18** printed pages.

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Data

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

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Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	$\rho g h$
gravitational potential	φ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T / °C + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
	v	=	$\pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
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	=	$\frac{ln2}{t_{1/2}}$

[Turn over

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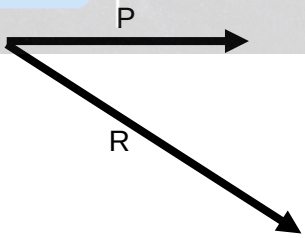
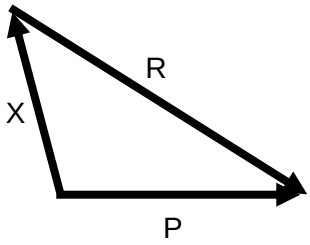
1 P and R are coplanar vectors.

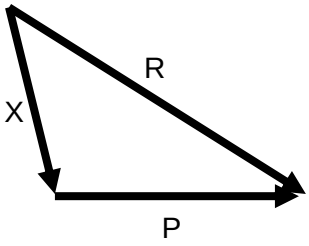


If X = P – R, which diagram best represents vector X?

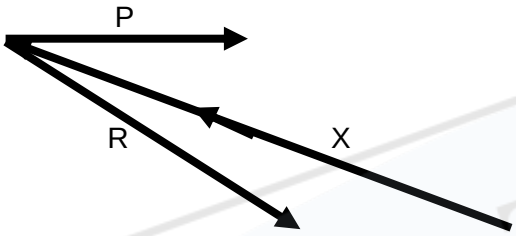
A



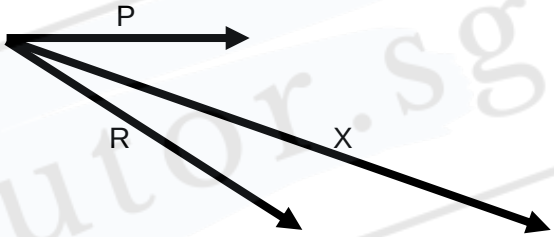
B



C



D



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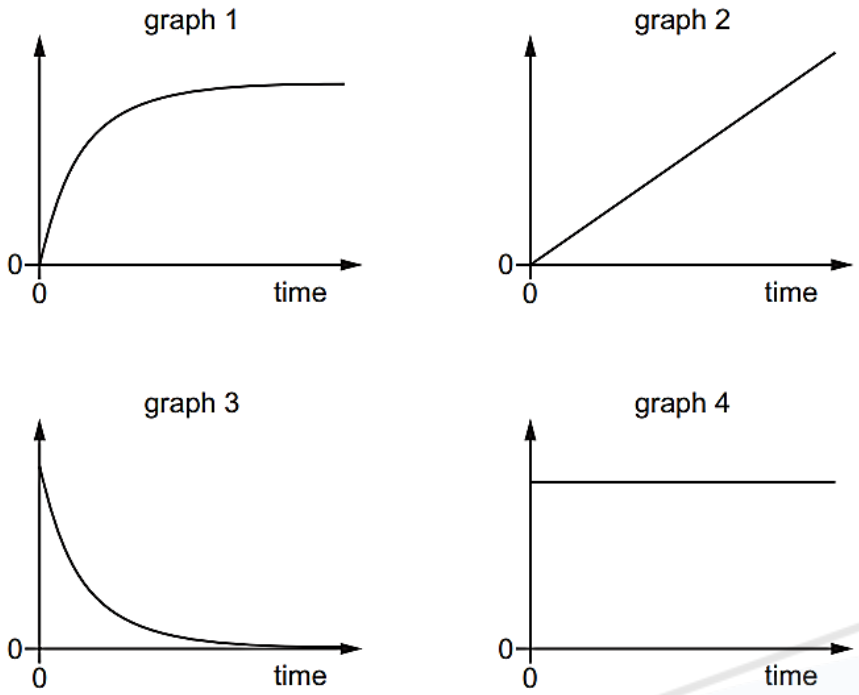
2 The following are graphs of various quantities plotted against time for an object dropped from a stationary balloon high in the atmosphere.



Which of the following statements most accurately describes the graphs?

A Graph 1 is acceleration against time and graph 3 is resultant force against time.

B Graph 1 is acceleration against time and graph 4 is resultant force against time.

C Graph 3 is acceleration against time and graph 1 is velocity against time.

D Graph 3 is acceleration against time and graph 2 is velocity against time.

[Turn over

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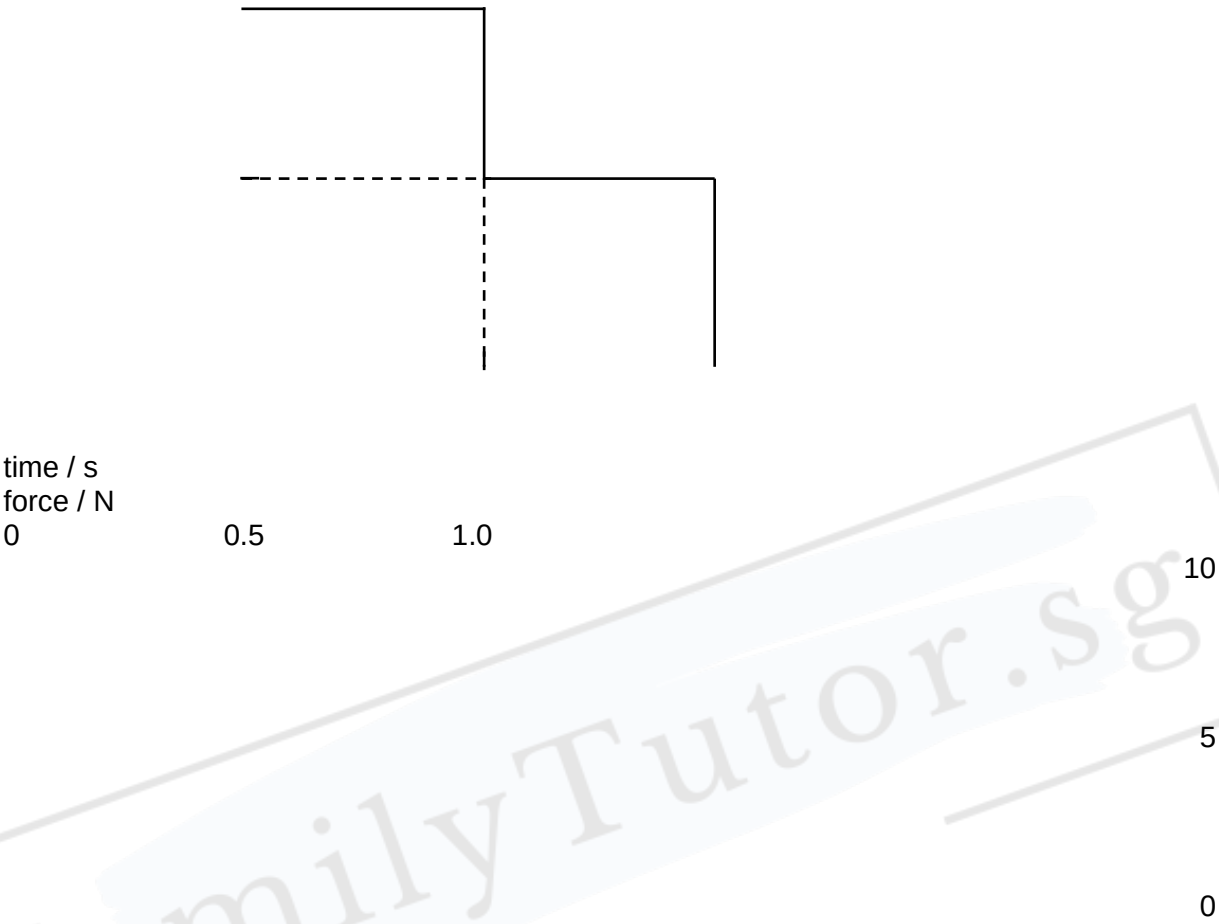
3 The force acting on a 3.0 kg mass varies with time as shown.

The object is initially moving at a velocity of 0.50 m s^{-1} in the same direction as the force.



What is the speed of the mass after 1.0 s?

A 2.5 m s^{-1} **B** 3.0 m s^{-1} **C** 5.0 m s^{-1} **D** 7.5 m s^{-1}

4 A particle X has initial momentum p. It collides with a stationary particle Y. The particle X is deflected through angle θ and its momentum is p_X. The particle Y moves off at angle α to the original direction of motion of particle X with momentum p_Y as shown.

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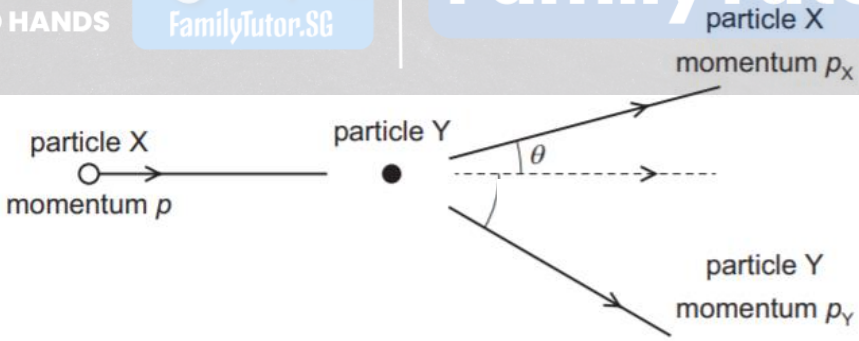


Which equation is a correct statement for momentum in this collision?

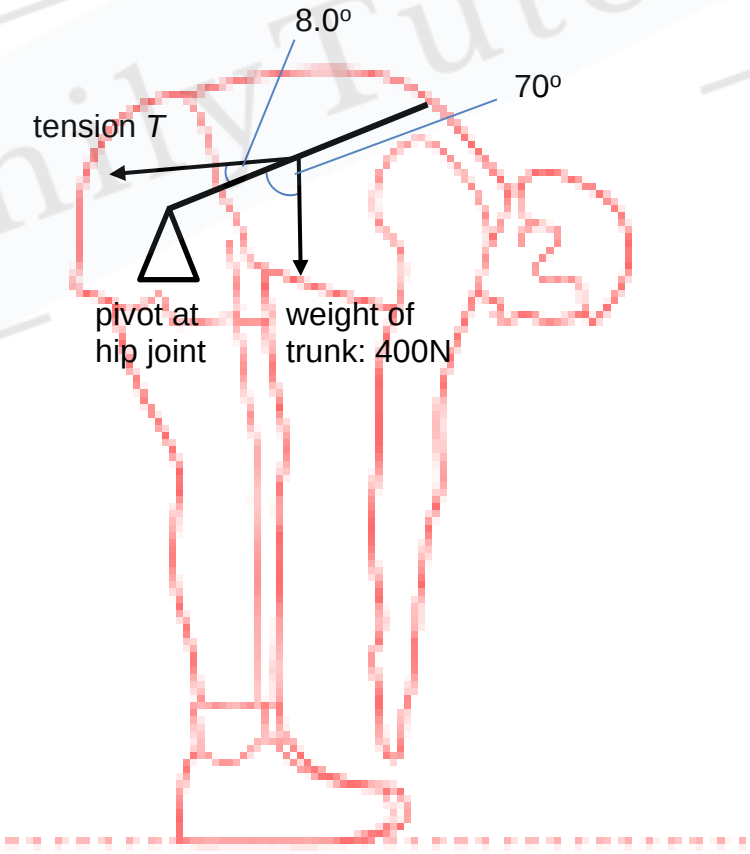
A $p_X \cos\theta = p_Y \cos\alpha$

B $p_X \sin\theta = p_Y \sin\alpha$

C $p_X \cos\theta + p_Y \cos\alpha = 0$

D $p = p_X \sin\theta + p_Y \sin\alpha$

5 A simplified diagram below represents the trunk of a person bent forward, with the spine at an angle of 70° to the vertical. The back muscle exerts a tension T and makes an angle of 8.0° to the spine. The weight of the person's trunk which is 400 N, acts at the point along the spine where the back muscle is attached.



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What is the tension *T* in the back muscle?

A 140 N **B** 380 N

C 980 N **D** 2700 N

6 When a pebble of volume 2.0×10^{-4} m^3 is hung on a spring balance, a reading of 8.0 N is obtained. The pebble is now totally immersed in a liquid of density 800 kg m^{-3}.

What is the reading on the spring balance now?

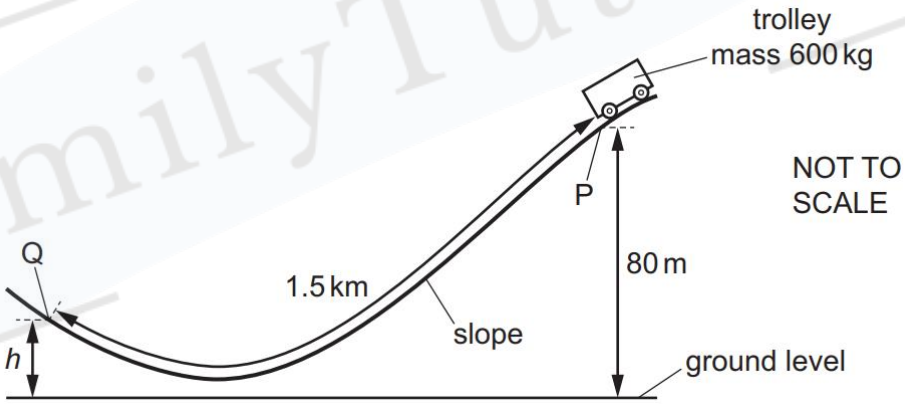
A 1.6 N

B 6.4 N

C 8.0 N

D 9.6 N

7 A trolley of mass 600 kg initially at point P on a slope, at height of 80 m above ground level, as shown. The trolley is released from rest and moves along the slope, reaches a speed of 12.0 m s^{-1} at point Q, at height *h* above the ground level.



The total distance PQ moved by the trolley along the slope is 1.5 km. A constant resistive force of 200 N opposes the motion of the trolley on the slope.

What is the value of *h*?

A 3.5 m **B** 22 m **C** 29 m **D** 55 m

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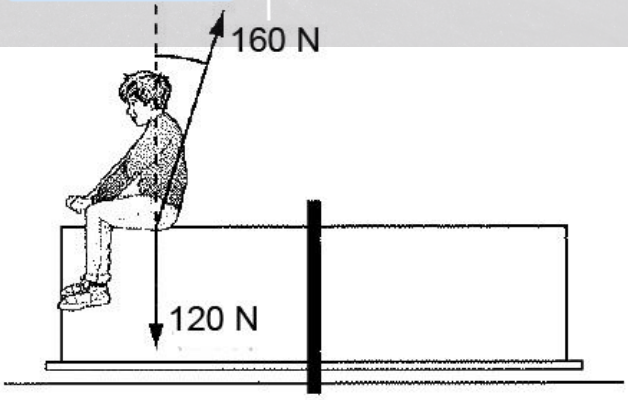
8 A boy is sitting on a playground turntable and is rotating with uniform angular velocity.



The reaction force that the turntable exerts on the child is 160 N.
The weight of the boy is 120 N.

What is the acceleration of the boy?

A 0.88 m s^{-2} **B** 3.3 m s^{-2} **C** 8.7 m s^{-2} **D** 84.3 m s^{-2}

9 A space probe is used to measure the gravitational field strength *g* of a planet at a distance *r* from its centre.

A graph of *g* against $\frac{1}{r^2}$ for this planet produces a straight line graph through the origin.

Which quantity can be determined from the gradient of the straight line graph?

A the density of the planet

B the radius of the planet

C the volume of the planet

D the mass of the planet

10 A satellite is in geostationary orbit above the Earth at a height of 36 000 km. The radius of the Earth is 6400 km.

What is the orbital speed of the satellite?

A 490 m s^{-1}

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B 2200 m s^{-1}

C 2600 m s^{-1}

D 3100 m s^{-1}

11 A fixed mass of an ideal gas is at a pressure of 1.0 x 10^5 Pa. It has a temperature of 300 K and a volume of 0.010 m^3.

What is the total kinetic energy of the gas molecules after the volume is changed to 0.0050 m^3 at constant temperature?

A 500 J

B 1000 J

C 1500 J

D 2000 J

12 The r.m.s. speed of the molecules of a gas at 295 K is decreased by 20 %.

What is the new temperature of the gas?

A – 84.4 °C

B – 37.2 °C

C 189 °C

D 236 °C

13 75 g of potato chips is used as fuel to heat up a calorimeter that contains 2.00 x 10^3 g of water initially at 297 K. The temperature rises by 12 °C. The heat capacity of the calorimeter is 200 J K^{-1} and the specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

How much heat is released per gram of potato chip?

A 1.37 kJ g^{-1}

B 7.10 kJ g^{-1}

C 100 kJ g^{-1}

D 103 kJ g^{-1}

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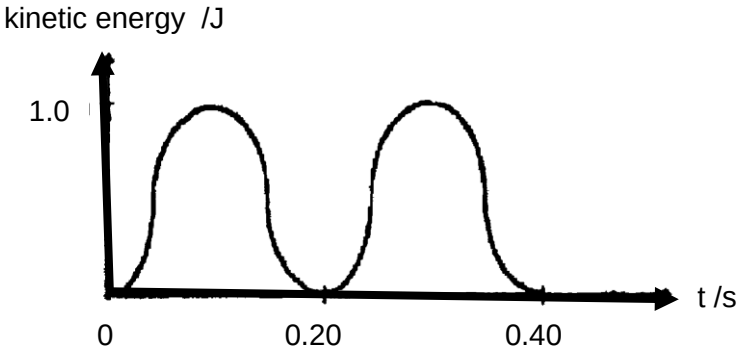
14 The graph shows the variation of the kinetic energy with time of a particle undergoing simple harmonic motion with an amplitude of 0.30 cm.



What is the maximum acceleration of the particle in m s^{-2}?

A 0.094

B 0.74

C 1.8

D 3.0

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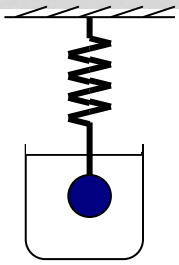
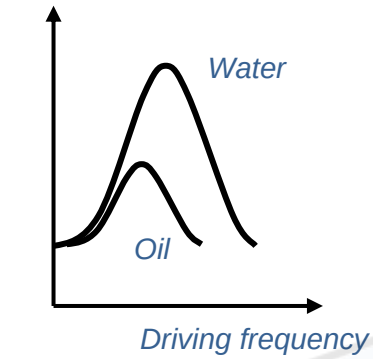
15 A mass oscillates vertically in water as shown. The support vibrates with a driving frequency which can be varied. Another similar setup is used replacing water with oil.



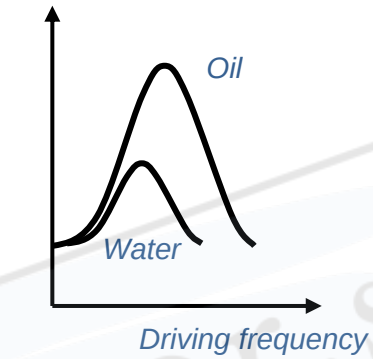
Given that oil has higher viscosity than water, which graph best represents the way in which the amplitudes of both cases vary with driving frequency?

[13A]

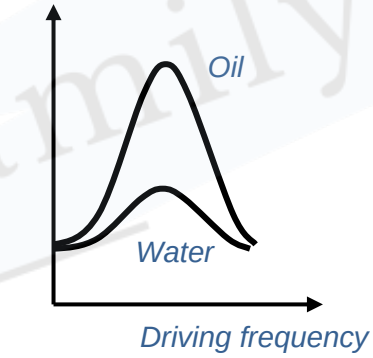
A



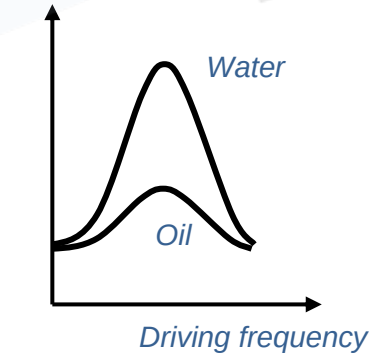
B



C



D



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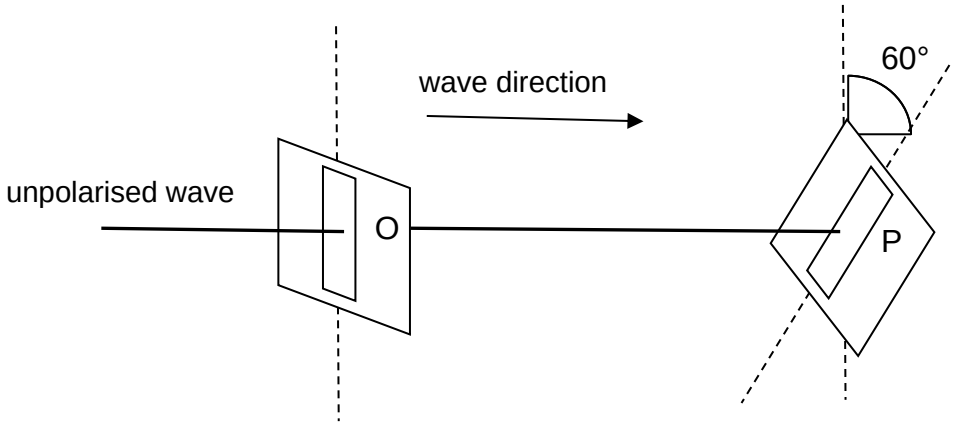
16 An unpolarised wave passes through polariser O such that the emerging wave is plane-polarized with an intensity of 2.0 W m^{-2}. A second polariser P is placed further such that the plane-polarised wave is incident normally on it. Polariser P is rotated clockwise by an angle of 60°.



What is the intensity of the wave after passing through polariser P ?

A 0.25 W m^{-2}

B 0.5 W m^{-2}

C 1.0 W m^{-2}

D 2.0 W m^{-2}

17 In order to demonstrate stationary waves, a student holds a tuning fork above a vertical glass tube containing some water and some air.

Which processes are responsible for the formation of the stationary wave?

A diffraction and polarization

B interference and diffraction

C polarisation and reflection

D reflection and interference

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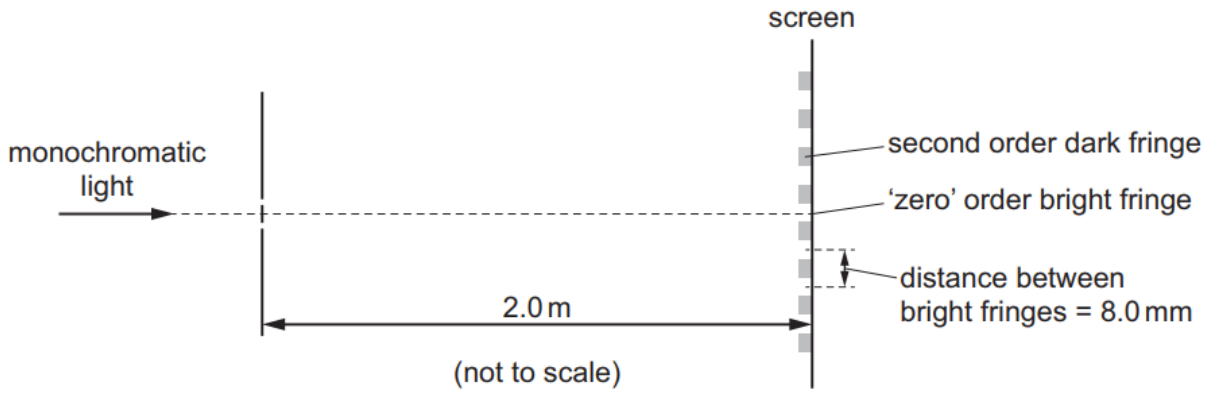
18 Monochromatic light is incident on a pair of narrow slits a distance of 0.10 mm apart. A series of bright and dark fringes are observed on a screen a distance of 2.0 m away. The distance between adjacent bright fringes is 8.0 mm.



What is the path difference between the light waves from the two slits that meet at the second order **dark** fringe?

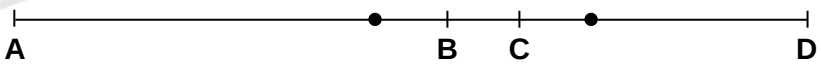
A $2.0 \cdot 10^{-7}$ m

B $4.0 \cdot 10^{-7}$ m

C $6.0 \cdot 10^{-7}$ m

D $8.0 \cdot 10^{-7}$ m

19 Two point charges $+4Q$ and $-Q$ are situated as shown.



At which point could the resultant electric field due to these charges be zero?

20 A positive charge of $2.6 \cdot 10^{-8}$ C is in a uniform electric field of field strength $3.0 \cdot 10^{5}$ N C^{-1}.

How much work must be done on the charge in order to slowly move it a distance of 4.0 mm in the opposite direction to the direction of the field?

A $3.1 \cdot 10^{-2}$ J **B** $3.1 \cdot 10^{-5}$ J

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C $3.1 \cdot 10^{-5}$ J

D $3.1 \cdot 10^{-2}$ J

21 A filament lamp is rated as “120V, 40W”.

The lamp is connected into a circuit so that it lights up normally.

Which statement is correct?

A The charge passing through the filament in one second is 3.0 C.

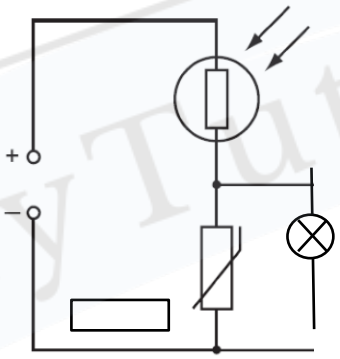
B The lamp transfer 40 J for each coulomb passing through the filament.

C The lamp transfers 120 J in 3.0 s.

D The supply provides 40 J to the lamp when the current is 3 A.

22 A filament lamp is connected into an electrical circuit with a negative temperature coefficient (NTC) thermistor and a light-dependent resistor (LDR).

Which pair of changes must cause the filament lamp to glow more brightly?



	light intensity incident on LDR	thermistor temperature
A	increase	decrease
B	increase	increase
C	decrease	decrease
D	decrease	increase

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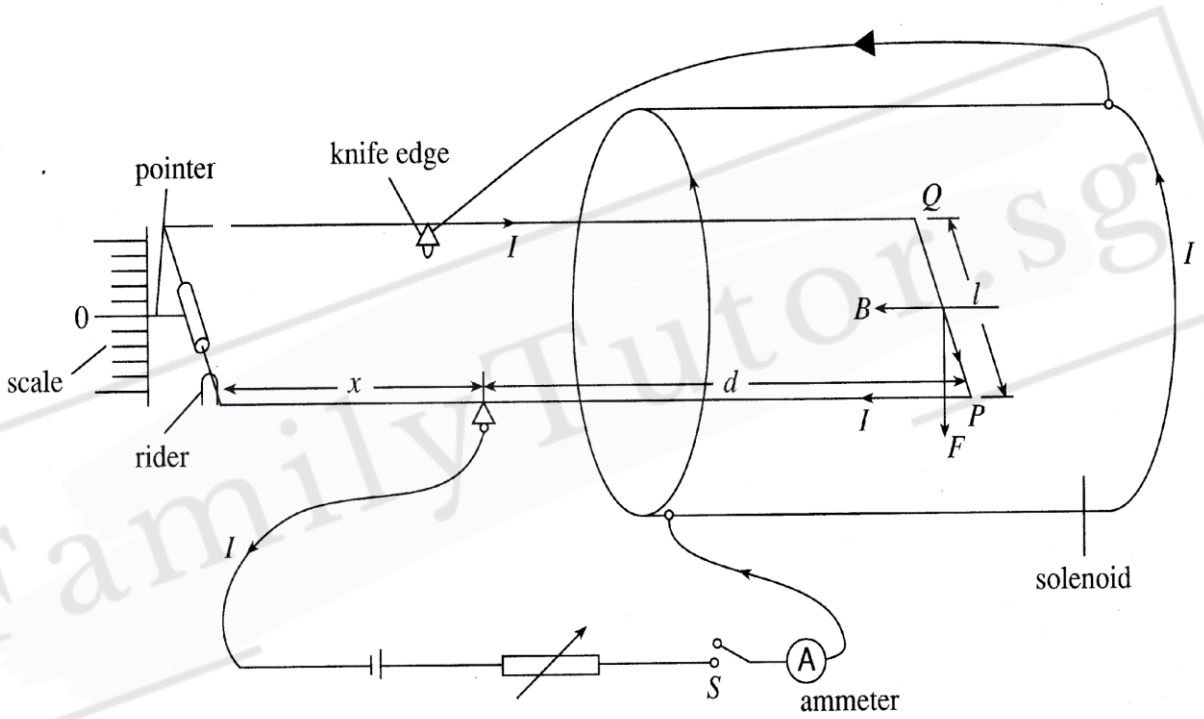
23 Two very long, straight, parallel wires carry equal steady current I in opposite directions. The distance between the wires is d. At a certain instant of time, a point charge q is at a point equidistant from the two wires, in the plane of the wires. Its instantaneous velocity v is perpendicular to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

A 0 N **B** $\frac{\mu_0 Iqv}{2\pi d}$ **C** $\frac{\mu_0 Iqv}{\pi d}$ **D** $\frac{2\mu_0 Iqv}{\pi d}$

24 A current balance device as shown in the figure below was set up to determine the magnetic field strength created by a solenoid. The first experiment determined the magnetic field strength as B. The setup was used again with one or some of the factors changed. A larger mass of the rider had to be used in the second experiment.



Which one of the following could most likely be the changes made?

A The knife edge was moved closer to PQ.

B Another frame with a shorter length for PQ was used.

C The current passing through the solenoid and the number of turns of the solenoid are reduced.

D The first experiment was set up such that the direction of the Earth's magnetic field is opposite to the magnetic field created by the coil while the second experiment had both magnetic fields in the same direction.

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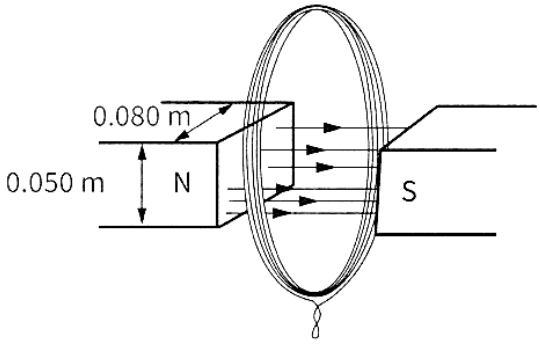
25 An electromagnet produces a uniform field from left to right in the gap between its poles. The gap has sides 0.050 m × 0.080 m and there is no field outside the gap. A circular coil of radius 0.100 m, has 40 turns and it surrounds all of the magnetic flux as shown below.



The ends of the coil are connected together so that an induced e.m.f. in the coil produces a current in the coil.

The magnetic flux density of the electromagnet fall linearly from 0.15 T to zero in a time of 3.0 s.

What is the average induced e.m.f. in the coil as the magnetic flux density decreases?

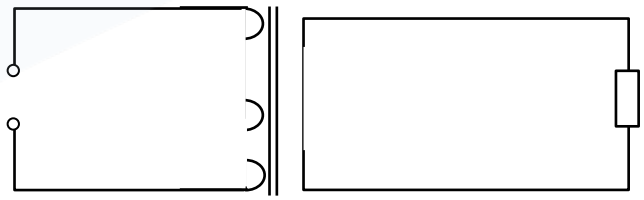
A 0.20 mV

B 8.0 mV

C 50 mV

D 63 mV

26 The primary coil of an ideal transformer has 1000 turns and is connected to an A.C. supply. The secondary coil has 40 turns and is connected to a load which has a power rating of 12 W.



1000 turns
40 turns

Load
12 W

A.C. supply

If the root-mean-square (r.m.s) voltage across the load is 6.5 V, what is the r.m.s current in the primary coil?

A 0.026 A

B 0.074 A

C 0.10 A

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D 0.15 A

27 The following are some statements on photoelectric effect. Which of the following statements is true?

A No emission of electrons occurs for very low intensity of illumination.

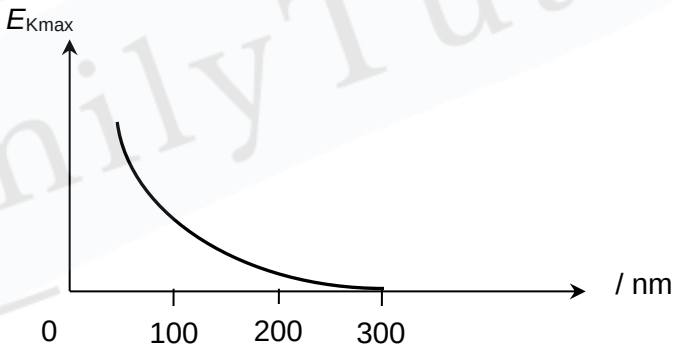
B Doubling the frequency of radiation will double the stopping potential.

C For a given metal, there is a minimum frequency of radiation below which no emission of photoelectrons occurs.

D The velocity of the emitted photoelectrons will increase if the intensity of the incident radiation increases on the metal surface.

28 In a photoelectric experiment, the maximum kinetic energy of the ejected photoelectrons is measured for various wavelength of incident electromagnetic radiation.

A graph of this maximum kinetic energy, E_{Kmax}, against the wavelength λ of the incident electromagnetic radiation falling on the surface of a metal is shown below.



What is the work function for this metal?

A 2.07 eV **B** 4.14 eV **C** 6.63 eV **D** 7.96 eV

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29 Consider the following nuclear reaction:

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{121}_{45}\text{Rh} + {}^{113}_{47}\text{Ag} + 2\,{}^{1}_{0}\text{n}$$

Data:

binding energy per nucleon of $^{235}_{92}\text{U}$ = 7.59 MeV

binding energy per nucleon of $^{121}_{45}\text{Rh}$ = 8.26 MeV

binding energy per nucleon of $^{113}_{47}\text{Ag}$ = 8.52 MeV

What is the energy change in this reaction?

A 73.9 MeV of energy is absorbed.

B 73.9 MeV of energy is released.

C 179 MeV of energy is absorbed.

D 179 MeV of energy is released.

30 A radioactive sample of element X has an activity of *A*.

Another radioactive sample of element Y with the same number of radioactive nuclei as the sample of X has an activity of 3*A*.

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

A 0.11 **B** 0.33 **C** 3.0 **D** 9.0

End of Paper

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millennia institute

2023 Preliminary Examinations
Pre-University 3

H2 PHYSICS **9749/02**

Paper 2 Structured Questions **14 September**

2 hours

Candidates answer on the Question Paper

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Do not turn over this page until you are told to do so.

Write your full name, class and Adm number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of this booklet.
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		/ 6
2		/ 7
3		/ 7
4		/ 8
5		/ 9
6		/ 9
7		/ 14
8		/ 20
Presentation		
Total		/ 80

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Data

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

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin\omega t$
velocity of particle in s.h.m.	$v = v_0 \cos\omega t$ $= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin\omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** The final velocity *v*, initial velocity *u*, acceleration *a* and displacement *s* of a body moving in a straight line at uniform acceleration is related by the equation

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

Show that this equation is homogenous. [2]

(b) A student measures the three dimensions of a solid cube:

width = 1.99 cm ± 1%,
length = 1.95 cm ± 1%,
height = 2.02 cm ± 1%.

The manufacturer of the cube quotes the density of the material used for the cube as (1.24 ± 0.05) g cm^{-3}.

Determine the mass of the cube. Express the mass of the cube together with its uncertainty.

mass = (±) g [4]

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2 A skateboarder starts from rest at point A as shown in Fig. 2.1.

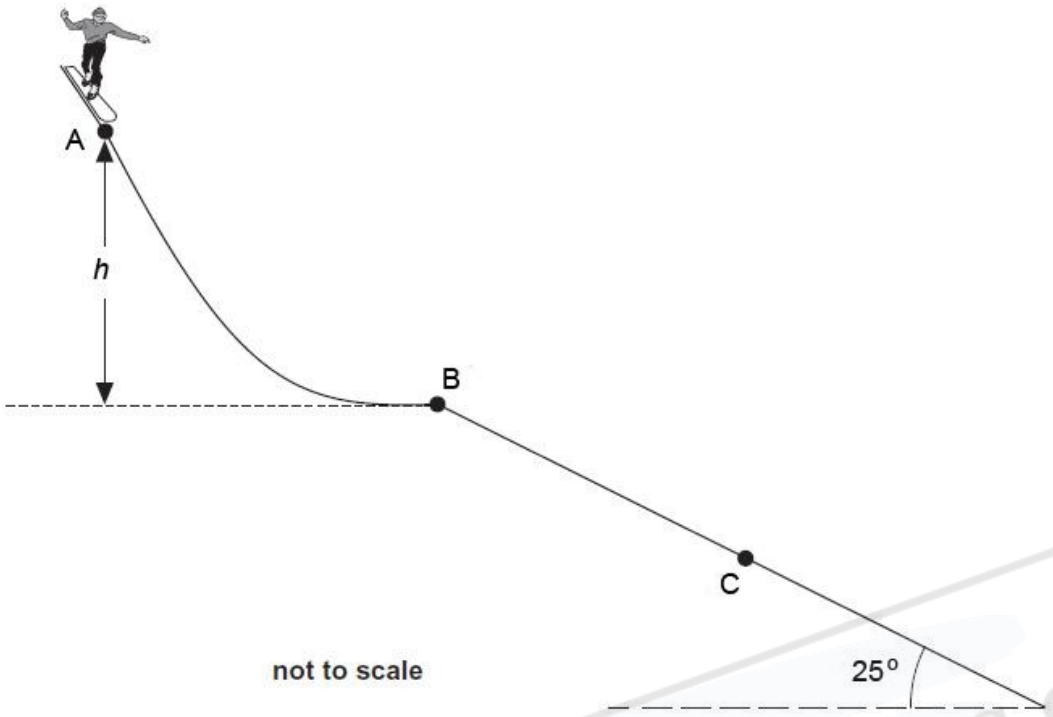

Fig. 2.1

The skateboarder reaches a speed of 17 m s^{-1} at point B.

Consider the skateboarder to be a point mass of 65 kg and ignore the effects of friction and air resistance.

(a) Calculate the height difference, *h*, between point A and point B.

h = ... m [1]

(b) The skateboarder takes off at point B, travelling horizontally with a velocity of 17 m s^{-1}.
He lands at point C after being in the air for 1.6 s.

(i) Calculate v_v, the vertical component of his velocity, just before landing at point C.

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

(ii) On Fig. 2.2**,** sketch the variation with time of the vertical component of the velocity v_v of the skateboarder from point B to point C.

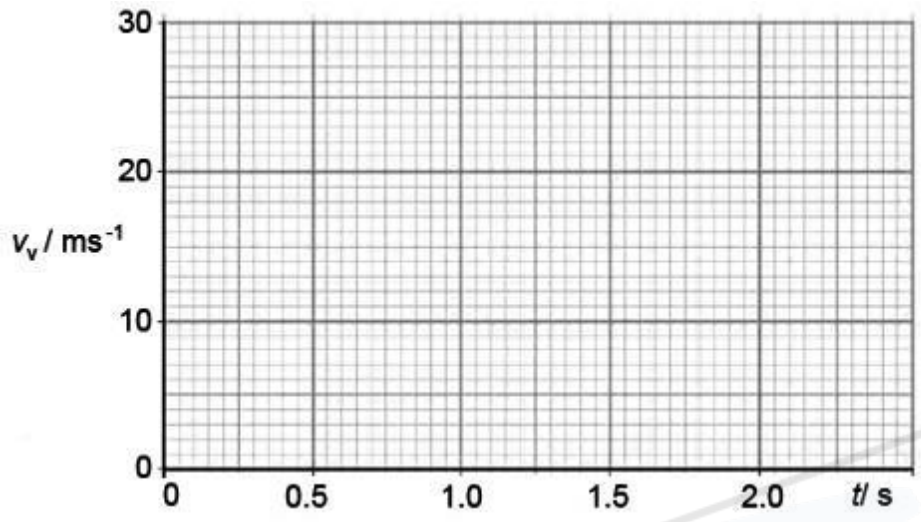

Fig. 2.2

[1]

(iii) Show that the magnitude of the resultant velocity just before landing at point C is 23 m s^{-1}.

[1]

(c) Explain why it is safer for the skateboarder to land on a downward slope than on a horizontal surface.

.....

.....

.....

.....

..... [2]

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[Total: 7]

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3 **(a)** **(i)** State Archimedes' principle.

.....

.....

.....[1]

(ii) Explain why an object submerged in a fluid experiences upthrust.

.....

.....

.....

.....[2]

(b) A mini submarine has a mass of 4800 kg and total volume 5.0 m^3. To dive into the sea, it takes on mass in the form of seawater into its ballast tank.

Fig. 3.1, Fig. 3.2 and Fig. 3.3 show a simplified cross sectional diagram of the mini submarine when it is at the surface of the sea, diving and submerged respectively.

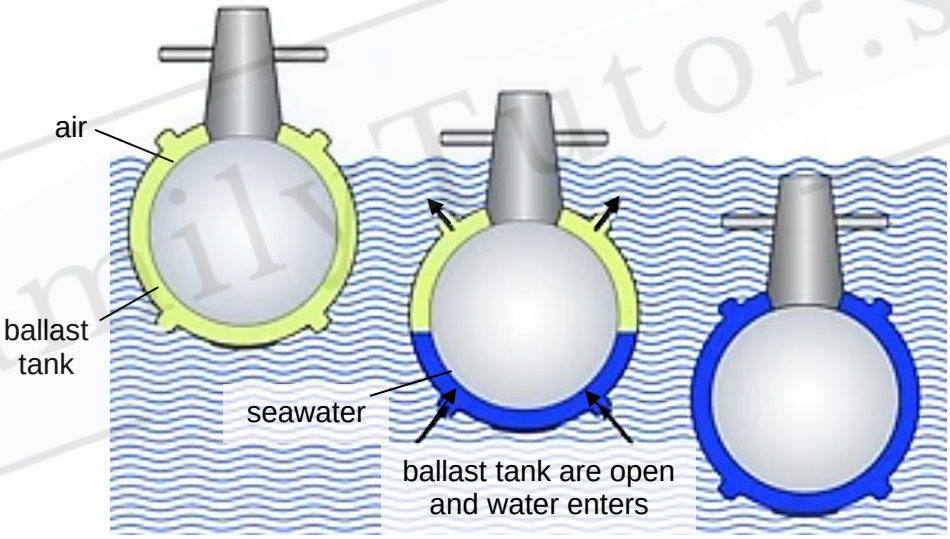

Fig. 3.1 **Fig.3.2** **Fig. 3.3**

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Calculate the mass of seawater that the fully submerged mini submarine must take on if it is to descend at a constant speed, when the average resistive force acting on it is 1100 N. Assume the density of seawater is 1030 kg m^{-3}.

mass of seawater = ... kg [3]

(c) Calculate the pressure at a sea depth of 200 m.
Assume the atmospheric pressure is 1.01×10^5 Pa.

pressure = ... Pa [1]

[Total: 7]

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4 A cyclist made a left turn on a rough level road surface at a constant speed *v*, as shown in Fig. 4.1. The total mass of the bicycle and rider is *m* and their combined centre of gravity is at G.

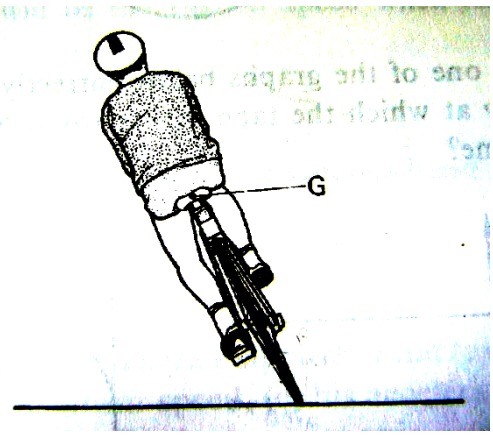

Fig. 4.1

(a) In Fig. 4.1, draw and label all the forces acting on the system of the cyclist and his bicycle. Ignore forces parallel to the direction of motion. [2]

(b) If the rider is negotiating a turn with a radius of curvature of 55 m, the total mass of the rider and bicycle is 80 kg, and the friction provided by the road surface is 70 N, calculate the speed with which he is turning.

speed = …….. m s^{-1} [1]

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(c) The rider now makes the same left turn on a rough surface banked at 20° to the horizontal as shown in Fig. 4.2.

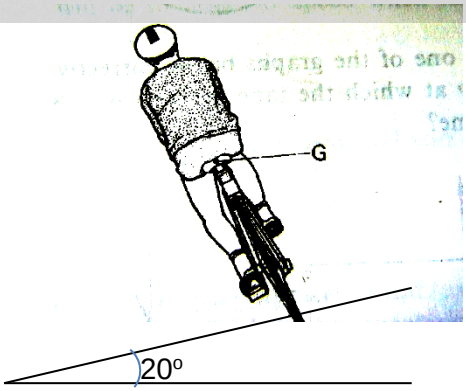

Fig. 4.2

Assuming that the frictional forces remain as 70 N, and radius of curvature is still 55 m,

(i) explain how the banked surface assists the cyclist in travelling around the corner at a higher speed.

.....

.....

.....

.....[2]

(ii) Calculate the new maximum speed with which the rider may negotiate the turn.

maximum speed = …….. m s^{-1} [3]

[Total: 8]

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5 A space rocket on Earth is fired for a few minutes to provide it with the necessary kinetic energy for it to travel directly to the Moon. Along the line joining the centres of the Earth and Moon, there is a point P where the rocket does not experience any gravitational force. P is 3.46×10^5 km from the centre of the Earth and 3.80×10^4 km from the centre of the Moon as shown in Fig. 5.1.

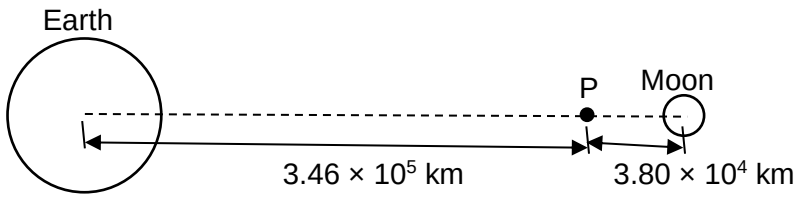

Fig. 5.1

(a) Explain why the rocket does not experience any gravitational force at P.

……..

……..

……..

……..… [1]

(b) Suggest two reasons why a return rocket from the Moon would need much less fuel than that required for the outward journey from the Earth.

……..

……..

……..

……..… [2]

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(c) Given that the mass of the Earth is 5.97×10^{24} kg, calculate the mass of the Moon.

mass = ... kg [2]

(d) A meteorite of mass 7.5 kg moves towards P under the gravitational attraction of the Earth and Moon. It is initially at rest at a large distance away from P.

(i) Define gravitational potential at a point.

……

……[1]

(ii) Calculate the kinetic energy of the meteorite when it reaches P.

kinetic energy = …… J [3]

[Total: 9]

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6 **(a)** A circuit is setup as shown below in Fig 6.1. A cell *E* with internal resistance *r* is connected to a network of resistors.

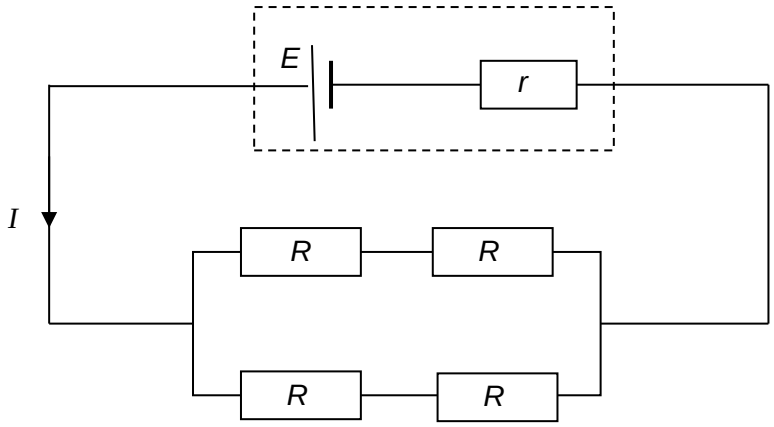

Fig 6.1

(i) Express the current I in the circuit, in terms of *R*, *r* and *E.*

[2]

(ii) Show that the fraction of power dissipated in the external resistors by the battery is $\frac{R}{R+r}$.
[1]

(iii) Suggest a reason for having 4 resistors connected in a network as shown in Fig 6.1 instead of just using a single resistor of resistance *R*.

……

……

…… [1]

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(b) A circuit is set up as shown in Fig 6.2 below. The potentiometer wire XY has a resistance of 1.5 Ω and is 1.00 m long. The movable contact J can be connected to any point along wire XY.

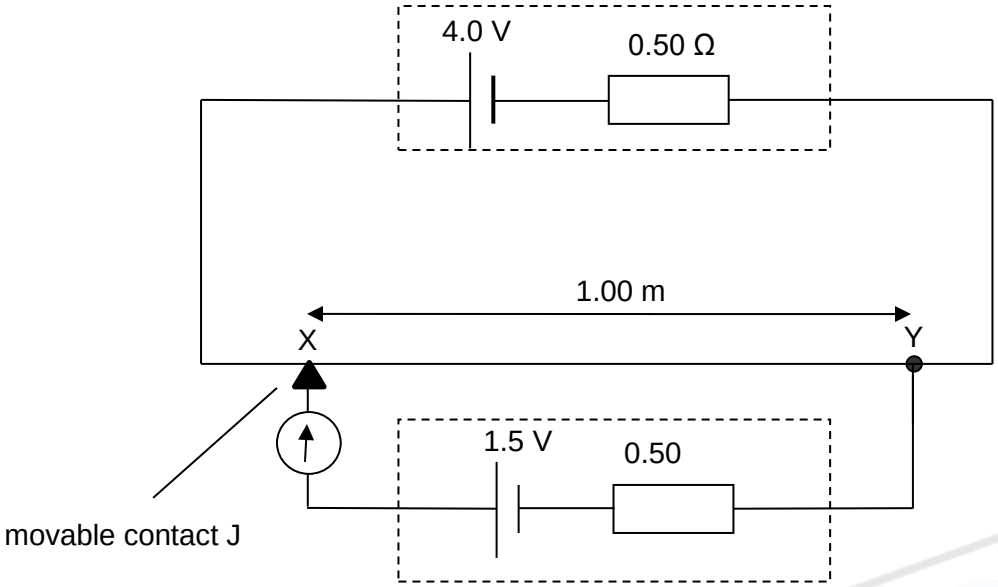

Fig 6.2

(i) Determine the distance of the contact J from Y, such that there is no deflection in the galvanometer.

distance JY = ... m [2]

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(ii) Now, a 4.7 Ω resistor is connected across points A and B.

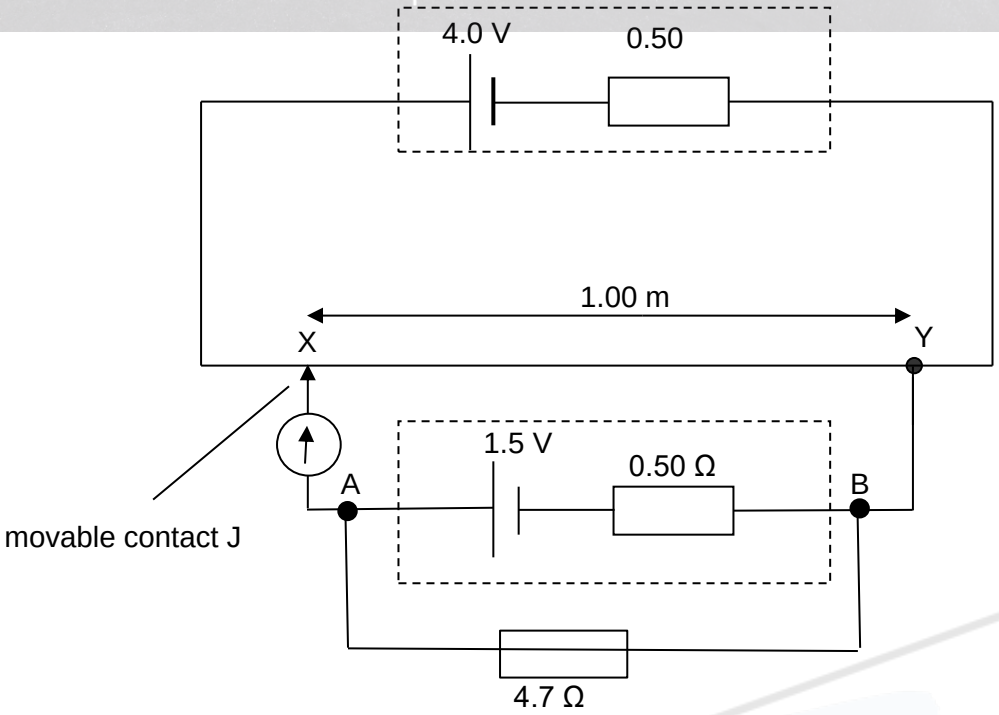

Fig 6.3

Determine the new distance of the contact J from Y, such that there is no deflection in the galvanometer.

new distance = ... m [3]

[Total: 9 marks]

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7 **(a)** For a particular gas, the emission and absorption spectra are obtained for the visible light spectrum.

State one similarity and one difference between the discrete lines of the absorption and emission spectra of this gas.

Similarity: ……

……

Difference: ……

…… [2]

(b) Fig. 7.1 gives information on three lines observed in the emission spectrum of hydrogen atoms.

wavelength / nm	**energy of photon / eV**
486	2.56
656	
1880	0.66

Fig. 7.1

(i) Complete Fig. 7.1 and show your working clearly in the space below. [2]

(ii) Fig. 7.2 is a partially completed diagram to show energy levels of a hydrogen atom.

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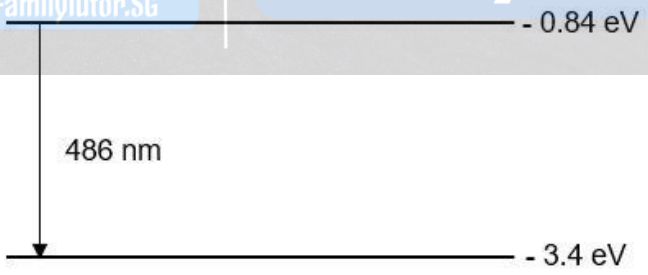

Fig. 7.2

On Fig. 7.2, draw an additional labelled energy level between the two given energy levels to account for the emission of the photons in Fig. 7.1 [1]

(c) Three of the energy levels of a lithium atom are shown in Fig. 7.3.

Fig. 7.3

One way to study the energy levels of an atom is to bombard the atom with electrons and measure the kinetic energies of the bombarding electrons before and after the collision. If a lithium atom which is originally in the – 5.02 eV level is bombarded with an electron of kinetic energy 0.92 eV, the scattered electron can have only two possible kinetic energies.

States these two kinetic energy values, and state what happens to the lithium atom in each case.

1st possible kinetic energy value: …… eV [1]

……

……[1]

2nd possible kinetic energy value: …… eV [1]

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.....[1]

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(d) X-ray photons are produced in an X-ray tube when electrons are accelerated through a potential difference V_o towards a metal target. An X-ray spectrum is shown in Fig. 7.4.

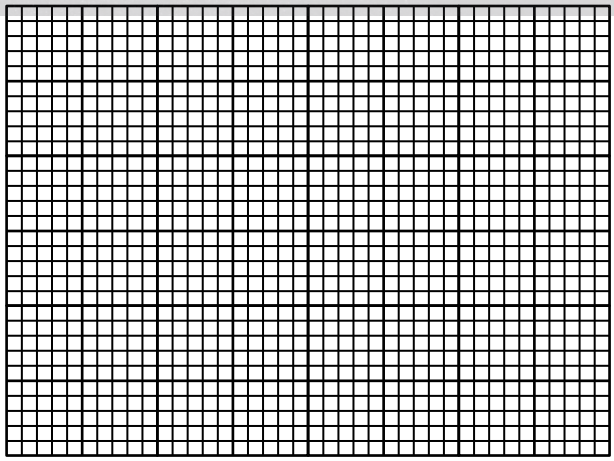

Fig. 7.4

(i) Explain how the characteristic X-ray photons are produced.

[2]

(ii) Determine the minimum potential difference V_o applied across the X-ray tube.

V_o = kV [2]

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(iii) The potential difference in **(d)(ii)** to accelerate the electrons is increased.

On Fig. 7.4, sketch the new spectrum obtained. [1]

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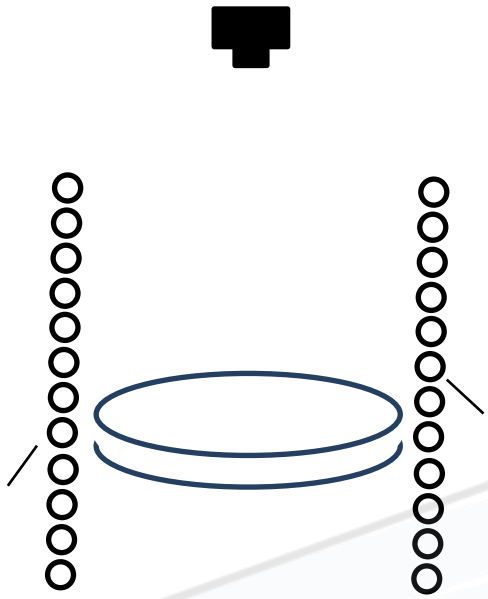
8 Read the passage below and answer the questions that follow.

Fig. 8.1 shows a bubble chamber which consists of a sealed chamber filled with a liquefied gas. The coils around the chamber provide a magnetic field. The pressure inside the chamber can be reduced quickly by an adjustable piston. The liquid is originally at a temperature just below its boiling point. When the pressure is reduced, the boiling point of the liquid becomes lower, so that it is less than the original temperature of the liquid, leaving the liquid superheated.



magnetic coils

charged particles

magnetic field

piston

magnetic coils

camera

liquid

Fig. 8.1

As beams of charged particles pass through the liquid, they deposit energy by ionising the liquid atoms. This causes the liquid to boil and tiny gas bubbles are formed along the paths of the charged particles.

Some charged particles may also collide with an atomic nucleus of the liquid and form products which are charged too. These charged products will move on and ionise the liquid, causing more trails of bubbles to form.

The chamber is illuminated so that the tracks of the charged particles can be photographed. By analyzing the tracks, the charged particles can be identified and any complex events involving the particles can be studied.

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In the presence of a magnetic field, the tracks of the charged particles will be curved. The degree of curvature depends on the mass, speed, and charge of each particle.

Neutral particles can be detected indirectly by applying various conservation laws to the events recorded in the bubble chamber or by observing their decay into pairs of oppositely charged particles.

Fig. 8.2 is a picture taken by the camera from a bubble chamber that is filled with liquid hydrogen. The lines show the path of the particles entering the chamber from one of the sides.

A parallel beam of K^- particles, each with an energy of 8.2 GeV and a charge of $-e$ enters from the bottom of Fig. 8.2.

The radius of any circular path made by a moving charged particle in the bubble chamber is proportional to the momentum and inversely proportional to the charge of the particle.

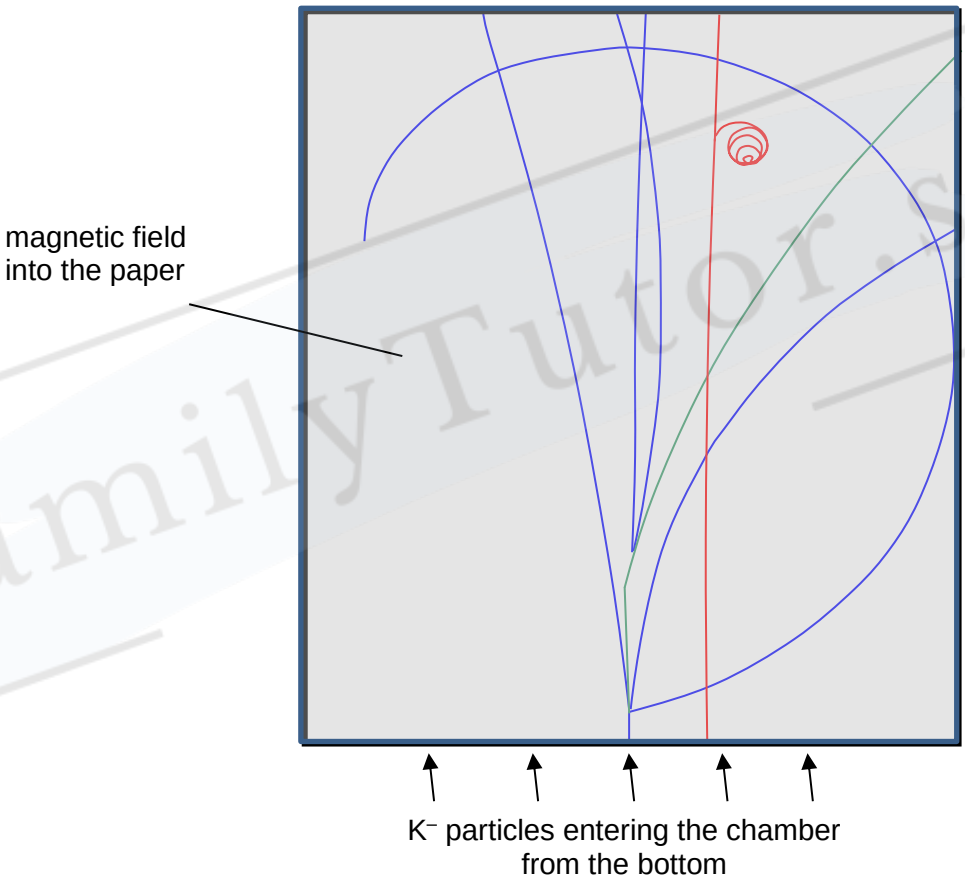

Fig. 8.2

(a) State and explain the number of positively charged particles as shown in Fig. 8.2.

.....

.....

..... [2]

[Turn over

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(b) Fig. 8.3 shows the enlarged picture of the little curly track at the top right quadrant of Fig. 8.2.

It has been proposed that this track is produced by an electron which is knocked out of the hydrogen atom by a passing K^- particle.

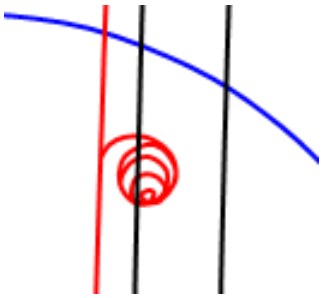

Fig. 8.3

(i) By comparing the curly path in Fig. 8.3 with paths made by other particles in Fig. 8.2, explain whether this proposal is possible.

……

……

……

…… [2]

(ii) Suggest why is this path a spiral.

……

……

……

…… [2]

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(c) Fig. 8.4 shows a K^- particle colliding with the positively charged nucleus of a hydrogen atom at point A. The collision produced four charged particles as illustrated by the four outgoing tracks, numbered 1 to 4.

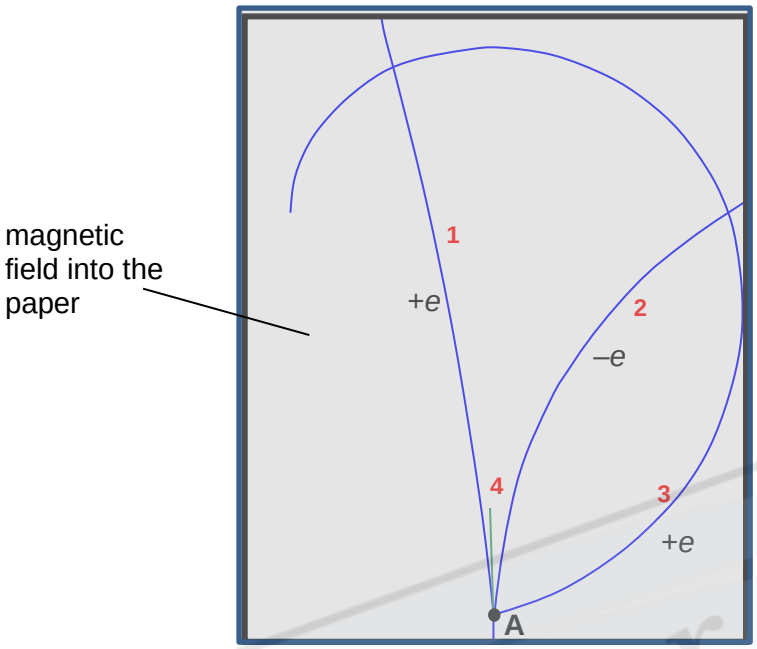

Fig. 8.4

The charges of three of the four outgoing particles after the collision are indicated beside their tracks.

(i) Deduce the charge of the fourth outgoing particle. Justify your answer.

……

……

……

…… [2]

(ii) State which of the outgoing particles 1 to 4 has the lowest momentum.

……

…… [1]

[Turn over

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(d) There is a fifth outgoing particle from the collision at point A which is neutral and does not produce any visible track. This particle eventually decays into two smaller particles at point B as shown in Fig. 8.5.

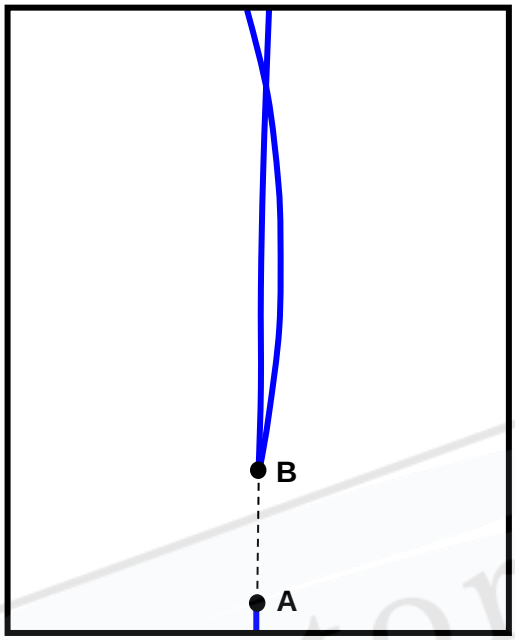

Fig. 8.5

(i) Explain why it leaves no track.

.....

.....

..... [1]

(ii) Deduce the charge of the two particles that are formed from the decay of the fifth particle. Explain your answer.

.....

.....

..... [2]

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(e) The bubble chamber is used to study the collision between a K^- particle and a stationary proton p. The total energy E and momentum in three dimensions p_x, p_y, p_z of each particle produced in a collision is governed by the formula

$$E^2 = (p_x^{\ 2} + p_y^{\ 2} + p_z^{\ 2})c^2 + m^2c^4$$

where m is the mass of the particle and c is the speed of light.

In a particular collision, three additional particles Ω^-, Ω^+ and K^0 are formed and the data collected are shown in Fig. 8.6 below.

Before collision

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	438.05	-13.24	0.81	1317.12
p	0.00	0.00	0.00	150.13
sum				

After collision

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	79.03	1.48	11.95	252.50
Ω^-	7.98	-0.60	2.07	33.38
Ω^+	2.02	-6.52	-1.21	30.51
p	80.46	6.85	-3.76	285.22
K^0	189.10	-8.69	-13.07	574.78
sum				

Fig. 8.6

(i) Complete Fig. 8.6 to show

1. the sum of the momentum in all the dimensions for the particles before and after the collision, [1]

2. the sum of the energy for the particles before and after the collision. [1]

[Turn over

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(ii) The sum of the total energies E before and after the collision are not equal, implying that more particles are formed but have gone undetected.

Assuming that there is only one undetected particle, determine

1. the components of its momentum p_x, p_y, p_z and its total energy E,

p_x = ...N s

p_y = ...N s

p_z = ...N s

E = ... J [4]

2. its mass m.

m = ... kg [2]

[Total: 20]

END OF PAPER

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2023 Preliminary Examination
Pre-University 3

H2 PHYSICS **9749/03**

Paper 3 Longer Structured Questions **19 September**

Candidates answer on the Question Paper. **2 hours**

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Do not turn over this page until you are told to do so.

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

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

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

For Examiner's Use		
Sect A		
1		**/ 10**
2		**/ 12**
3		**/ 12**
4		**/ 12**
5		**/ 14**
Sect B		
6		**/ 20**
7		**/ 20**
Presentation		
Total		**/80**

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Data

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

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin\omega t$
velocity of particle in s.h.m.	$v = v_0 \cos\omega t$ $= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin\omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

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

1 An object A of mass 9.0 kg and object B of mass 1.0 kg travel towards each other along a smooth horizontal surface in a straight line and collide head-on. The initial speeds of object A and B before the collision are u and $3u$ respectively.

In Fig. 1.1, the variation with time t of momentum p is shown from t = 0 to 3.0 s for particle A and from t = 0 to 1.0 s for particle B.

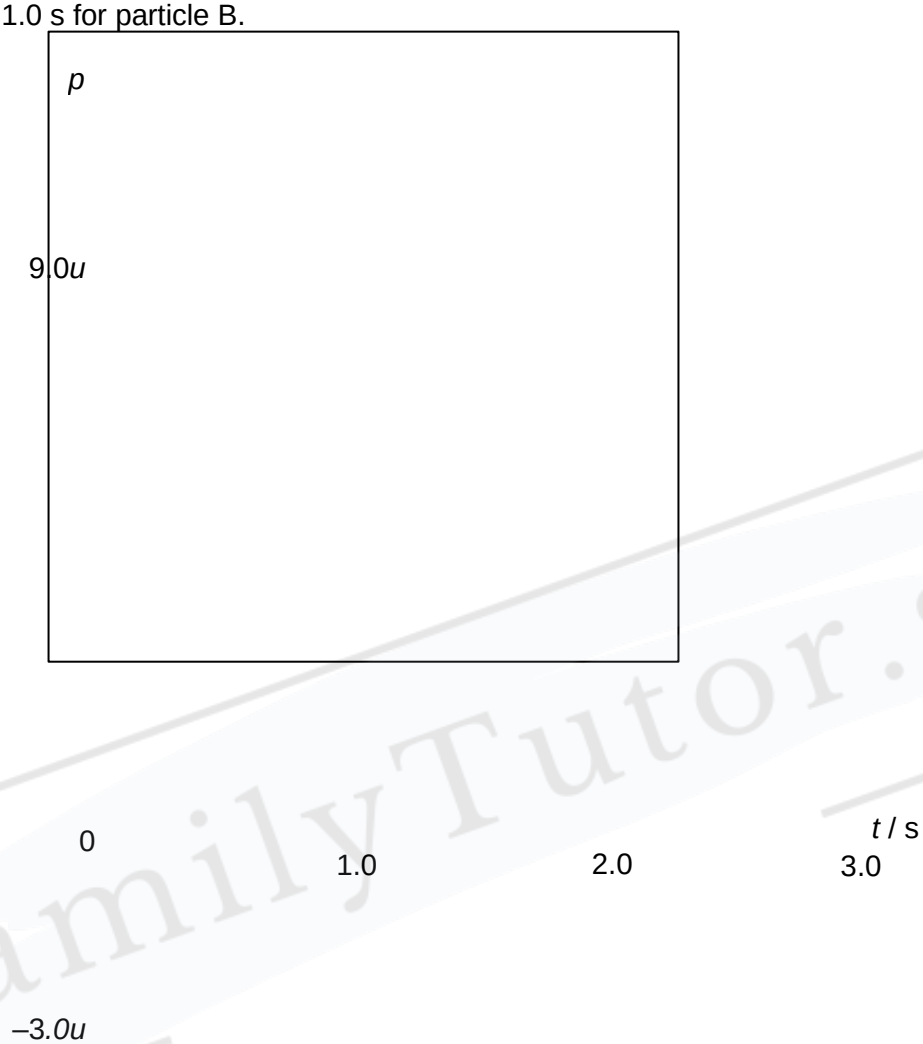

Fig. 1.1

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(a) **(i)** Momentum is conserved when two objects collide or interact. State the condition under which momentum is conserved.

……..... [1]

(ii) On Fig. 1.1, draw the variation with *t* of *p* from 1.0 s to 3.0 s for object B. [2]

(iii) Explain how the principle of conservation of momentum is used to complete the graph in **(a)(ii)**.

……...

……...

……... [1]

(b) Explain, with appropriate working, whether the collision between objects A and B is elastic.

……

……... [3]

(c) **(i)** Show that the magnitude of the force acting on object A during the collision is 7.2*u*.

[1]

(ii) Explain how the graphs in Fig. 1.1 are consistent with Newton's third law of motion during the collision.

……...

……...

……...

……...

……...

……... [2]

[Total: 10]

[Turn over

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2 **(a)** The kinetic theory of gases is based on a number of assumptions about the molecules of a gas. State the assumption that is related to the volume of the molecules of the gas.

.....

..... [1]

(b) An ideal gas occupies a volume of 950 cm^3 at a pressure of 2.10×10^5 Pa and a temperature of 280K. Each molecule has a diameter of approximately 3×10^{-10} m. Estimate the total volume of the gas molecules.

[3]

volume = ...m^3

(c) With reference to your answer in **(b)**, suggest why the assumption in **(a)** is justified.

.....

..... [1]

(d) The ideal gas undergoes the cycle of changes PQRP as shown in Fig. 2.1.

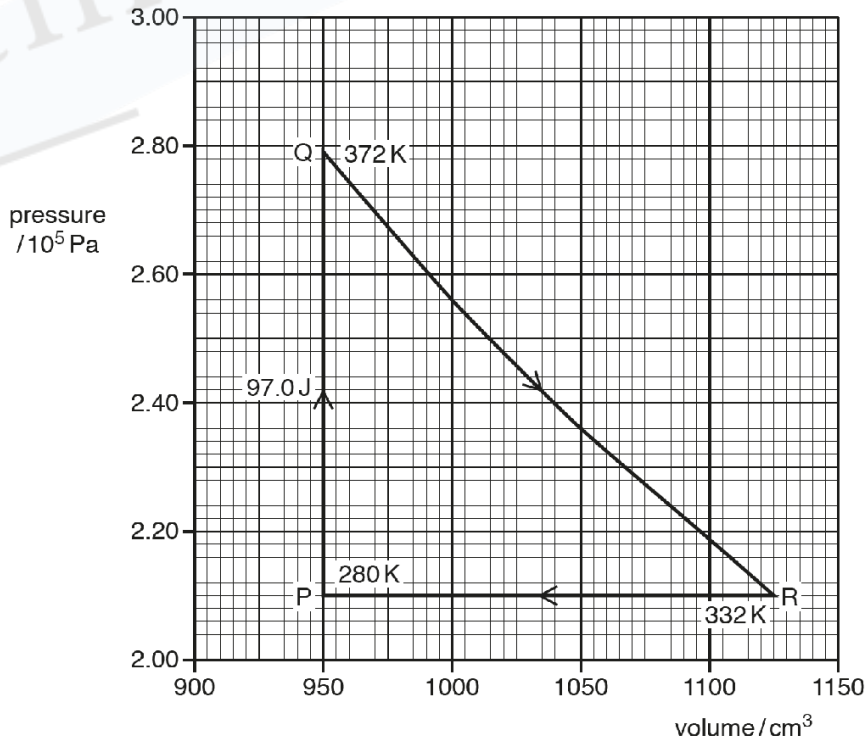

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Fig. 2.1

Some energy changes during one complete cycle of PQRP are shown in Table. 2.1.

	change P → Q	change Q → R	change R → P
thermal energy transferred to gas / J	+97.0	0	.....
work done on gas / J	.....	–42.5	.....
increase in internal energy of gas / J	.....	.....	.....

Table. 2.1

(i) State the total change in internal energy of the gas during one complete cycle PQRP. Explain your answer.

.....

.....

..... [2]

(ii) Complete Table 2.1 to show the energy changes for the gas.
Show your working clearly in the space below.

[5]

[Total: 12]

[Turn over

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3 A small wooden block (cuboid) of mass *m* floats in water, as shown in Fig. 3.1.

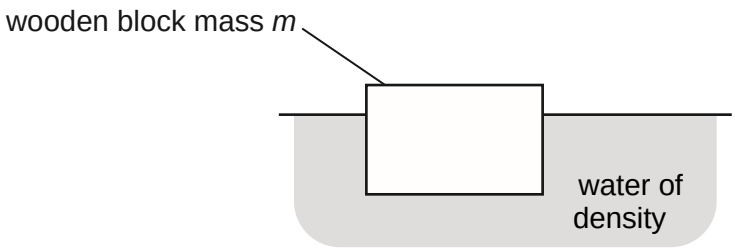

Fig. 3.1

The top face of the block is horizontal and has area *A*. The density of the water is ⟩.

(a) State the names of the two forces acting on the block when it is stationary.

……..... [1]

(b) The block is now displaced downwards as shown in Fig. 3.2 so that the surface of the water is higher up the block.

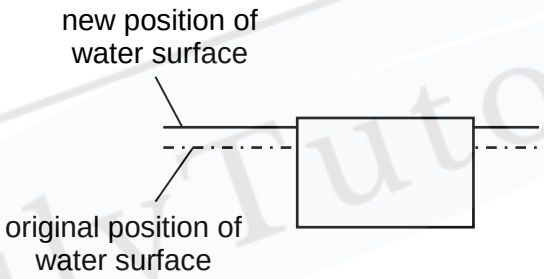

Fig. 3.2

State and explain the direction of the resultant force acting on the wooden block in this position.

……..

……..... [1]

(c) The block in **(b)** is now released so that it oscillates vertically.

The resultant force *F* acting on the block is given by

$$F = -Ag\rho x$$

where *g* is the gravitational field strength and *x* is the vertical displacement of the block from the equilibrium position.

(i) Explain why the oscillations of the block are simple harmonic.

……..

……..

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.....

[2]

.....

(ii) Show that the angular frequency ω of the oscillations is given by

$$\omega = \sqrt{\frac{A\rho g}{m}}$$

[2]

(d) The block is now placed in a liquid with a greater viscosity. The block is displaced and released so that it oscillates vertically. The variation with displacement x of the acceleration a of the block is measured for the first half oscillation, as shown in Fig. 3.3.

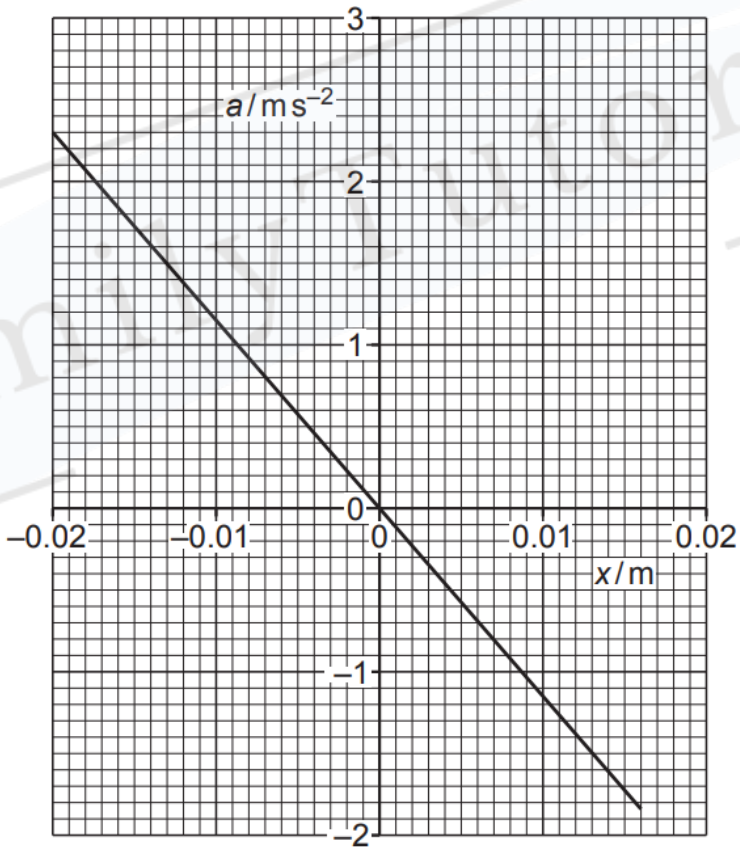

Fig. 3.3

(i) Explain why the maximum negative displacement of the block is not equal to its maximum positive displacement.

.....

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[Turn over

.....

.....

[1]

(ii) Use Fig. 3.3 to determine the frequency of the block.

frequency = ... Hz [2]

(iii) The mass of the block is 0.57 kg.

Use Fig. 3.3 to determine the decrease $\otimes E$ in energy of the oscillation for the first half oscillation.

$\otimes E$ = ... J [3]

[Total: 12]

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4 Two small charged metal spheres A and B are situated in a vacuum. The distance between the centres of the spheres is 12.0 cm, as shown in Fig. 4.1.

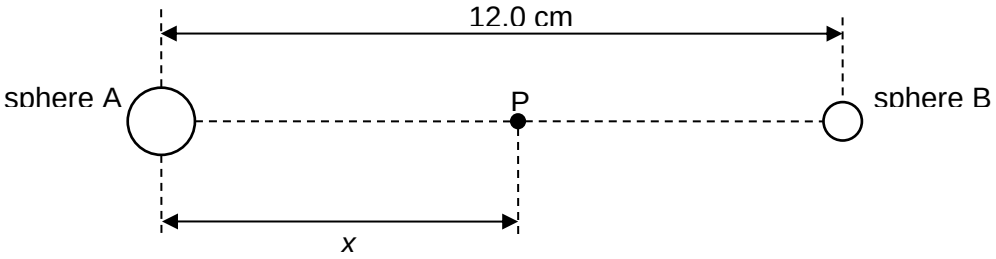

Fig. 4.1

The charge on each sphere may be assumed to be a point charge at the centre of the sphere. Point P lies on the line joining the centres of the two spheres. P is at a distance *x* from the centre of sphere A.

The variation with distance *x* of the electric field strength *E* at point P is shown in Fig. 4.2.

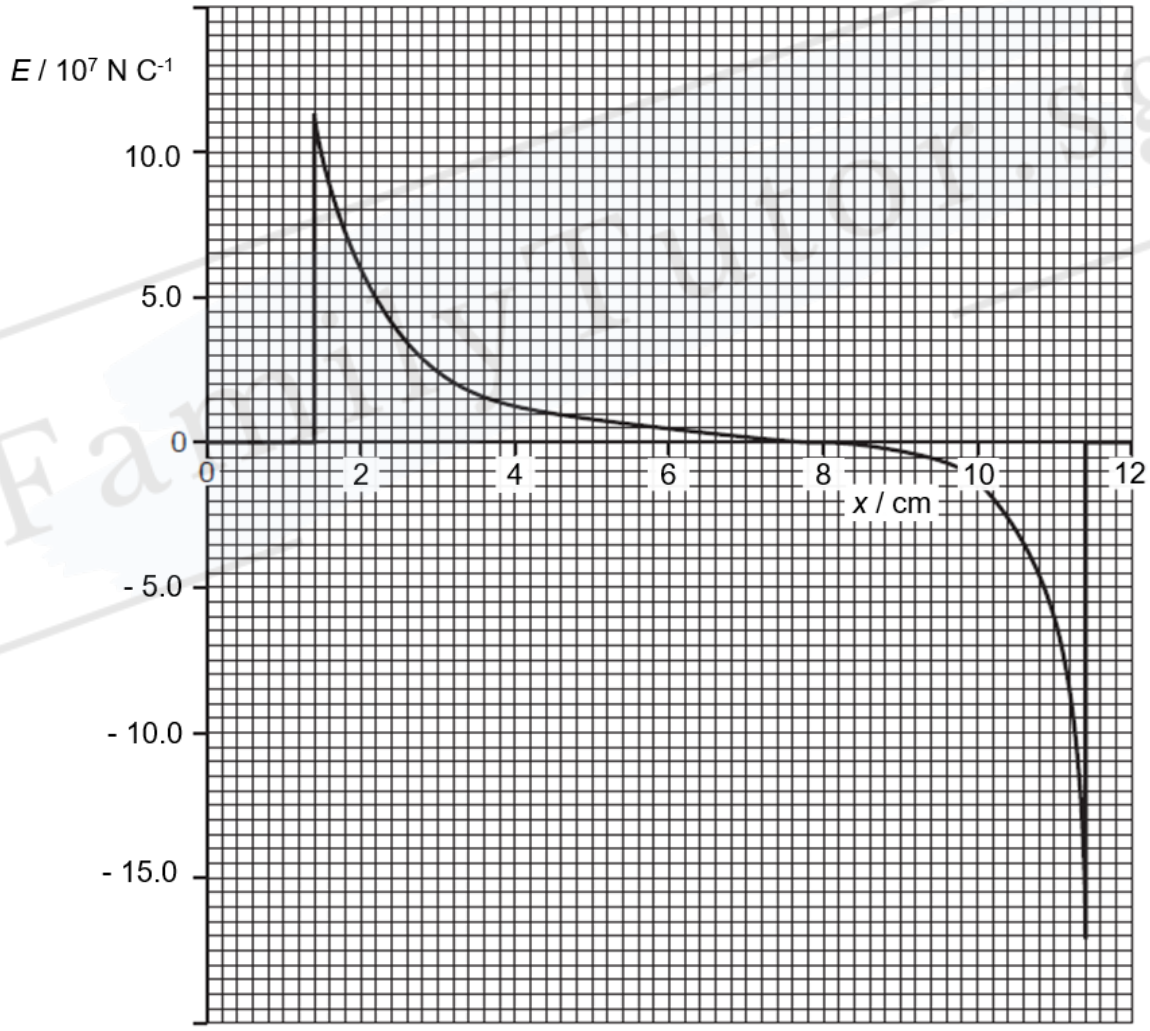

Fig. 4.2

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(a) State the evidence provided by Fig. 4.2 that the spheres are conductors.

……..... [1]

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

……

……

…… [2]

(c) Use Fig. 4.2 to determine the ratio $\frac{\text{charge on sphere A}}{\text{charge on sphere B}}$.

ratio = …… [3]

(d) Hence, on Fig. 4.3, sketch the electric field lines due to these two charges.

sphere A ○ ○ sphere B

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Fig. 4.3 [3]

(e) A proton moves along the line joining the centres of the two spheres.
Estimate the change in energy of the proton as it moves from the point where x = 3.0 cm to the point where x = 1.4 cm.

energy = ... J [3]

[Total: 12]

5 **(a)** When a star has fused all its hydrogen to helium, it will start to fuse helium into carbon through the following reaction.

$$24He + 24He + 24He \rightarrow 6\,12C$$

The binding energy per nucleon of helium and carbon are given in Fig. 5.1.

nuclide	binding energy per nucleon / MeV
$6\,12C$	7.680
$24He$	7.074

Fig. 5.1

(i) Calculate the energy, in MeV, produced from this fusion reaction.

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energy produced = ... MeV [2]

(ii) A star in the milky way gives off energy at a rate of 2.75 x 10^{26} W solely due to the fusion of helium into carbon in its core.

Calculate the number of helium nuclei *N*, that reacted in one second.

N = ... s^{-1} [3]

(b) The nuclide *614C* (carbon-14) is unstable and undergoes β decay, emitting a high-energy electron and a neutrino to form a nuclide X.

(i) The equation for this decay is shown.

$$^{14}_{6}C \rightarrow \begin{matrix}\cdots\cdots\\ \cdots\cdots\end{matrix}X + \begin{matrix}\cdots\cdots\\ \cdots\cdots\end{matrix}e + {}^{0}_{0}\nu$$

Complete the equation. [2]

(ii) Neutrinos were first proposed to exist more than 20 years before they were directly detected, in order to explain a particular experimental observation about β-decay.

1. State an observation about β-decay that is explained by the existence of neutrinos.

.....
.....

[1]

2. Suggest how the existence of neutrinos explains the observation in **(b)(i)1**.

.....
.....

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…… [2]

……

(c) The variation with time t of the number N of undecayed nuclei in a sample of a radioactive isotope is shown in Fig. 5.2.

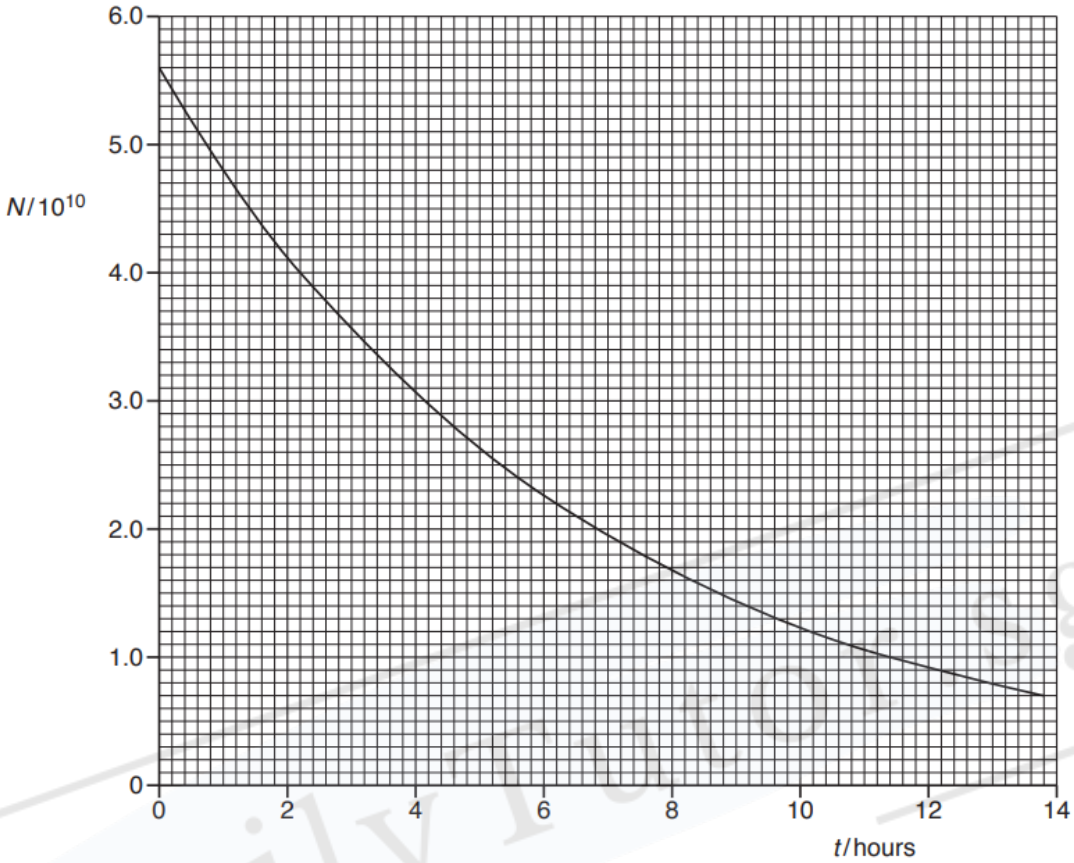

Fig. 5.2

(i) Using Fig. 5.2, determine the activity, in Bq, of the sample at time t = 4.0 hours.

activity = ... Bq [2]

(ii) Use your answer in **(c)(i)** to show that the decay constant λ of the isotope is approximately 4×10^{-5} s^{-1}

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[2]

[Total: 14]

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6 **(a)** State what is meant by the *wavelength* of a progressive wave.

……

…….... [1]

(b) A cathode-ray oscilloscope (CRO) is used to analyse a sound wave. The screen of the CRO is shown in Fig. 6.1.

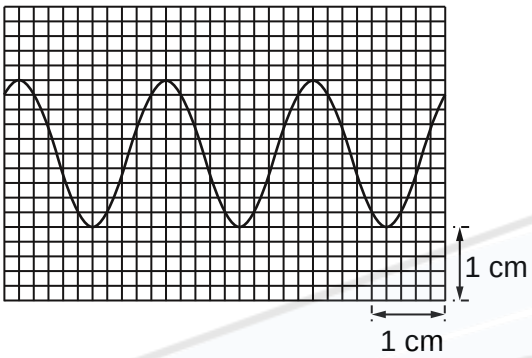

Fig. 6.1

The time-base setting of the CRO is 2.5 ms cm^{-1}.

Determine the frequency of the sound wave.

frequency = ...Hz [1]

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(c) The source emitting the sound in **(b)** is placed near the bottom opening of a vertical tube of length 0.80m. The tube is open at both ends, as shown in Fig. 6.2.

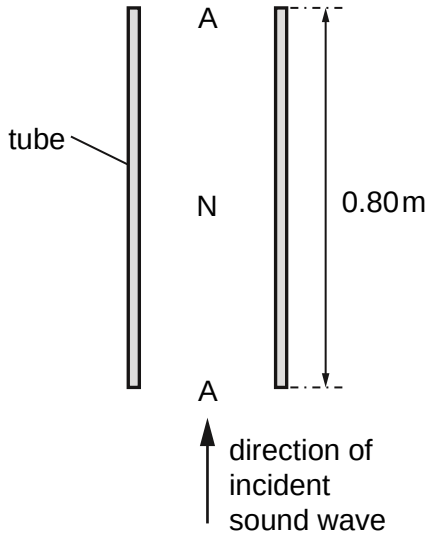

Fig. 6.2

A stationary wave is then formed in the air column in the tube with antinodes A at both ends and a node N at the midpoint.

(i) Explain how the stationary wave is formed from the incident sound wave.

……

……

……

…… [2]

(ii) On Fig. 6.3, sketch a graph to show the variation of the amplitude of the stationary wave with height *h* above the bottom of the tube.

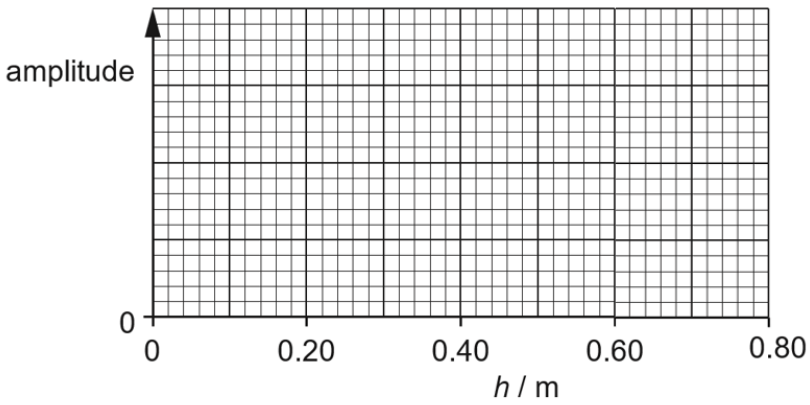

Fig. 6.3 [2]

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(iii) For the stationary wave, state

1. the direction of the oscillations of an air particle at a height of 0.15 m above the bottom of the tube

…… [1]

2. the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = ... ° [1]

(iv) Determine the wavelength of the sound wave.

wavelength = …… m [1]

(d) The source emitting the sound in **(b)** is then placed at point A as shown in Fig. 6.4.

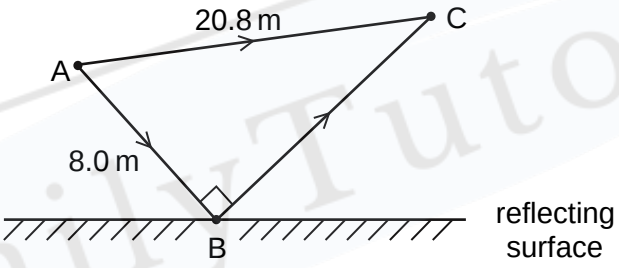

Fig. 6.4 (not to scale)

The sound waves travel from the source to point C along two different paths, AC and ABC. Distance AB is 8.0 m and distance AC is 20.8 m. Angle ABC is 90°.

Assume that there is no phase change of the sound wave due to the reflection at point B.

(i) Show that the waves meeting at C have a path difference of 6.4 m

[1]

(i) Explain why an intensity maximum is detected at point C.

……

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[2]

(ii) Determine the difference between the time taken for the sound waves to travel from the source to point C along the two different paths.

time difference = ...s [2]

(iii) The wavelength of the sound is gradually increased. Calculate the wavelength of the sound when an intensity maximum is next detected at point C.

wavelength = ...m [2]

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(e) Fig. 6.5 shows an ideal polarizer A arranged so that its polarizing direction is vertical. Polariser B is oriented with its plane parallel to that of A and with its polarizing direction at 45° to the vertical.

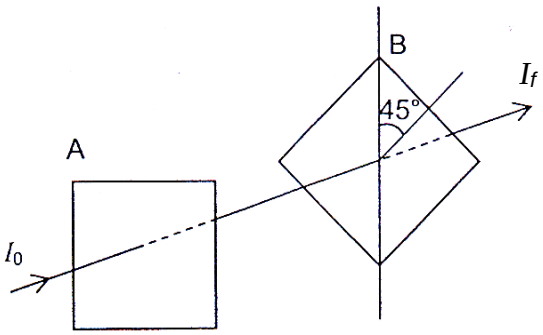

Fig. 6.5 a

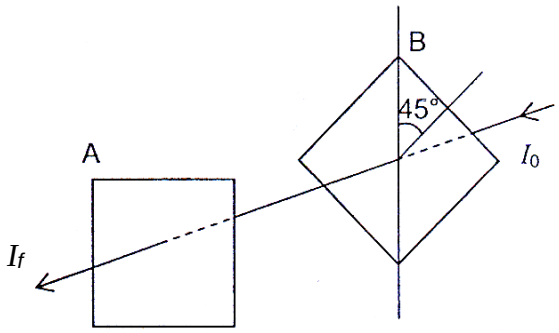

Fig. 6.5 b

A beam of vertically-polarised light, of initial intensity I_o, passes through the polarisers in turn.

Determine the intensity I_f and the orientation of the emergent beam when the beam passes through the polarizer system

(i) in the direction from A to B (Fig. 6.5a),

intensity I_f = ...

orientation to the vertical =.....

[2]

(ii) in the direction from B to A (Fig. 6.5b).

intensity I_f = ...

orientation to the vertical =.....

[2]

[Total: 20]

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[Turn over

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

……

…… [1]

(ii) An application of electromagnetic induction is inductive charging. In inductive charging, the device to be charged is placed on a charging plate as shown in Fig. 7.1.

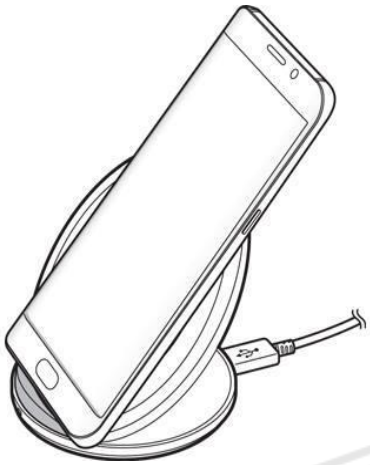

Fig. 7.1

Using the laws of electromagnetic induction, suggest how inductive charging works.

……

……

……

……

…… [3]

……

(iii) Suggest one advantage and one disadvantage of inductive charging.

Advantage:

……

…… [1]

Disadvantage:

……

……

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[1]

(b) The charging plate must be connected to an alternating power supply. The variation with time t of the supply voltage V is given by

$$V = 340\sin(377t)$$

where V is measured in volts and t in seconds.

(i) Calculate the frequency of the supply voltage.

frequency = ... Hz [2]

(ii) Calculate the root-mean-square value of the supply voltage.

root-mean-square value = ... V [2]

(iii) With reference to heating effect, explain what is meant by the root-mean-square value calculated in **(b)(ii)**.

.....

.....

..... [1]

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(c) Two conducting rods, AB and CD, are placed on two horizontal, parallel and smooth metal rails of negligible resistance as shown in Fig 7.2. The two rails are 10.0 cm apart. A uniform magnetic field of flux density 0.54 T is applied perpendicularly into the plane of the rails.

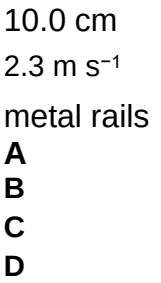

Fig. 7.2 (plan view)

Rod AB has a resistance of 0.83 ∧ while rod CD has negligible resistance. Both rods have the same mass of 34 g.

Rod CD is suddenly made to move at a constant speed of 2.3 m s^{-1} to the right.

(i) Calculate the e.m.f. induced in rod CD.

e.m.f. induced = …… V [2]

(ii) State which end of rod CD is at a higher potential.

…… [1]

(iii) Calculate the initial current in rod AB.

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current = …… A [2]

(iv) State and explain the direction of the initial force acting on rod AB.

……

…… [2]

(v) Determine the magnitude of the initial acceleration of rod AB.

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acceleration = …… m s^{-2} [2]

[Total: 20]

End of Paper

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CENTRE NUMBER	S	INDEX NUMBER	

PHYSICS 9749/01

Paper 1 Multiple Choice **22 September 2023**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class, Centre number and index number in the spaces at the top of this page.

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

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

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

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Data

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

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \mathrm{K} = T / ^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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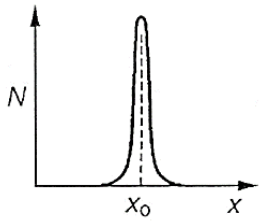
1	**B**	6	**D**	11	**B**	16	**A**	21	**A**	26	**D**
2	**C**	7	**B**	12	**A**	17	**A**	22	**B**	27	**C**
3	**C**	8	**A**	13	**D**	18	**A**	23	**A**	28	**D**
4	**A**	9	**D**	14	**A**	19	**D**	24	**D**	29	**A**
5	**A**	10	**C**	15	**D**	20	**D**	25	**B**	30	**A**

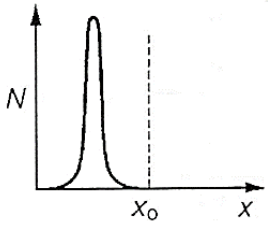
1 A quantity x is measured many times and the number N of measurements giving a value of x is plotted against x. The true value of the quantity is x_o.

Which graph best represents precise measurements with poor accuracy?

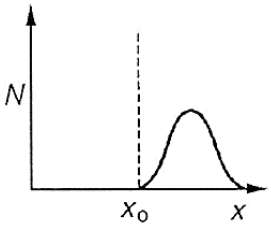
A



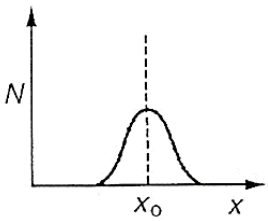
B



C



D



Ans: B

2 Errors in measurement may be either systematic or random.

Which of the following involves random error?

A Not allowing for zero error on an analog voltmeter

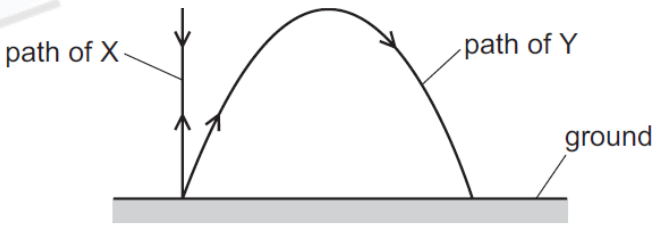
B Not subtracting background count rate when determining the count rate from a radioactive source

C Stopping a stopwatch at the end of a race

D Using the value of g as 10 $N\,kg^{-1}$ when calculating weight from mass

Ans: C

3 Two projectiles, X and Y, are launched into the air from the same place on level ground. They reach the same maximum height as shown.



Projectile X is launched vertically upwards and projectile Y is launched at an angle to the horizontal. Air resistance is negligible.

Which statement is correct?

A X and Y are at rest at their maximum heights.

B X and Y are launched with the same speed.

C X and Y take the same time to return to the ground.

D X and Y travel the same distance.

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Ans: C
X and Y subjected to the same acceleration due to gravity in the vertical direction, so both reach the ground at the same time. Since X and Y reach the same maximum height, they must be launched with the same initial *vertical* speed (and NOT same speed since Y's initial vertical speed is $u\sin\theta$)

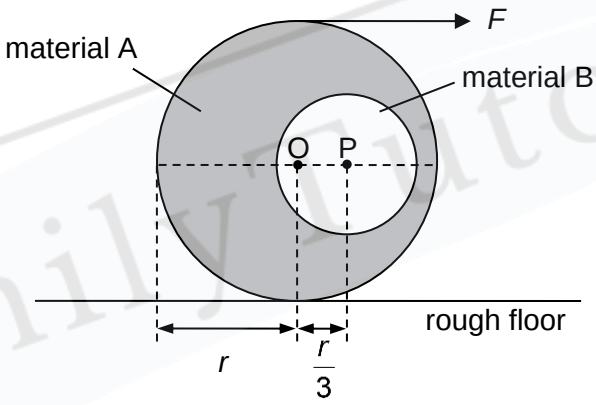
4 A tractor of mass 1000 kg pulls a trailer of mass 1000 kg via a tow-bar. The total resistance to motion has a constant value of 4000 N. One fifth of this resistance acts on the trailer. If the maximum breaking force of the tow-bar is 3000N, what is maximum acceleration of the tractor and trailer?

A 2.2 m s^{-2} **B** 3.0 m s^{-2} **C** 3.8 m s^{-2} **D** 7.0 m s^{-2}

Ans: A
For the trailer, $\Sigma F = ma$
Max breaking force $- 800 = 1000\, a$
$a = (3000 - 800) / 1000 = 2.2$ m s^{-2}

5 A cylinder of radius r, made of material A and B, is placed on a rough floor as shown. The portion made of material B has a radius of $0.45r$ and a density of ρ that is half that of material A. O is the centre of the cylinder and P is the centre of the portion made of material B. The distance between O and P is $\frac{r}{3}$. If the cylinder is entirely made of material A, its weight will be 90 N.

A force F is applied horizontally to the top of the cylinder so that O and P are at the same height from the floor as shown.



What is the force F required to keep the cylinder in this equilibrium position?

A 1.5 N **B** 2.0 N **C** 4.5 N **D** 7.5 N

Ans: A
If the entire cylinder is A, the system would be in equilibrium without F. With B, and the system requires F to be in equilibrium. Hence, the moment due to F (and the resulting friction) should be equal to that due to the weight of (portion of A that is replaced by B - B).
With F in place, translational equilibrium in the horizontal direction requires a friction f equal in magnitude to F but acting in the opposite direction to F. F and f form a couple.
Weight of section replaced by (B) = $W_A - W_B = (\rho_A - \rho_B)(V_B)\, g = \frac{1}{2}\, \rho_A\, V_B\, g$
Taking centre of mass of cylinder A as pivot
Moment due to the weight of section replaced by B
$= \frac{1}{2}\, \rho_A\, \pi(0.45r)^2\, \ell g \times r/3 = 0.03375 r^3\, \pi\, \rho_A\, lg$
Since $\rho_A\, V_A\, g = \rho_A\, \pi(r)^2\, \ell g = 90$ N,
$0.03375 r^3\, \pi\, lg = 3.04\, r$ N
Moment due to the couple of F and $f = F \times 2r$
Equating the two moments, $F = 1.5$ N

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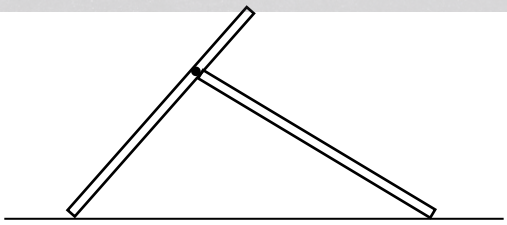
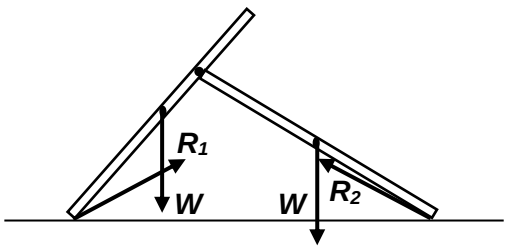
6 Two identical uniform rods, each of weight W, are hinged together to form a structure which is resting on a rough floor as shown.

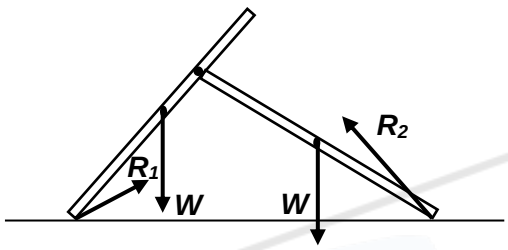


If the reaction forces acting on the structure by the floor are R_1 and R_2, which of the following shows the forces acting on the structure?

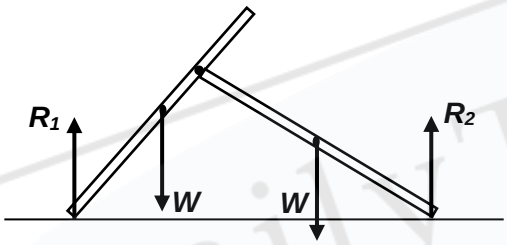
A



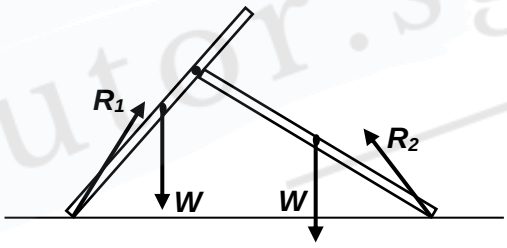
B



C



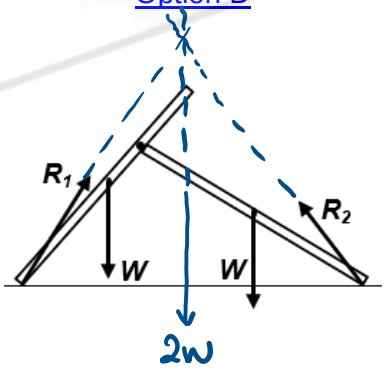
D



Ans: D

Combine the two W into a single $2W$, situated at the centre of the two W. Then extends the forces for $2W$ and the two R. There must intersect at one point. This will eliminate option B and C.

Option D



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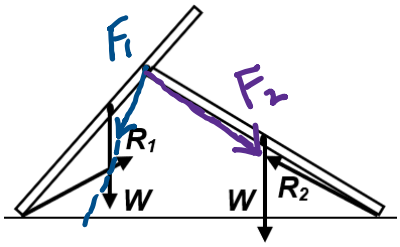
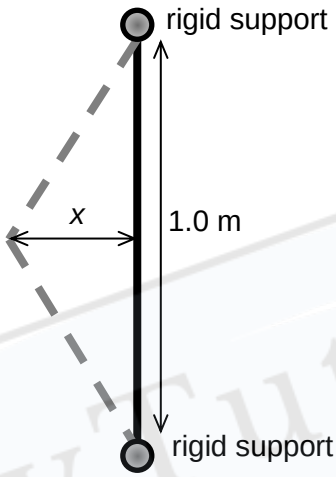
To eliminate option A, refer to the FBD of the left rod of A. There must be a force F_1 pointing downward and leftward to maintain equilibrium of the left rod.
Then, refer to FBD of right rod. There must be a F_2 pointing downward and rightward to maintain equilibrium of this rod. But as these two forces are action and reaction pair, they must point in opposite direction, which is not true in the drawing below. Hence option A is not the answer.

Option A



7 A student builds a launcher using an elastic cord of negligible mass and natural length of 1.0 m attached to two rigid supports.



Assuming that the elastic cord obeys Hooke's Law with a spring constant of 80 N m^{-1} and that the cord is pulled at its midpoint, what is the minimum draw length x needed such that a 200 g water balloon may be propelled with a speed of 10 m s^{-1}?

A 0.50 m **B** 0.56 m **C** 0.75 m **D** 1.5 m

Ans: B
By COE,
Loss in EPE = Gain in KE
$0.5ke^2 - 0 = 0.5mv^2 - 0$
$80(2\sqrt{0.50^2 + x^2} - 1.0)^2 = 0.200(10)^2$
$x = 0.56$ m

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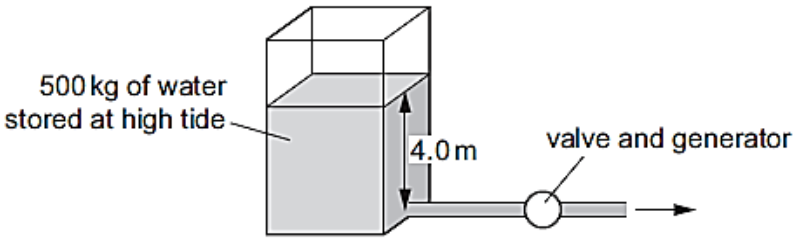
8 A simple idea for generating electricity from the tides allows water stored in a container at high tide to flow away through a generator at low tide.



At high tide 500 kg of water is stored to a height of 4.0 m. When the valve is opened the container empties in 5.0 s and the generator operates with an efficiency of 40%.

What is the average electrical power generated during the period of water flow?

A 780 W **B** 1600 W **C** 2000 W **D** 3900 W

Ans: A

$$P_{out} = \frac{mgh}{t} \times 0.40$$

$$P_{out} = \frac{500(9.81)(4.0/2)}{5.0} \times 0.40 = 784.8 = 780 \text{ W}$$

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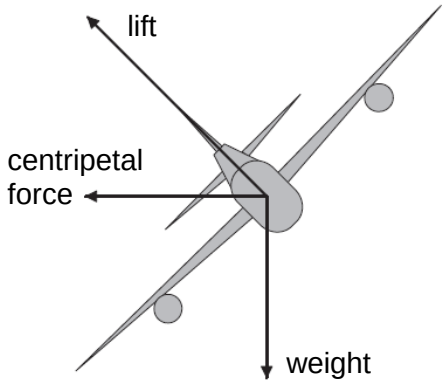
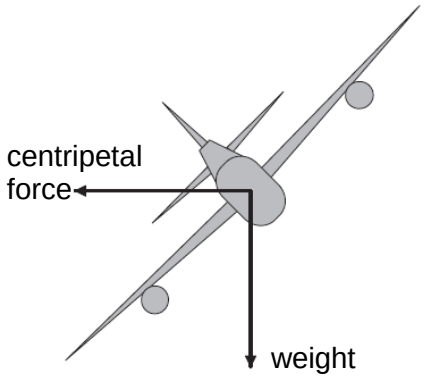
9 An aircraft is flying at constant speed in a horizontal circle.

Which of the following diagrams best illustrates the forces acting on the aircraft?

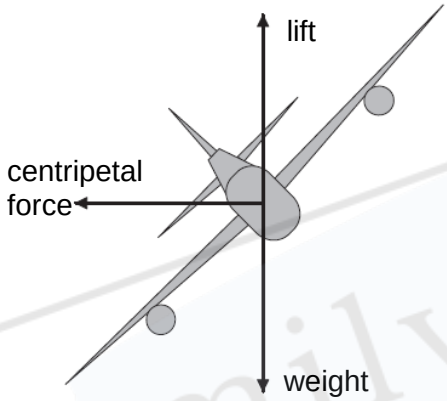
A



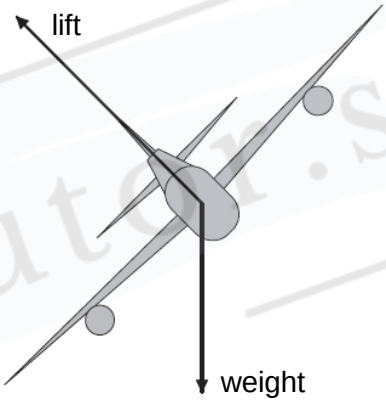
B



C

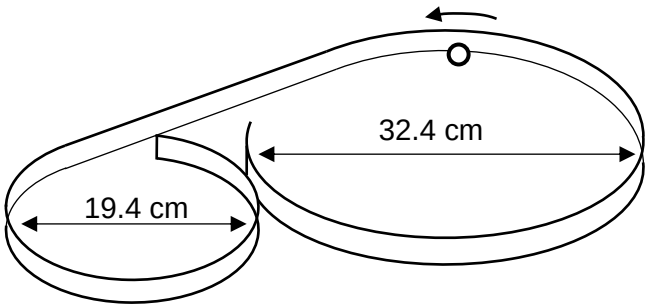


D



Ans: D
Centripetal force is a resultant force which should not be included in a FBD.

10 A small sphere is travelling horizontally around the circumference of the bigger circular loop in the figure below with an angular velocity of 63.0 rad s^{-1}.



The sphere then moves into the smaller loop and continues to move along its circumference.

What will be the angular velocity of the sphere when it is moving in the smaller loop?

A 37.7 rad s^{-1} **B** 63.0 rad s^{-1} **C** 105 rad s^{-1} **D** 126 rad s^{-1}

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Ans: C

$v_{small} = v_{big}$

$r_{small}\omega_{small} = r_{big}\omega_{big}$

$(0.194 / 2)\omega_{small} = (0.324 / 2)(63.0)$

$\omega_{small} = 105 \text{ rad s}^{-1}$

11 A satellite is orbiting the Earth with a radius of 6610 km at a speed of 7780 m s^{-1}. The satellite is boosted to a higher orbit of radius 6890 km. Given that the mass of the Earth is 6.0×10^{24} kg, the speed of the satellite in the new orbit is

A 7460 m s^{-1} **B** 7620 m s^{-1} **C** 7940 m s^{-1} **D** 8110 m s^{-1}

Ans: B

$\frac{GMm}{r^2} = \frac{mv^2}{r}$

$\frac{GM}{r} = v^2$

$v^2 \propto \frac{1}{r}$

$\left(\frac{v_f}{v_i}\right)^2 = \frac{r_i}{r_f}$

$\left(\frac{v_f}{7780}\right)^2 = \frac{6610}{6890}$

$v_f = 7620 \text{ m s}_{-1}$

Note that you cannot assume total energy of satellite remains the same as the satellite is 'boosted' to a higher orbit (meaning that there is an input energy).

12 A small ice cube of mass 20 g is heated and changes from the solid to the liquid state. During this change in state the temperature of the substance does not change.

Which statement about this change in state is **not** correct?

A The amount of energy the ice absorbs is equal to the specific latent heat of fusion.

B The average kinetic energy of the molecules remains unchanged.

C The average potential energy of the molecules increases.

D The total mass of ice and water remains constant throughout.

Ans: A

A is only true if it is phrased like this '*The amount of energy the ice absorbs is equal to the ~~specific~~ latent heat of fusion.*'

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13 The contents of a refrigerator are at a constant temperature, and the surroundings of the refrigerator are at a higher temperature. As a result, heat is transferred into the refrigerator from the surroundings. With the help of the cooling mechanism, heat from the refrigerator is also removed at the same rate.

The first law of thermodynamics may be applied to the contents of the refrigerator. This law is represented by $\Delta U = Q + W$, where ΔU is the increase in internal energy of the contents, Q is the net heat supplied to the contents, and W is the work done on the contents.

For the contents of the refrigerator, which of the quantities ΔU, Q and W is/ are zero?

A ΔU only **B** Q only

C W only **D** ΔU, Q and W

Ans: D
ΔU is zero since temperature is maintained constant. While there is heat entering from surrounding to content of fridge, the cooling mechanism also removes heat out of the content of fridge, hence net Q is also zero. By 1st law of Thermodynamics, W is also zero.

14 The air in an aircraft when travelling has the following energy as listed in the table below.

Type of energy	**As a result of**	**Amount of energy / MJ**
Kinetic energy	motion of the aircraft	8
Kinetic energy	random movement of the air molecules	30
Potential energy	altitude of the aircraft	75
Potential energy	intermolecular attraction between the air molecules	-3

What is the internal energy of the air in the aircraft?

A 27 MJ **B** 33 MJ **C** 35 MJ **D** 110 MJ

Ans: A
Internal energy only includes kinetic energy due to random movement of the air molecules and potential energy due to intermolecular attraction between the air molecules.

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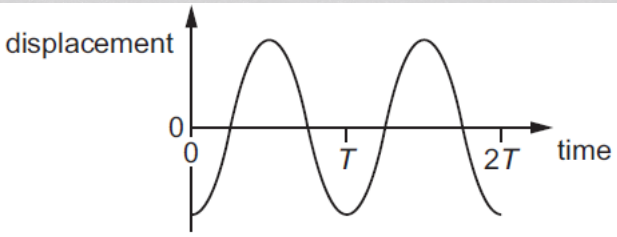
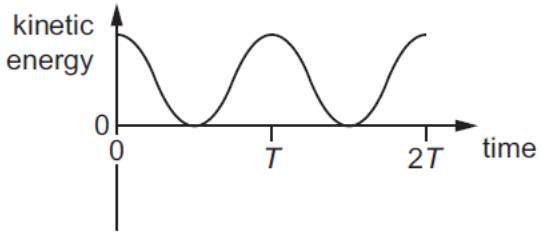
15 When sound travels through air, the particles oscillate. A graph of displacement against time for a single particle is shown.

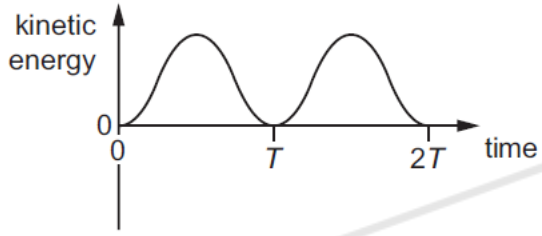


Which graph best shows how the kinetic energy of the air particle varies with time?

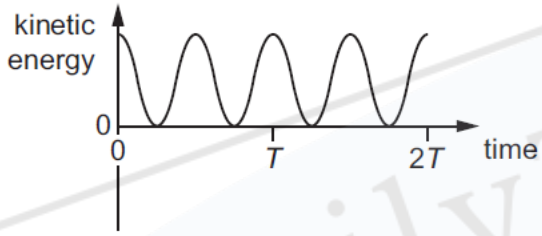
A



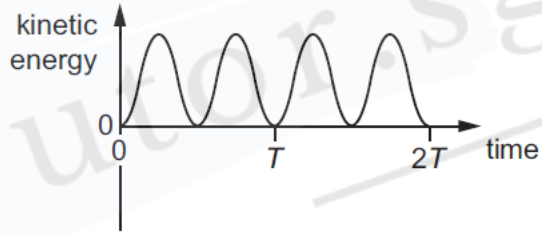
B



C



D



Ans: D
There should be 2 cycles per period and since object started with maximum displacement, then KE must start with zero.

16 Two coherent light waves that are same plane polarized of equal frequency and intensity superpose at a point that is equal distance from the two sources. The intensity of light at that point is twice the intensity of light due to either wave alone.

What is a possible phase difference between the two waves at that point?

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

Ans: A

Try drawing two sinusoidal waves that have a phase difference of $\frac{\pi}{2}$. You can do this by drawing a sine curve and a cosine curve, each of amplitude A, on the same grid. You will see that the resultant wave has an amplitude of $1.414A$ (when horizontal axis is $\frac{\pi}{4}$ rad). When $1.414A$ is squared and multiplied with constant k, it will give you $2I$ of intensity.

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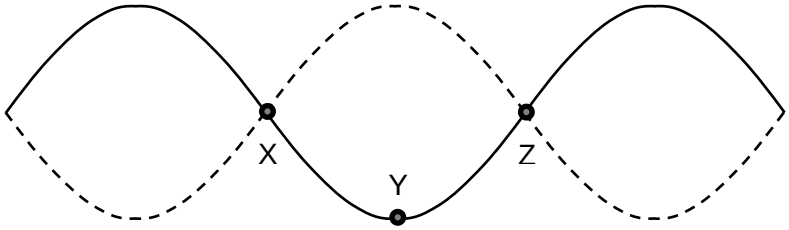
17 The stationary wave shown below is the result of the superposition of two identical waves travelling in opposite directions.



Which of the following best states the phase difference between the two waves at points X, Y and Z?

	X	Y	Z
A	$-\pi$	0	π
B	$-\pi/2$	0	$\pi/2$
C	$\pi/2$	π	$3\pi/2$
D	0	π	2π

Ans: A
Nodes : π (destructive); Antinodes : 0 (constructive)

18 A coil contains *N* turns of insulated copper wire wound on to a cylindrical iron core of diameter *D.* The copper wire has a diameter *d*. The resistivity of copper is *ρ*. Diameter *D* is much greater than diameter *d*.

What is the total resistance between the two ends of the coil?

A $\frac{4N\rho D}{d^2}$ **B** $\frac{4N\rho d}{D^2}$ **C** $\frac{8N\rho D}{d^2}$ **D** $\frac{8N\rho d}{D^2}$

Ans: A

$$R = \rho\frac{L}{A} = \rho\frac{N(\pi D)}{\pi(\frac{d}{2})^2} = \frac{4N\rho D}{d^2}$$

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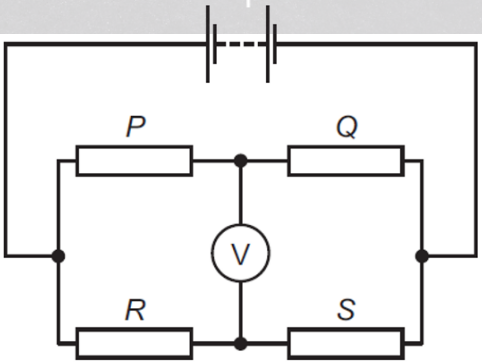
19 The circuit diagram shows four resistors of different resistances *P*, *Q*, *R* and *S* connected to a battery.



The voltmeter reading is zero.

Which equation is must be correct?

A $P - Q = R - S$

B $P - S = Q - R$

C $PQ = RS$

D $PS = QR$

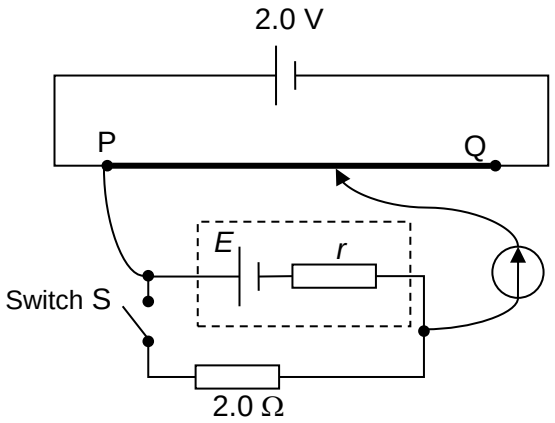
Ans: D
Since voltmeter reading is zero, it means no current passes through it.
Current in P = current in Q and current in R = current in S

$$\frac{P}{Q} = \frac{R}{S}$$

$$PS = QR$$

20 The diagram below shows a potentiometer circuit used to determine the internal resistance *r* of a cell of e.m.f. *E*. The driver cell has an e.m.f. of 2.0 V with negligible internal resistance and the resistance wire PQ is 1.0 m long. The cell is connected in parallel with a resistor of 2.0 Ω. When the switch is open, the balance length is 0.70 m and when the switch is closed, the balance length is 0.50 m.

What is the value of *r*?



A 0.15 Ω **B** 0.40 Ω **C** 0.50 Ω **D** 0.80 Ω

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Ans: D
When the switch is open, at balance position, there is no current passing through the unknown emf cell.

$$E = \frac{0.70}{1.0} \times 2.0 = 1.4\ \text{V}$$

When switch is closed, at balance position, there is current flowing in the secondary circuit below.

$$E - Ir = \frac{0.50}{1.0} \times 2.0$$

$$1.4 - \left(\frac{1.4}{2.0 + r}\right) r = 1.0$$

$$r = 0.80\ \Omega$$

21 A charged oil droplet of mass *m* is falling, initially freely, in a vacuum between two horizontal metal plates that are separated by a distance *x*.

A potential difference (p.d.) *V* is then applied across the plates. This results in the oil droplet continuing to accelerate downwards but with a reduced acceleration *a*.

The polarity of the applied p.d. is then reversed so that the direction of the electric force on the droplet is reversed. This results in the downwards acceleration of the oil droplet increasing to 3*a*.

What is the magnitude of the charge on the oil droplet?

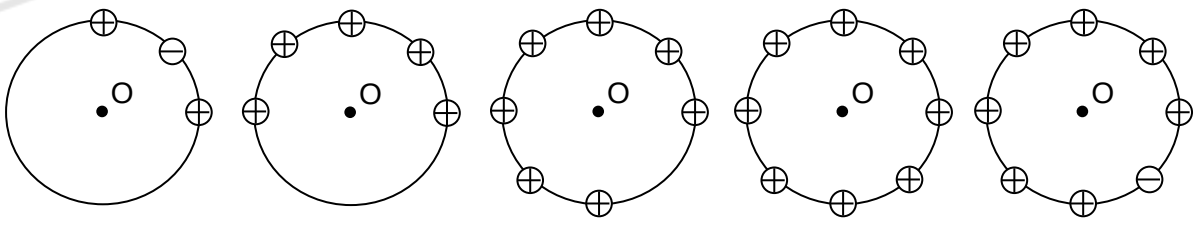
A $\frac{max}{V}$ **B** $2\frac{max}{V}$ **C** $3\frac{max}{V}$ **D** $4\frac{max}{V}$

Ans: A
For case 1, $mg - F_E = ma$ --- (1)
For case 2, $mg + F_E = 3ma$ --- (2)
(2) – (1):
$2F_E = 2ma$

$$q\frac{V}{x} = ma$$

$$q = \frac{max}{V}$$

22 The diagrams below show 5 different arrangements of charges around a circle with centre O. Rank in *ascending* order the magnitude of the electric field strength at point O



1 2 3 4 5

A 1 2 3 5 4 **B** 4 1 3 5 2 **C** 1 2 5 3 4 **D** 4 3 5 2 1

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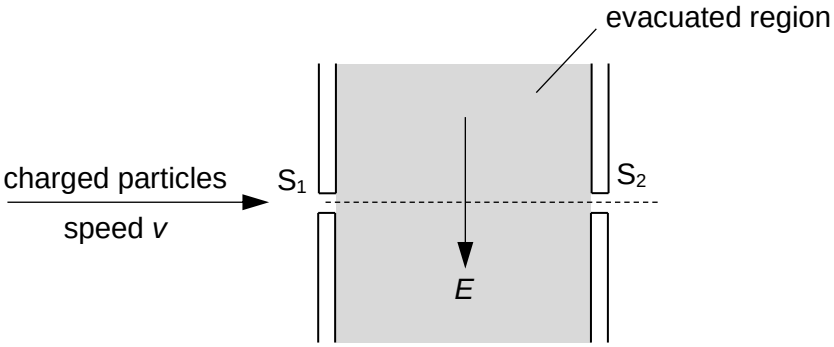
Ans: B
Arrangement 4 has zero field strength since each charge has an opposite charge.
Arrangement 1 has a smaller field strength than arrangement 2 because there is a negative charge that negates the effect due to the two positive charges.

23 A narrow parallel beam of charged particles, each with speed v, passes through a slit S_1 into an evacuated region, moving in the direction towards slit S_2.

The evacuated region is shown shaded on the diagram.



Uniform magnetic and electric fields are applied in the same evacuated region, with the electric field E in the direction shown. The particles continue to exit through slit S_2.

What is the magnitude and direction of the magnetic field?

	magnitude	direction
A	$\frac{E}{v}$	into the plane of the paper
B	$\frac{E}{v}$	out of the plane of the paper
C	Ev	into the plane of the paper
D	Ev	out of the plane of the paper

Ans: A

$$F_B = F_E$$
$$Bqv = qE$$
$$B = \frac{E}{v}$$

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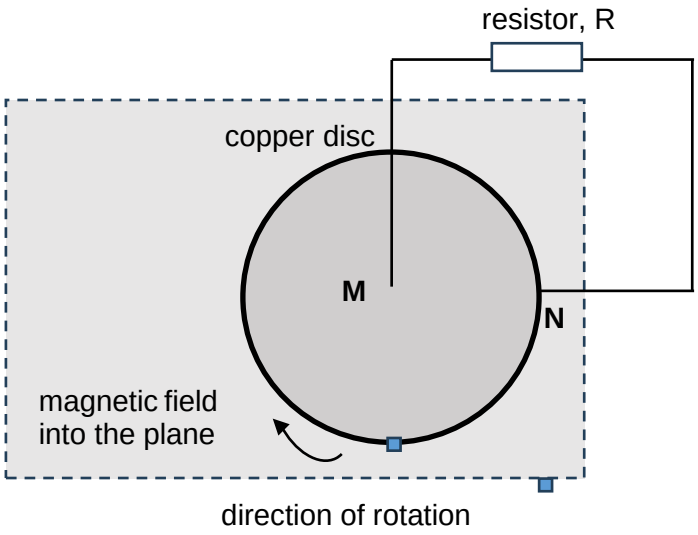
24 A copper disc rotates with a constant angular velocity in a uniform magnetic field applied perpendicular to its surface, as shown. The axle and the edge of the disc are in contact with metallic brushes M and N which are connected to a resistor R via wires.



Which of the following statements is correct?

A There is no current through R because there is no flux change through the disc.

B There is an alternating current through R.

C There is a steady current from M, through R, to N.

D There is a steady current from N, through R, to M.

Ans: D
Draw a line from M to N. When the disc is rotating in a clockwise direction, this line is moving downward. By Lenz's Law, an upward force acts on this line, and by FLHR, the induced current is in a direction from M to N. Hence this current goes from N, through R, to M.

25 A 240 V supply is connected to an ideal transformer. The output of the transformer is connected to five 12 V, 24 W lamps connected in parallel. The lamps are operating normally.

What is the current drawn from the supply?

A 0.10 A **B** 0.50 A **C** 2.0 A **D** 10.0 A

Ans: B
The five lamps are all parallel to the secondary coil. Current through one lamp = 24/12 = 2.0 A
Current through secondary coil, $I_s = 5 \times 2.0 = 10$ A
$V_s I_s = V_p I_p$,
$12 \times 10 = 240 \times I_p$
$I_p = 0.50$ A

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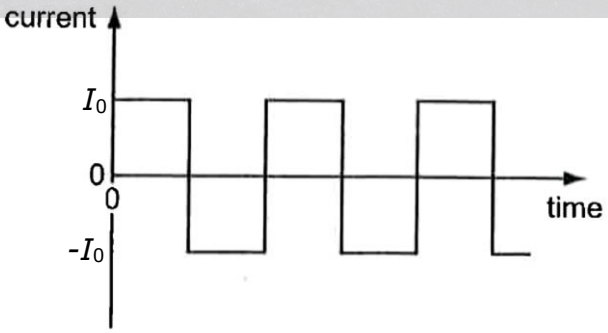
26 The graph shows an alternating current with a square waveform.



The peak value of the current is I_o and the average power dissipated in the circuit is given by P.

What is the new average power dissipated if the peak value is now doubled to $2I_o$?

A P **B** $1.4P$ **C** $2P$ **D** $4P$

Ans: D

The I_{rms} of the square waveform is I_o.

(working: $I_{rms} = \sqrt{\dfrac{I_o^2 \times \dfrac{T}{2} + I_o^2 \times \dfrac{T}{2}}{T}} = I_o$)

The average power is given by
$P = I^2 R = (I_o)^2 R$

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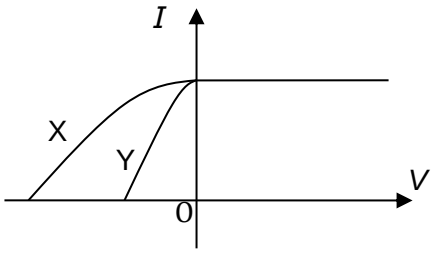
27 In a photoelectric effect experiment, a metallic surface X in an evacuated tube is illuminated with light of wavelength 275 nm causing the emission of photoelectrons which are collected at an adjacent electrode.

The experiment is repeated by replacing metallic surface X by another metallic surface Y.

The variation of photocurrent I with the potential difference V between each of the metallic surfaces and the adjacent electrode is shown in the diagram below.



The table below lists the work functions of some elements.

Element	Work Function (eV)
Sodium	2.7
Aluminium	4.3
Copper	4.7

What materials are the metallic surfaces X and Y made of?

	metallic surface X	metallic surface Y
A	copper	copper
B	copper	aluminium
C	sodium	aluminium
D	sodium	copper

Ans: C
Photon of wavelength 275 nm has 4.52 eV of energy. Copper will not have any emission. Sodium having the smallest work function will release photoelectrons with greatest kinetic energy. Sodium will require the largest stopping voltage. The stopping voltage is the value of V such that the photocurrent I = 0 (x-intercept).

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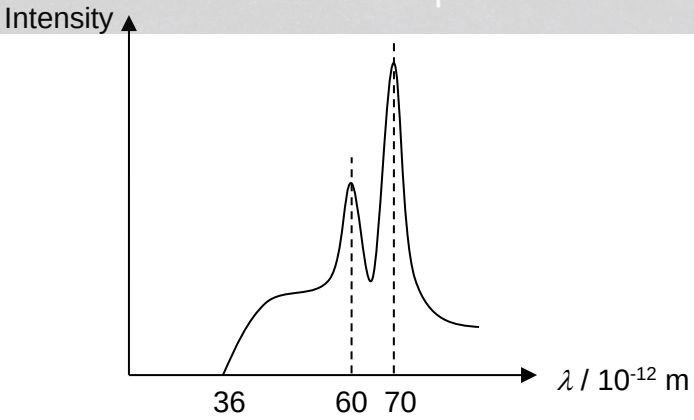
28 The x-ray spectrum produced by bombarding a metal target with electrons is shown below.



Which of the following statements is correct?

A The graph shows that electrons with a range of kinetic energies are used to bombard the target.

B The wavelength corresponding to the peaks allow the energy of the electrons used to bombard the target to be calculated.

C The smallest wavelength detected, 36×10^{-12} m, is dependent on the target material.

D The wavelength corresponding to the peaks can be used to identify the element of target.

Ans: D
Option A is not correct because since the X-ray spectra will always contain bremsstrahlung radiation whether the electrons bombarding the metal target has a single energy or have a range of energies. Option B is not correct because the the position (wavelength) corresponding to the characteristic peaks is dependent only on the kind of target and not on the energy of the incoming electrons. Option C is not correct because minimum wavelength (cutoff wavelength) depends on the maximum energy of the incident electrons.

29 The fusion of two deuterium nuclei produces a nuclide of helium and a neutron. The reaction liberates 3.27 MeV of energy.

How does the combined mass of the two deuterium nuclei, $\Sigma M_{Reactants}$, compare with the combined mass of the helium nucleus and neutron, $\Sigma M_{Products}$?

A $\Sigma M_{Reactants}$ is 5.8×10^{-30} kg greater than $\Sigma M_{Products}$.

B $\Sigma M_{Reactants}$ is 5.8×10^{-30} kg smaller than $\Sigma M_{Products}$.

C $\Sigma M_{Reactants}$ is 5.8×10^{-36} kg greater than $\Sigma M_{Products}$.

D $\Sigma M_{Reactants}$ is 5.8×10^{-36} kg smaller than $\Sigma M_{Products}$.

Ans: A
3.27 Mev = 5.23×10^{-30}J
Mass equivalent = 5.8×10^{-30} kg
Greater mass before fusion to liberate the energy.

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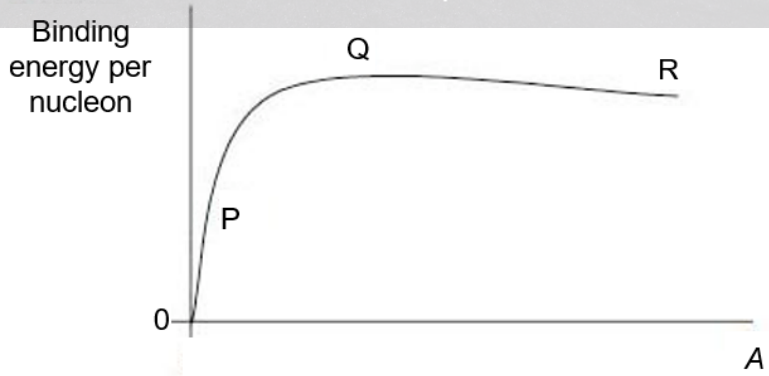
30 The graph shows how the binding energy per nucleon of a nucleon of a nucleus varies with nucleon number, *A*.



Which of the following statements is **not** true?

A Energy is released in nuclear fission reactions from nuclei in region P.

B Nuclei in region Q are more stable than nuclei in region R.

C Nuclear fusion reactions from nuclei in region P produce nuclei closer to region Q.

D The binding energy per nucleon increases most significantly when nuclei in region P undergo nuclear fusion reactions.

Ans: A
Nuclear fission is improbable in region P.

End of Paper

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Paper 1 Multiple Choice **22 September 2023**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class, Centre number and index number in the spaces at the top of this page.

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

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

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

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Data

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

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / ^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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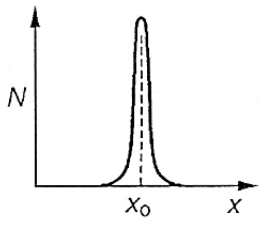
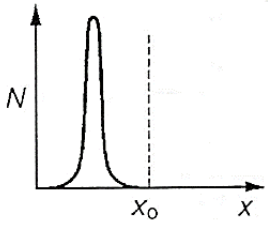
1 A quantity x is measured many times and the number N of measurements giving a value of x is plotted against x. The true value of the quantity is x_o.

Which graph best represents precise measurements with poor accuracy?

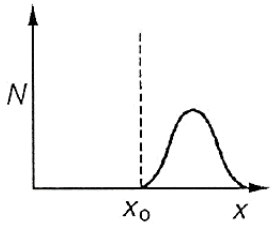
A



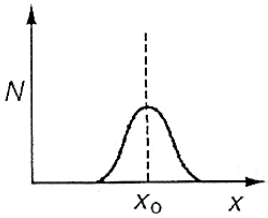
B



C



D



2 Errors in measurement may be either systematic or random.

Which of the following involves random error?

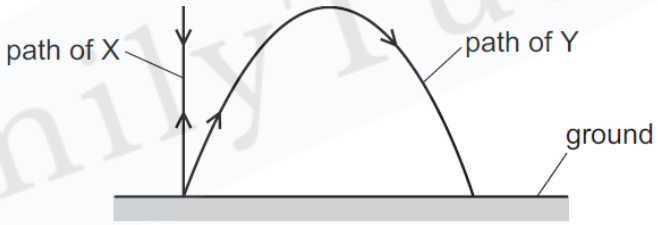
A Not allowing for zero error on an analog voltmeter

B Not subtracting background count rate when determining the count rate from a radioactive source

C Stopping a stopwatch at the end of a race

D Using the value of g as 10 N kg^{-1} when calculating weight from mass

3 Two projectiles, X and Y, are launched into the air from the same place on level ground. They reach the same maximum height as shown.



Projectile X is launched vertically upwards and projectile Y is launched at an angle to the horizontal. Air resistance is negligible.

Which statement is correct?

A X and Y are at rest at their maximum heights.

B X and Y are launched with the same speed.

C X and Y take the same time to return to the ground.

D X and Y travel the same distance.

4 A tractor of mass 1000 kg pulls a trailer of mass 1000 kg via a tow-bar. The total resistance to motion has a constant value of 4000 N. One fifth of this resistance acts on the trailer. If the maximum breaking force of the tow-bar is 3000N, what is maximum acceleration of the tractor and trailer?

A 2.2 m s^{-2} **B** 3.0 m s^{-2} **C** 3.8 m s^{-2} **D** 7.0 m s^{-2}

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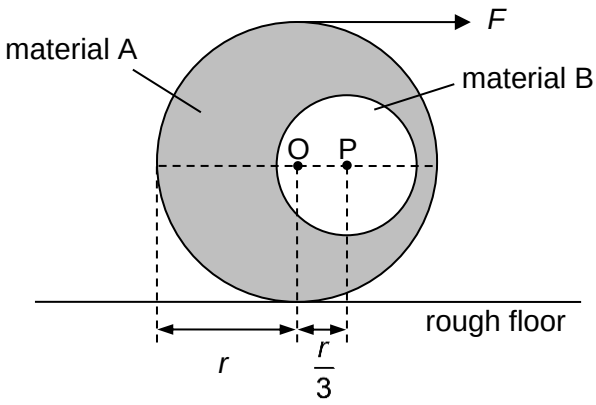
5 A cylinder of radius r, made of material A and B, is placed on a rough floor as shown. The portion made of material B has a radius of $0.45r$ and a density of ρ that is half that of material A. O is the centre of the cylinder and P is the centre of the portion made of material B. The distance between O and P is $\frac{r}{3}$. If the cylinder is entirely made of material A, its weight is 90 N.

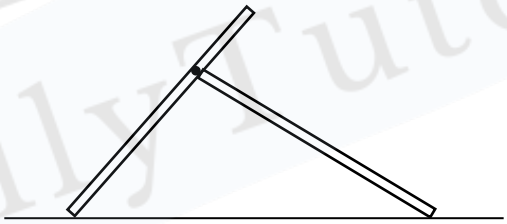
A force F is applied horizontally to the top of the cylinder so that O and P are at the same height from the floor as shown.



What is the force F required to keep the cylinder in this equilibrium position?

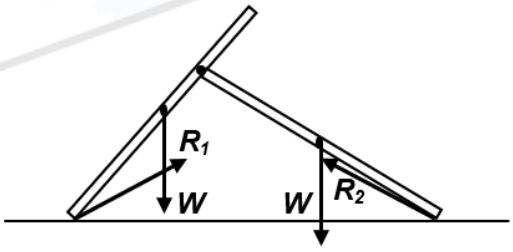
A 1.5 N **B** 2.0 N **C** 4.5 N **D** 7.5 N

6 Two identical uniform rods, each of weight W, are hinged together to form a structure which is resting on a rough floor as shown.

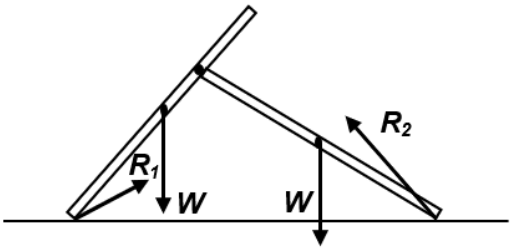


If the reaction forces acting on the structure by the floor are R_1 and R_2, which of the following shows the forces acting on the structure?

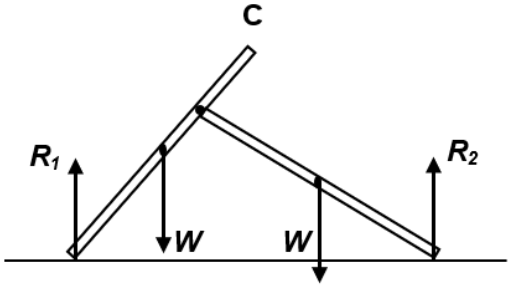
A



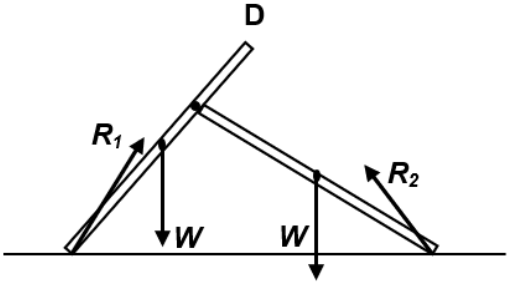
B



C



D



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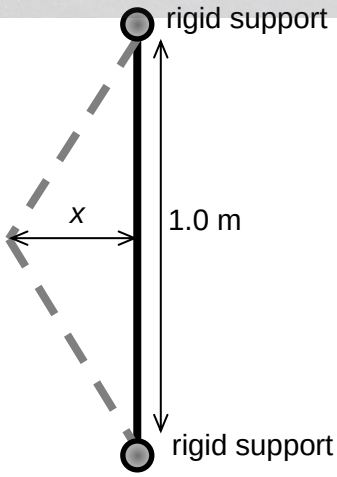
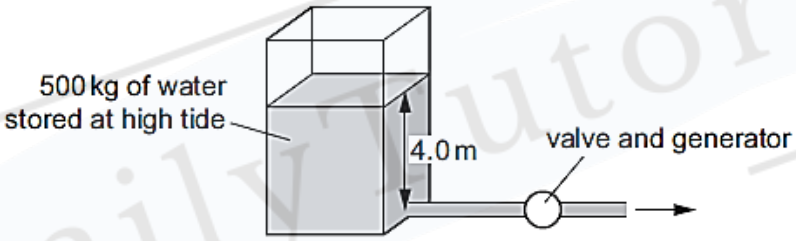
7 A student builds a launcher using an elastic cord of negligible mass and natural length of 1.0 m attached to two rigid supports.



Assuming that the elastic cord obeys Hooke's Law with a spring constant of 80 N m^{-1} and that the cord is pulled at its midpoint, what is the minimum draw length *x* needed such that a 200 g water balloon may be propelled with a speed of 10 m s^{-1}?

A 0.50 m **B** 0.56 m **C** 0.75 m **D** 1.5 m

8 A simple idea for generating electricity from the tides allows water stored in a container at high tide to flow away through a generator at low tide.



At high tide 500 kg of water is stored to a height of 4.0 m. When the valve is opened the container empties in 5.0 s and the generator operates with an efficiency of 40%.

What is the average electrical power generated during the period of water flow?

A 780 W **B** 1600 W **C** 2000 W **D** 3900 W

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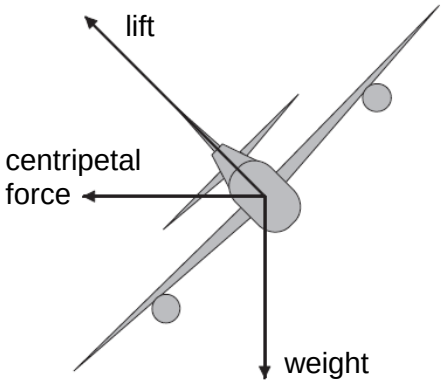
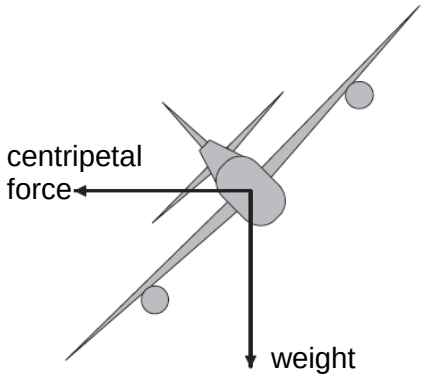
9 An aircraft is flying at constant speed in a horizontal circle.

Which of the following diagrams best illustrates the forces acting on the aircraft?

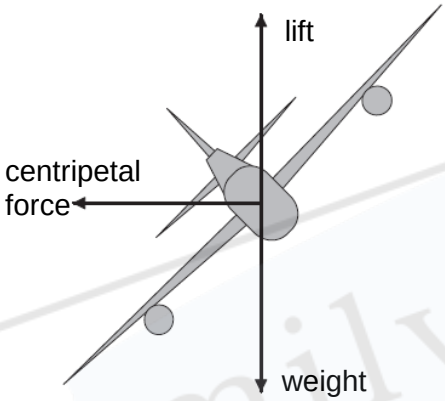
A



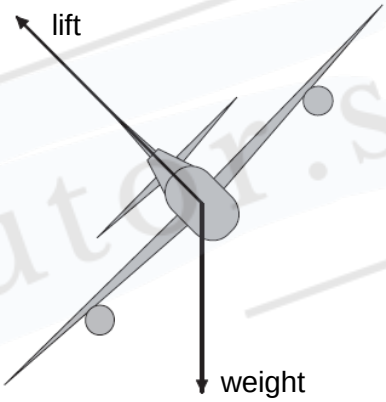
B



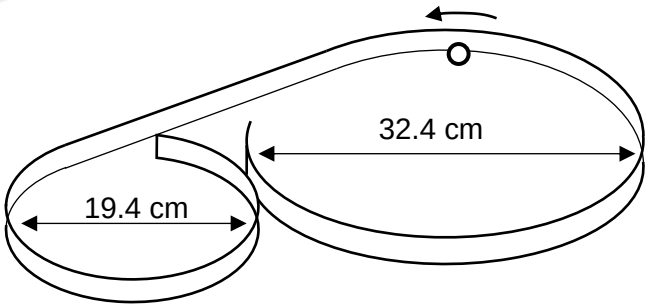
C



D



10 A small sphere is travelling horizontally around the circumference of the bigger circular loop in the figure below with an angular velocity of 63.0 rad s^{-1}.



The sphere then moves into the smaller loop and continues to move along its circumference.

What will be the angular velocity of the sphere when it is moving in the smaller loop?

A 37.7 rad s^{-1} **B** 63.0 rad s^{-1} **C** 105 rad s^{-1} **D** 126 rad s^{-1}

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11 A satellite is orbiting the Earth with a radius of 6610 km at a speed of 7780 m s^{-1}. The satellite is boosted to a higher orbit of radius 6890 km. Given that the mass of the Earth is 6.0×10^{24} kg, the speed of the satellite in the new orbit is

A 7460 m s^{-1} **B** 7620 m s^{-1} **C** 7940 m s^{-1} **D** 8110 m s^{-1}

12 A small ice cube of mass 20 g is heated and changes from the solid to the liquid state. During this change in state the temperature of the substance does not change.

Which statement about this change in state is **not** correct?

A The amount of energy the ice absorbs is equal to the specific latent heat of fusion.

B The average kinetic energy of the molecules remains unchanged.

C The average potential energy of the molecules increases.

D The total mass of ice and water remains constant throughout.

13 The contents of a refrigerator are at a constant temperature, and the surroundings of the refrigerator are at a higher temperature. As a result, heat is transferred into the refrigerator from the surroundings. With the help of the cooling mechanism, heat from the refrigerator is also removed at the same rate.

The first law of thermodynamics may be applied to the contents of the refrigerator. This law is represented by $\Delta U = Q + W$, where ΔU is the increase in internal energy of the contents, Q is the net heat supplied to the contents, and W is the work done on the contents.

For the contents of the refrigerator, which of the quantities ΔU, Q and W is/ are zero?

A ΔU only **B** Q only

C W only **D** ΔU, Q and W

14 The air in an aircraft when travelling has the following energy as listed in the table below.

Type of energy	**As a result of**	**Amount of energy / MJ**
Kinetic energy	motion of the aircraft	8
Kinetic energy	random movement of the air molecules	30
Potential energy	altitude of the aircraft	75
Potential energy	intermolecular attraction between the air molecules	-3

What is the internal energy of the air in the aircraft?

A 27 MJ **B** 33 MJ **C** 35 MJ **D** 110 MJ

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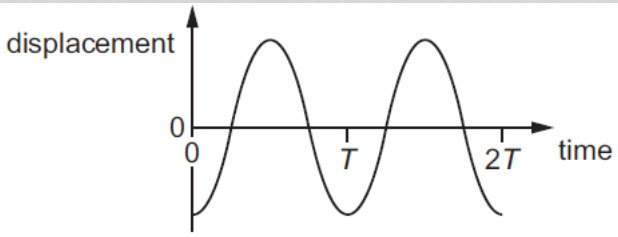
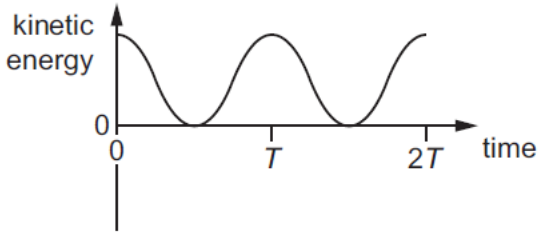
15 When sound travels through air, the particles oscillate. A graph of displacement against time for a single particle is shown.

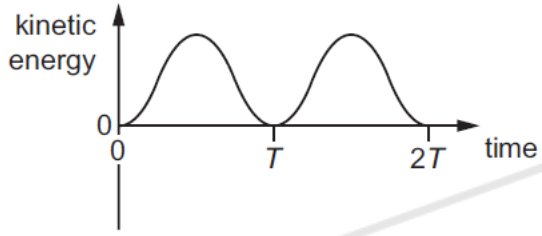


Which graph best shows how the kinetic energy of the air particle varies with time?

A



B



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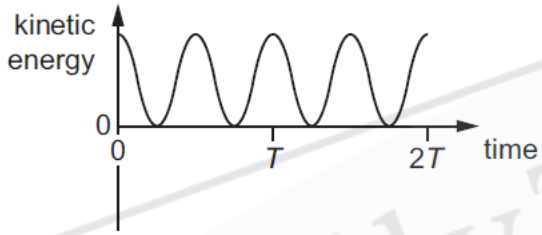

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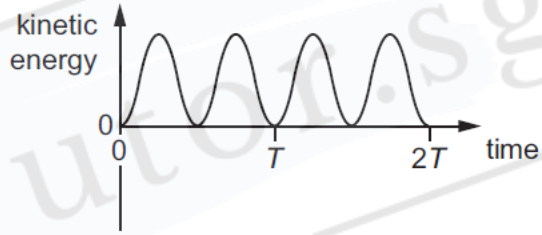

16 Two coherent light waves that are same plane polarized of equal frequency and intensity superpose at a point that is equal distance from the two sources. The intensity of light at that point is twice the intensity of light due to either wave alone.

What is a possible phase difference between the two waves at that point?

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

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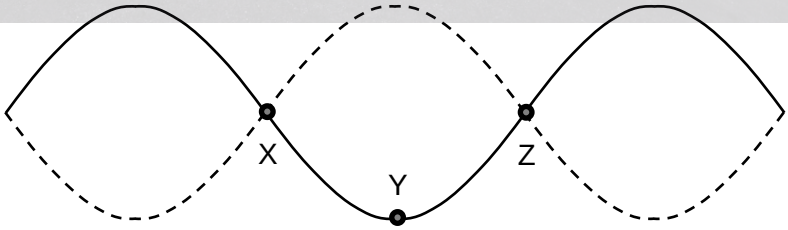
17 The stationary wave shown below is the result of the superposition of two identical waves travelling in opposite directions.



Which of the following best states the phase difference between the two waves at points X, Y and Z?

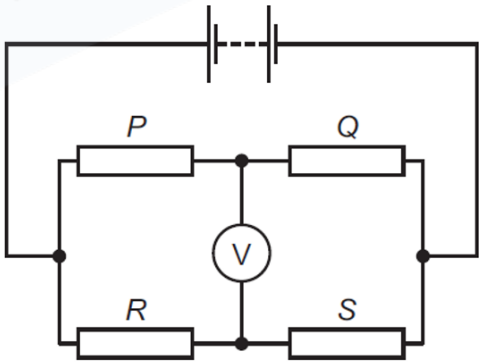
	X	Y	Z
A	$-\pi$	0	π
B	$-\pi/2$	0	$\pi/2$
C	$\pi/2$	π	$3\pi/2$
D	0	π	2π

18 A coil contains N turns of insulated copper wire wound on to a cylindrical iron core of diameter D. The copper wire has a diameter d. The resistivity of copper is ρ. Diameter D is much greater than diameter d.

What is the total resistance between the two ends of the coil?

A $\frac{4N\rho D}{d^2}$ **B** $\frac{4N\rho d}{D^2}$ **C** $\frac{8N\rho D}{d^2}$ **D** $\frac{8N\rho d}{D^2}$

19 The circuit diagram shows four resistors of different resistances P, Q, R and S connected to a battery.



The voltmeter reading is zero.

Which equation is must be correct?

A $P - Q = R - S$

B $P - S = Q - R$

C $PQ = RS$

D $PS = QR$

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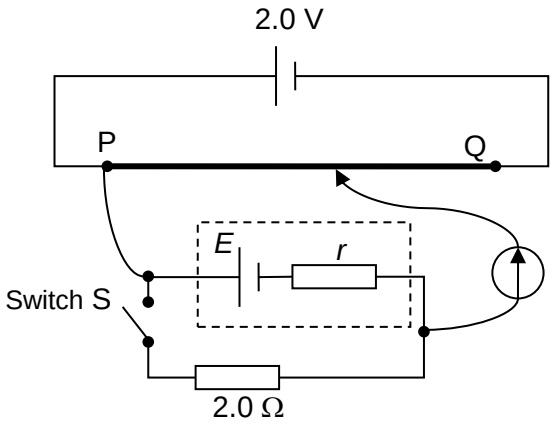
20 The diagram below shows a potentiometer circuit used to determine the internal resistance *r* of a cell of e.m.f. *E*. The driver cell has an e.m.f. of 2.0 V with negligible internal resistance and the resistance wire PQ is 1.0 m long. The cell is connected in parallel with a resistor of 2.0 Ω. When the switch is open, the balance length is 0.70 m and when the switch is closed, the balance length is 0.50 m.

What is the value of *r*?



A 0.15 Ω **B** 0.40 Ω **C** 0.50 Ω **D** 0.80 Ω

21 A charged oil droplet of mass *m* is falling, initially freely, in a vacuum between two horizontal metal plates that are separated by a distance *x*.

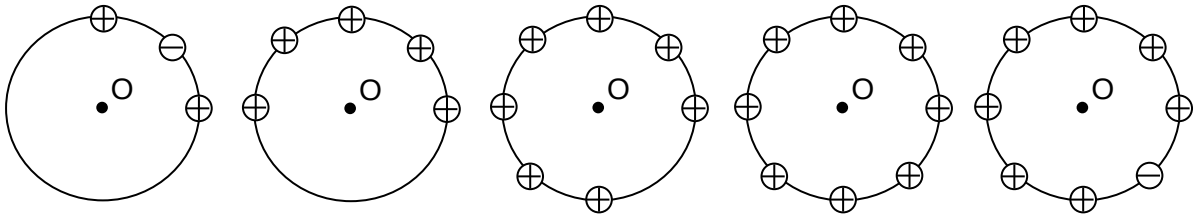
A potential difference (p.d.) *V* is then applied across the plates. This results in the oil droplet continuing to accelerate downwards but with a reduced acceleration *a*.

The polarity of the applied p.d. is then reversed so that the direction of the electric force on the droplet is reversed. This results in the downwards acceleration of the oil droplet increasing to 3*a*.

What is the magnitude of the charge on the oil droplet?

A $\frac{max}{V}$ **B** $2\frac{max}{V}$ **C** $3\frac{max}{V}$ **D** $4\frac{max}{V}$

22 The diagrams below show 5 different arrangements of charges around a circle with centre O. Rank in *ascending* order the magnitude of the electric field strength at point O



1 2 3 4 5

A 1 2 3 5 4 **B** 4 1 3 5 2 **C** 1 2 5 3 4 **D** 4 3 5 2 1

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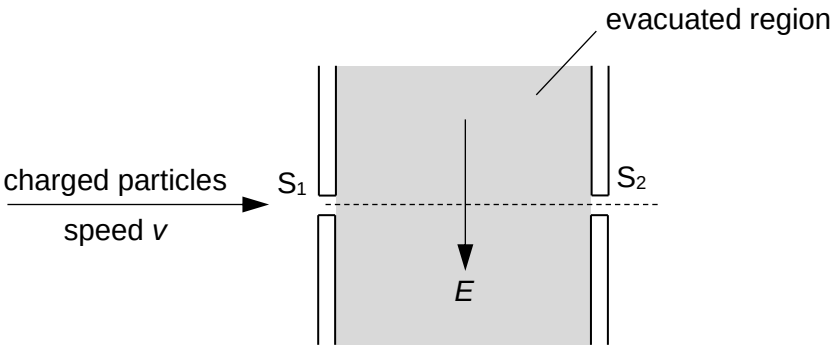
23 A narrow parallel beam of charged particles, each with speed v, passes through a slit S_1 into an evacuated region, moving in the direction towards slit S_2.

The evacuated region is shown shaded on the diagram.



Uniform magnetic and electric fields are applied in the same evacuated region, with the electric field E in the direction shown. The particles continue to exit through slit S_2.

What is the magnitude and direction of the magnetic field?

	magnitude	direction
A	$\frac{E}{v}$	into the plane of the paper
B	$\frac{E}{v}$	out of the plane of the paper
C	Ev	into the plane of the paper
D	Ev	out of the plane of the paper

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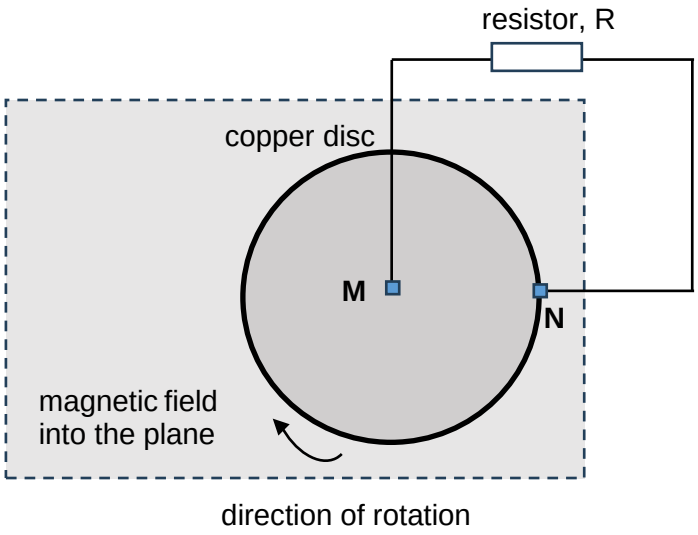
24 A copper disc rotates with a constant angular velocity in a uniform magnetic field applied perpendicular to its surface, as shown. The axle and the edge of the disc are in contact with metallic brushes M and N which are connected to a resistor R via wires.



Which of the following statements is correct?

A There is no current through R because there is no flux change through the disc.

B There is an alternating current through R.

C There is a steady current from M, through R, to N.

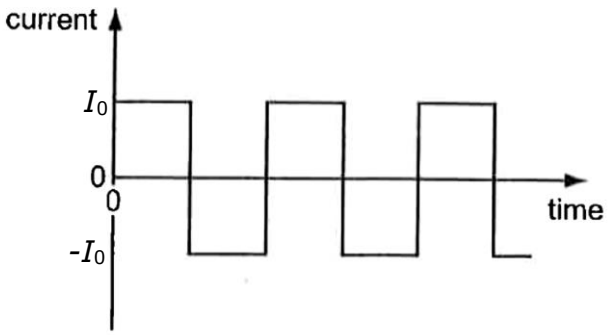
D There is a steady current from N, through R, to M.

25 A 240 V supply is connected to an ideal transformer. The output of the transformer is connected to five 12 V, 24 W lamps connected in parallel. The lamps are operating normally.

What is the current drawn from the supply?

A 0.10 A **B** 0.50 A **C** 2.0 A **D** 10.0 A

26 The graph shows an alternating current with a square waveform.



The peak value of the current is I_o and the average power dissipated in the circuit is given by *P*.

What is the new average power dissipated if the peak value is now doubled to $2I_o$?

A *P* **B** 1.4*P* **C** 2*P* **D** 4*P*

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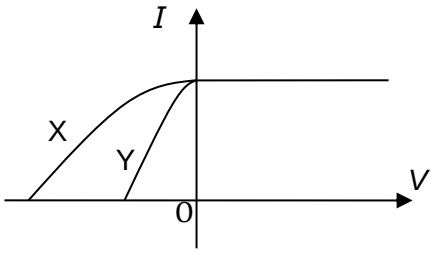
27 In a photoelectric effect experiment, a metallic surface X in an evacuated tube is illuminated with light of wavelength 275 nm causing the emission of photoelectrons which are collected at an adjacent electrode.

The experiment is repeated by replacing metallic surface X by another metallic surface Y.

The variation of photocurrent I with the potential difference V between each of the metallic surfaces and the adjacent electrode is shown in the diagram below.



The table below lists the work functions of some elements.

Element	Work Function (eV)
Sodium	2.7
Aluminium	4.3
Copper	4.7

What materials are the metallic surfaces X and Y made of?

	metallic surface X	metallic surface Y
A	copper	copper
B	copper	aluminium
C	sodium	aluminium
D	sodium	copper

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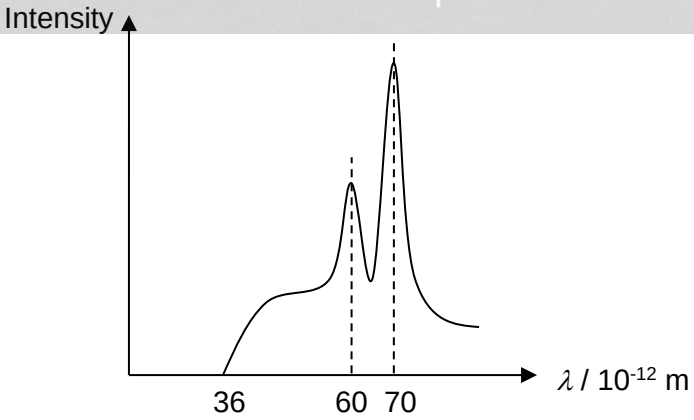
28 The x-ray spectrum produced by bombarding a metal target with electrons is shown below.



Which of the following statements is correct?

A The graph shows that electrons with a range of kinetic energies are used to bombard the target.

B The wavelength corresponding to the peaks allow the energy of the electrons used to bombard the target to be calculated.

C The smallest wavelength detected, 36×10^{-12} m, is dependent on the target material.

D The wavelength corresponding to the peaks can be used to identify the element of target.

29 The fusion of two deuterium nuclei produces a nuclide of helium and a neutron. The reaction liberates 3.27 MeV of energy.

How does the combined mass of the two deuterium nuclei, $\Sigma M_{\text{Reactants}}$, compare with the combined mass of the helium nucleus and neutron, $\Sigma M_{\text{Products}}$?

A $\Sigma M_{\text{Reactants}}$ is 5.8×10^{-30} kg greater than $\Sigma M_{\text{Products}}$.

B $\Sigma M_{\text{Reactants}}$ is 5.8×10^{-30} kg smaller than $\Sigma M_{\text{Products}}$.

C $\Sigma M_{\text{Reactants}}$ is 5.8×10^{-36} kg greater than $\Sigma M_{\text{Products}}$.

D $\Sigma M_{\text{Reactants}}$ is 5.8×10^{-36} kg smaller than $\Sigma M_{\text{Products}}$.

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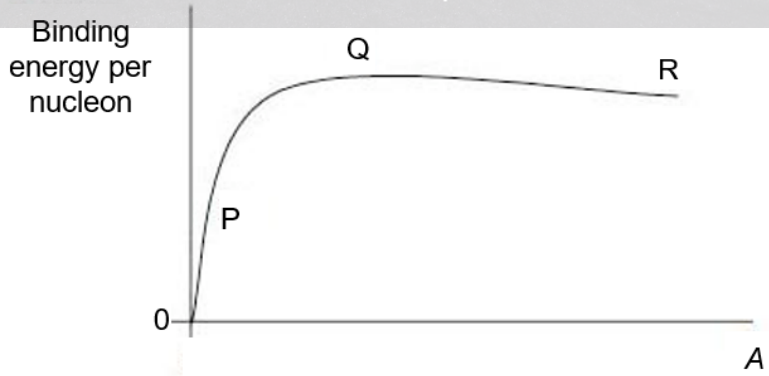
30 The graph shows how the binding energy per nucleon of a nucleus varies with nucleon number, *A*.



Which of the following statements is **not** true?

A Energy is released in nuclear fission reactions from nuclei in region P.

B Nuclei in region Q are more stable than nuclei in region R.

C Nuclear fusion reactions from nuclei in region P produce nuclei closer to region Q.

D The binding energy per nucleon increases most significantly when nuclei in region P undergo nuclear fusion reactions.

End of Paper

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JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
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CENTRE NUMBER	S	INDEX NUMBER	

PHYSICS 9749/02

Paper 2 Structured Questions **14 September 2023**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

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

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

For Examiner's Use	
1	/ 8
2	/ 9
3	/ 8
4	/ 7
5	/ 8
6	/ 8
7	/ 10
8	/ 22
Total	/ 80

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

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Data

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

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / ^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 Fig. 1.1 shows the variation of velocity v with time t for a fuel-propelled model rocket travelling upwards.

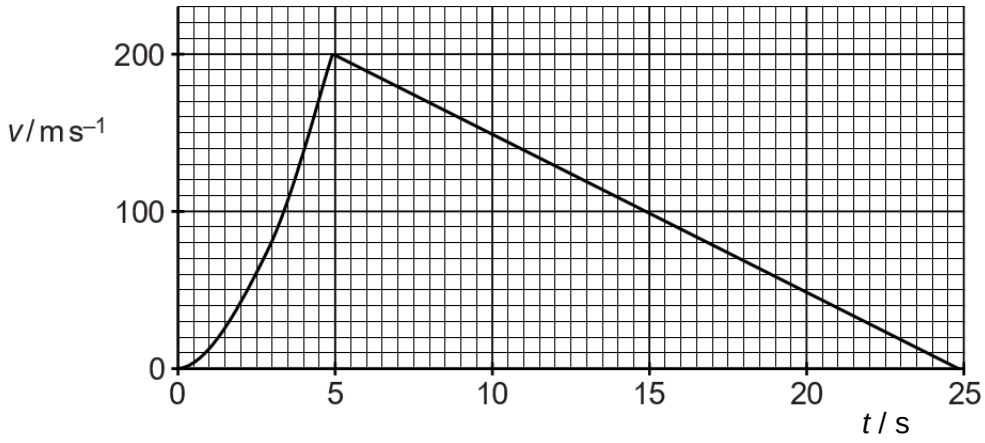

Fig. 1.1

(a) (i) Define *acceleration*.

It is the rate of change of velocity [B1] .....[1]

(ii) State the time interval when the rocket has the greatest acceleration.

between t = 3.5 to 4.0 s to t = 5.0 s [1] [B1]

(iii) Explain why the acceleration of the rocket increases between t = 0 to t = 5.0 s.

[Intended ans] Fuel is burnt and mass gradually decreases, so with a constant thrust force, net force increases causing acceleration to increase [B1]

.....[1]

(b) (i) Suggest a reason for the abrupt change in the motion of the rocket at t = 5.0 s.

All fuel has been burnt / No more thrust [B1]

.....[1]

(ii) Explain how it can be deduced from Fig. 1.1 that air resistance has a negligible effect on the motion of the rocket.

As the rocket continues to rise, it experiences **constant** deceleration between t = 5.0 s to t = 25 s [B1]

numerically equal to **10 m s^{-2}** (or value of g stated) [B1]

OR reverse argument: If air resistance were not negligible, then deceleration would be > g and not constant as indicated in Fig. 1.1. .....[2]

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(c) Use Fig. 1.1 to determine the maximum height reached by the rocket.

max height = area under graph from t = 0 to t = 25 s

$= (73 \text{ squares} \times 0.5 \times 10) + \frac{1}{2}(20)(200)$ [M1]

$= 365 + 2000$

$= 2365$ m [A1]

height = 2350 to 2380 m [2]

[Total: 8]

2 **(a)** State the *principle of moments*.

.....

.....[1]

(b) Fig. 2.1 shows part of a cable-stayed bridge. Each section of the bridge is supported by eight equally spaced cables that pass through a central supporting pillar.

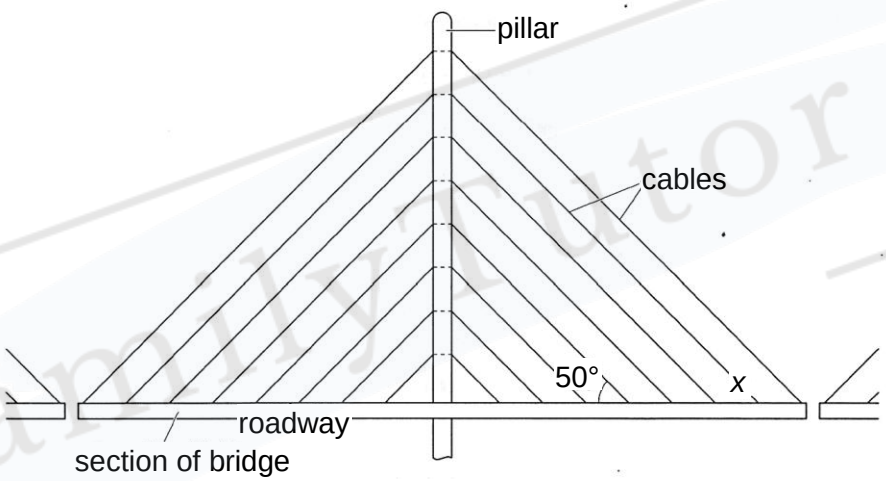

Fig. 2.1 (not to scale)

The cables are at an angle of 50° to the horizontal and the maximum tension allowed in each cable is 7.8×10^5 N.

(i) The mass of the roadway in this section is 350 tonnes (1 tonne = 1000 kg).
Calculate the maximum mass of traffic that is allowed on this section of the roadway.

The section of the roadway must stay in equilibrium. Therefore, the resultant force must be zero. Taking upwards as positive,

$$\sum F = 0$$

$$16 \times 7.8 \times 10^5 \sin 50^0 - (350\ 000 + m) \times 9.81 = 0$$

$$m = 6.20 \times 10^5 \text{ kg}$$

mass = ... kg [2]

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(ii) Suggest a reason why the maximum tension allowed in each cable is well below the breaking tension.

This is to ensure that if any of the cables break unexpectedly (e.g. due to fatigue and corrosion), the other cables will be able to support the allowable mass of traffic.

.....[1]

(c) Fig. 2.2 shows a suspension bridge. The cables of the bridge are anchored into large free-standing anchor blocks of concrete.

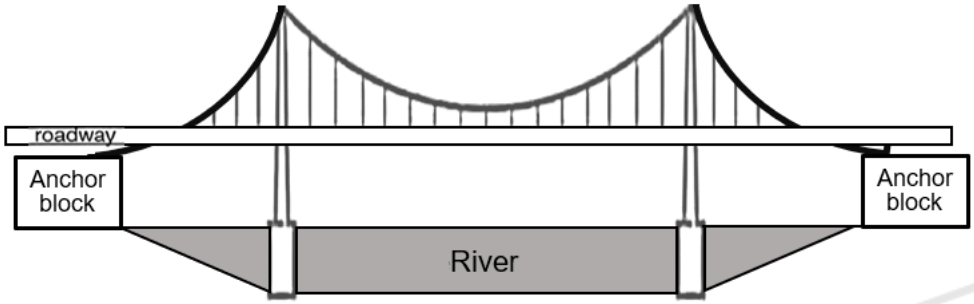

Fig. 2.2

The anchor block on the right is shown on a larger scale in Fig. 2.3. It has a length of 30.0 m and its cross-section and density are uniform.

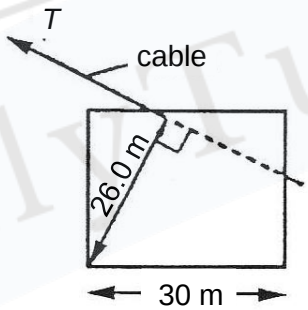

Fig. 2.3

This block is standing on the ground. The maximum force which the cables could exert on this block is 5.50×10^8 N for a particular bridge. This force acts in the direction shown so that its line of action is 26.0 m from the point about which the block might possibly rotate.

(i) Calculate the minimum mass of the block needed to prevent rotation, when the force exerted by the cable has its maximum value.

Taking moments about the point of rotation

$Mg\ (15) = 5.50 \times 10^8\ (26)$

$M = 9.7 \times 10^7$ kg

minimum mass = ... kg [2]

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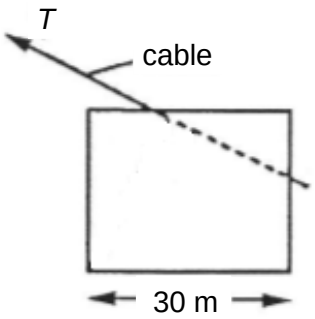
(ii) Draw on Fig. 2.4 the two other forces acting on the block under normal operating conditions (i.e. when the maximum force of the cable on the block is not at the maximum value). [3]



Weight at the geometrical centre pointing vertically downwards [1]
Normal contact force acting on the left half upwards [1] (application of ∑F=0)
All forces point towards a common point.[1]
(-1 overall if arrows are not drawn with rulers)

Fig. 2.4

[Total: 9]

3 **(a)** **(i)** By reference to the direction of propagation of energy, state how plane-polarised light differs from unpolarised light.

oscillations/vibrations (of all electric/magnetic vectors) of plane-polarised light in a single plane versus all possible planes for unpolarised light [B1]

plane perpendicular/normal to direction of energy transfer / wave propagation [B1] [2]

(ii) Explain why sound waves cannot be polarised.

Sound waves are longitudinal waves [B1] (which cannot be polarised as vibrations are parallel to direction of energy transfer / wave propagation) [1]

(b) Light from a laser incident normally on an ideal polarising filter. The polarising filter is slowly rotated about a horizontal axis that is parallel to the incident light as shown in Fig. 3.1.

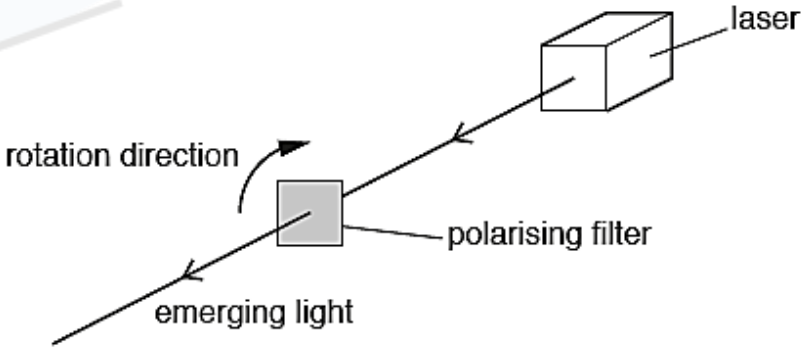


Fig. 3.1

It was observed that the intensity of the emerging light varies from I_o to 0.

(i) State what may be deduced from this observation.

Laser light is polarised [B1] [1]

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(ii) On Fig. 3.2, sketch a graph to show how the intensity of the emerging light may vary with the angle θ which the filter is rotated. [2]

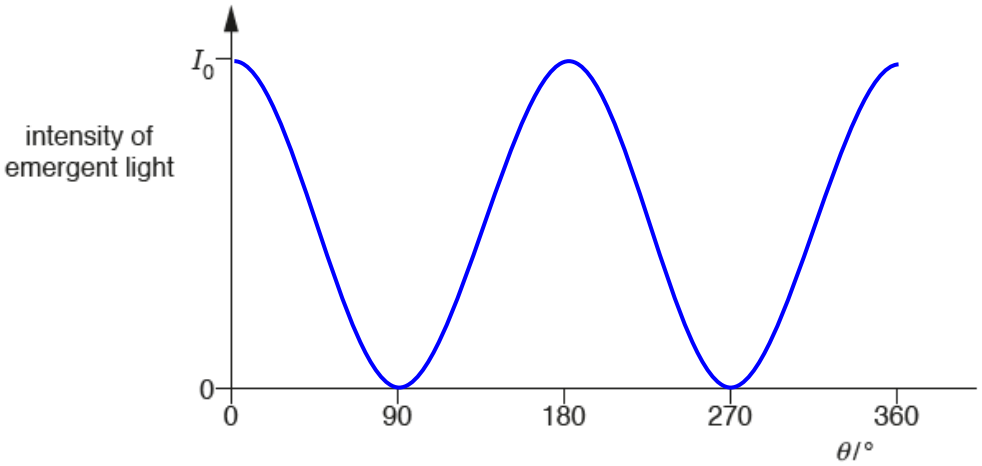

Fig. 3.2

sinusoidal square curve [B1]
2 complete cycles [B1]

(c) Fig. 3.3 shows a beam of sunlight that is reflected from a surface and passes through a vertical polarising filter.

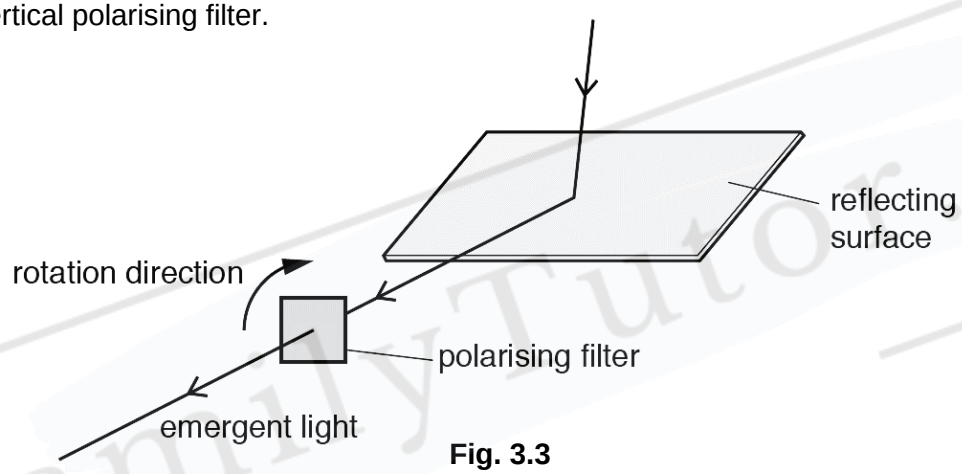

Fig. 3.3

The light that reflects from the surface is an unequal mixture of vertically polarised and horizontally polarised light.

When the polarising direction of the filter is vertical, the intensity of the emergent light is 0.262 I_o. When the polarising direction of the filter is horizontal, the intensity is 0.850 I_o.

Determine the intensity of the emergent light when the polarising direction of the filter is 30° from the vertical.

$\text{Intensity} = 0.262I_o \cos^2 30^\circ + 0.850I_o \sin^2 30^\circ$ [C1]

$= 0.409I_o$ [A1]

intensity = ... I_o [2]

[Total: 8]

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4 **(a)** Explain what is meant by a *field of force*.

A region (of space) where a force is experienced by a body.

.....[1]

(b) State **one** similarity and **one** difference between the fields produced by an isolated point charge and by an isolated point mass.

similarity: Both fields are pointing in radial direction or the strengths of both fields are inversely proportional to the square of distance from the source.

difference: For charge, the field can be away or toward the charge, but for mass, the field can only be toward the mass. Do not accept repulsive/attractive field/force/effects of field.

[2]

(c) An isolated solid metal sphere A of radius R has charge $+Q$, as illustrated in Fig. 4.1.

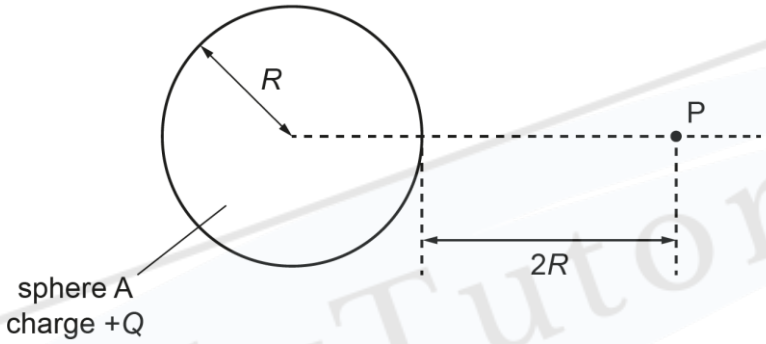

Fig. 4.1

A point P is distance $2R$ from the surface of the sphere.

Determine an expression that includes the terms R and Q for the electric field strength E at point P.

$E = \frac{Q}{4\pi\varepsilon_0 x^2} = \frac{Q}{4\pi\varepsilon_0 (3R)^2} = \frac{Q}{36\pi\varepsilon_0 R^2}$ [A1]

E = ... [1]

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(d) A second identical solid metal sphere B is now placed near sphere A. The centres of the spheres are separated by a distance 6*R*, as shown in Fig. 4.2.

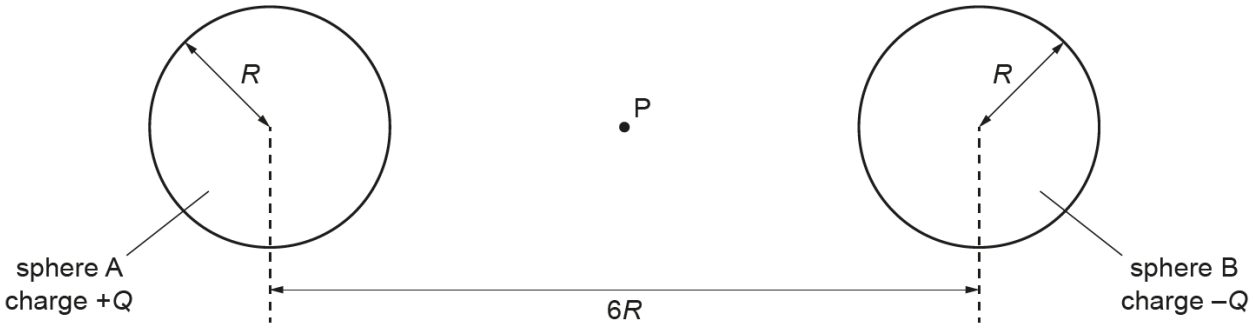

Fig. 4.2

Point P lies midway between spheres A and B.

Sphere B has charge –*Q*.

Explain why

(i) the magnitude of the electric field strength at P is given by the sum of the magnitudes of the field strengths due to each sphere.

The fields due to each sphere are in the same direction.

[1]

(ii) the electric field strength at point P due to the charged metal spheres is not, in practice, equal to 2*E*, where *E* is the electric field strength determined in **(c)**.

The charges on the spheres attract each other / charge distribution on each sphere distorted by the other sphere [B1]

The charges on the spheres does not appear to act from the centres of the spheres / distance between charges to P is not equal to 3*R* [B1]

[2]

[Total: 7]

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5 A battery of electromotive force (e.m.f.) 8.0 V and internal resistance 2.0 Ω is connected to a resistor X and a wire Y, as shown in Fig. 5.1.

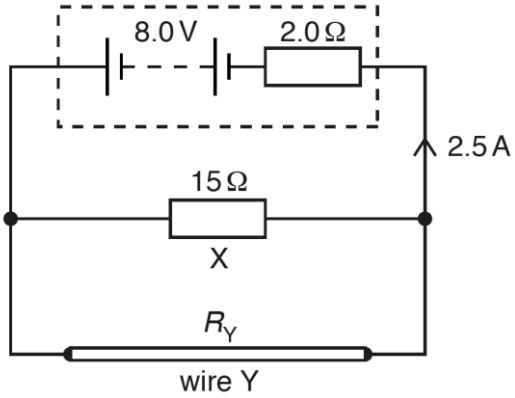

Fig. 5.1

The resistance of X is 15 Ω. The resistance of Y is R_Y. The current in the battery is 2.5 A.

(a) Calculate

(i) the thermal energy dissipated in the battery in a time of 5.0 minutes,

$E = I^2rt = (2.5)^2(2.0)(5 \times 60)$ [C1]
$= 3750 = 3800$ J [A1]

energy = ... J [2]

(ii) the terminal potential difference of the battery.

$V_t = E - Ir = 8.0 - 2.5(2.0) = 3.0$ V [A1]

terminal potential difference = ... V [1]

(b) Determine the resistance R_Y.

$V_t = IR_{//}$
$3.0 = 2.5R_{//}$
$R_{//} = 1.2\ \Omega$ [C1]
$1.2 = (\frac{1}{15} + \frac{1}{R_Y})^{-1}$ [C1]
$R_Y = 1.30 = 1.3\ \Omega$ [A1]

$V_t = I_{15}R_{15}$
$3.0 = I_{15}(15)$
$I_{15} = 0.20$ A [C1]
$I_Y = 2.5 - 0.20 = 2.30$ A [C1]
$R_Y = \frac{3.0}{2.30} = 1.3\ \Omega$ [A1]

R_Y = ... Ω [3]

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(c) Wire Y is replaced in the circuit by a new wire Z which has less resistance than wire Y. By considering the current in the battery, state and explain the effect of changing the wires on the total power produced by the battery.

The current in the battery increases [M1]

hence power produced by the battery increases too. [A1]

[2]

[Total: 8]

6 **(a)** Define *magnetic flux*.

The magnetic flux through a plane surface is the product of the component of the magnetic flux density normal to the surface and the area of the surface.

product of magnetic flux density and area [B1]

component of B normal to surface of area [B1]

[2]

(b) A solenoid has a coil C of wires wound tightly about its centre, as shown in Fig. 6.1.

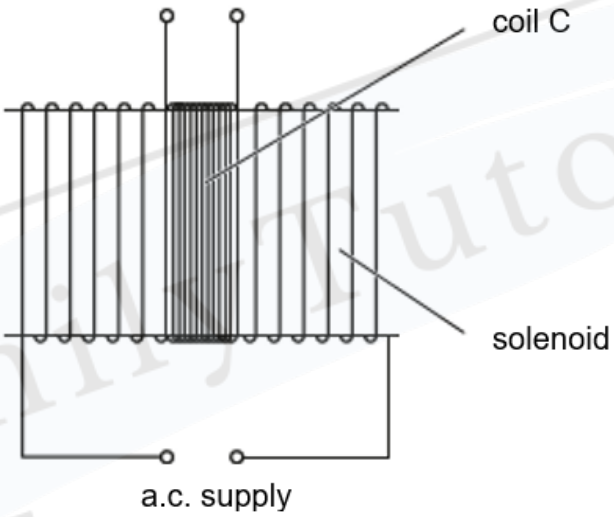

Fig. 6.1

Coil C has 86 turns.

The uniform magnetic flux Φ (in weber) in the solenoid is given by the expression

$$\Phi = 6.8 \times 10^{-6} \times I$$

where I is the current in the solenoid.

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The variation with time t of the current I in the solenoid by the a.c. supply is shown in Fig. 6.2.

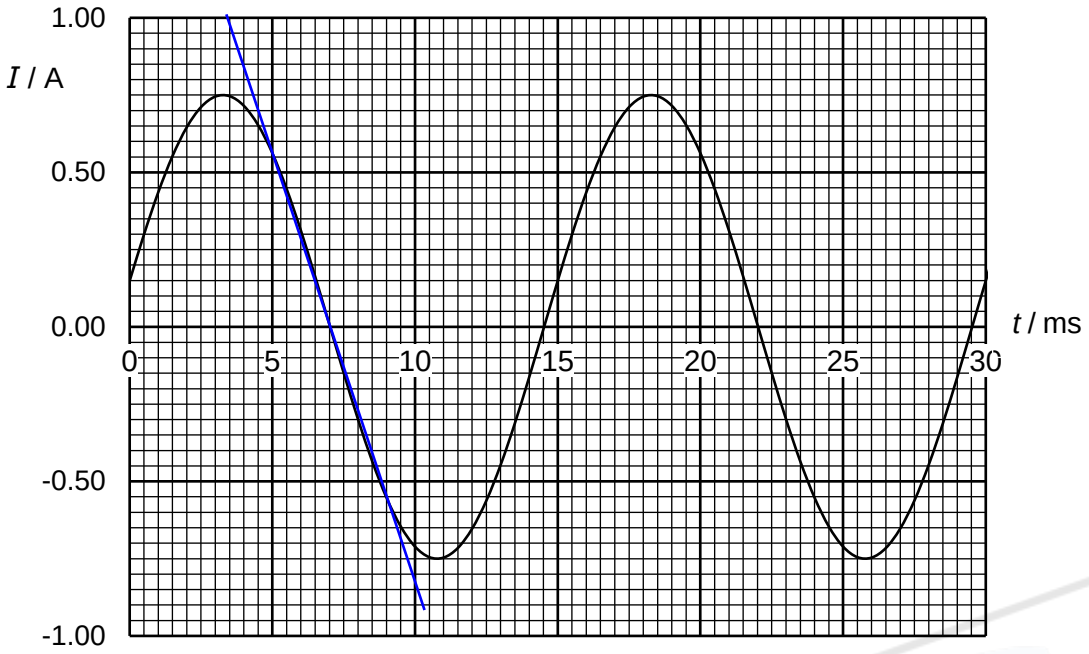

Fig. 6.2

(i) Explain how electromotive force (e.m.f.) is induced in coil C.

As the current passes through the solenoid varies periodically, it sets up a periodical magnetic flux around the solenoid. An e.m.f. proportional to the rate of change of magnetic flux linkage across coil C will be induced in coil C.

[2]

(ii) Use Fig. 6.2 to determine the maximum e.m.f. induced in coil C.

$$|\varepsilon_{max}| = N\left|\frac{d\Phi}{dt}\right|_{max}$$

$$= 86 \times 6.8 \times 10^{-6} \times \left|\frac{1.00-(-0.80)}{(3.5-10)\times 10^{-3}}\right|$$

$$= 0.16 \text{ V}$$

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

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(iii) The a.c supply is changed to a non-sinusoidal periodic wave as shown in Fig. 6.3.

On Fig. 6.3, draw the corresponding e.m.f. that is induced in coil C.

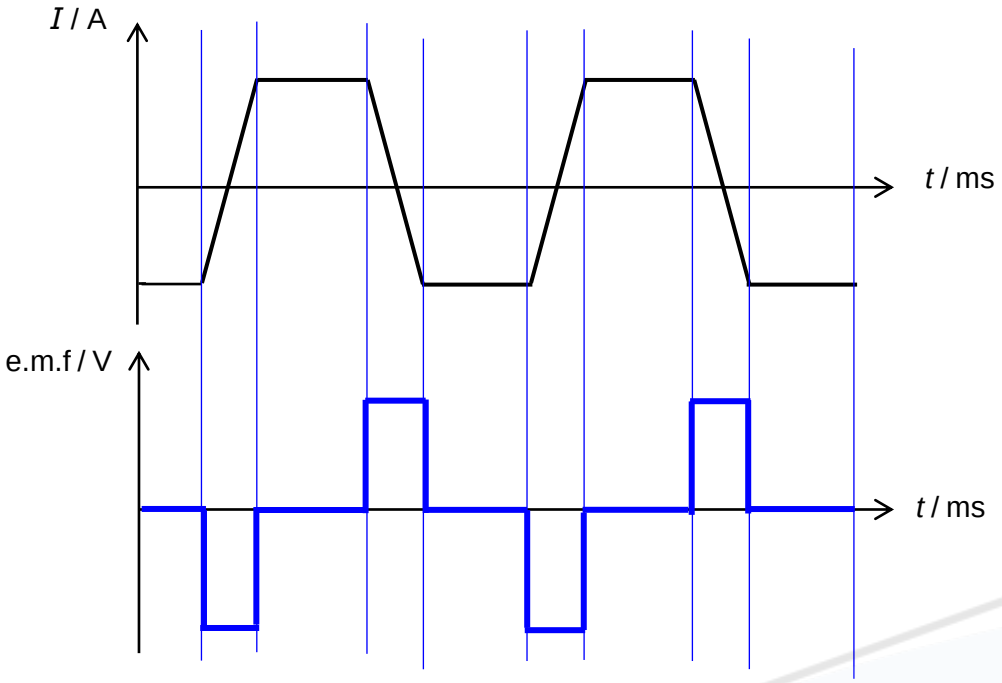

Fig. 6.3

[2]

[Total: 8]

7 **(a)** The radioactive isotope of Bismuth $^{210}_{83}$Bi decays into Polonium (chemical symbol: Po) with the emission of a beta particle.

(i) State the origin of the beta particle.

Beta particle is emitted from the nucleus OR

Transmutation from one neutron in Bi : $^{1}_{0}n \rightarrow {}^{1}_{1}H + {}^{0}_{-1}\beta$ [B1] [1]

(ii) Write down the equation representing the beta decay of $^{210}_{83}$Bi .

$^{210}_{83}Bi \rightarrow {}^{0}_{-1}\beta + {}^{210}_{84}Po$ [A1] [1]

(iii) State two quantities that are conserved in any radioactive decay process.

1. total momentum/ total mass-energy/ total nucleon no/ total atomic no/ total charge/ proton no.
2. ~~Don't accept no of proton/electrons~~

[2]

Any two. [A2]

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(iv) The mass of a $^{210}_{83}Bi$ nucleus is 209.939*u*. Show that its mass defect is 1.767 *u*. (mass of proton, m_p = 1.00729 *u*; mass of neutron, m_n = 1.00867 *u*)

Mass of protons + neutrons = [(83 x 1.00729) + (127 x 1.00867)]

= 211.706 u [M1]

Mass defect = 211.706 u - 209.939 u [M1]

Mass defect = 1.767 u [A0]

[2]

(v) Calculate the binding energy per nucleon, in MeV, of $^{210}_{83}Bi$.

Binding energy = $1.767 \times 1.66 \times 10^{-27} \times (3 \times 10^{-8})^2 = 2.64 \times 10^{-10}$ J [M1]

Binding energy per nucleon = $[2.64 \times 10^{-10} / 1.6 \times 10^{-19} \times 10^6]/210$ = 7.86 MeV [A1]

binding energy per nucleon = ... MeV [2]

(b) Fig. 7.1 shows the energy spectrum for beta particles emitted during the decay of $^{210}_{83}Bi$. The intensity indicates the number of beta particles emitted with each particular kinetic energy.

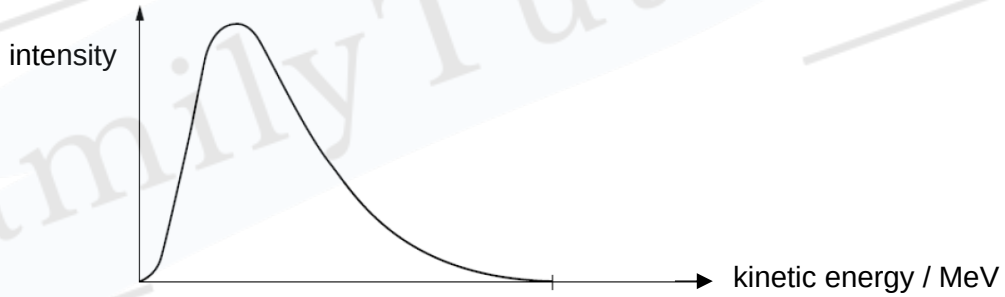

Fig. 7.1

Explain how a consideration of this kinetic energy spectrum provide evidence for the prediction of the existence of the antineutrino.

There is a range of energies.

Energy per decay is constant due to conservation of energy.[B1]

Antineutrino has the remaining energy. [B1]

.....

.....

.....[2]

[Total: 10]

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

Stars

Stars are formed from the gravitational collapse of gas clouds called nebulae. Gravitational potential energy is converted to internal energy of hot gases which emit electromagnetic radiation. Thus, the search for new stars usually involves the use of infra-red telescopes in space.

Once the core of a young star is hot enough to initiate hydrogen fusion, it is called a main sequence star. Such stars are stable, lasting for millions or billions of years. One example is our Sun, which produces energy when hydrogen nuclei fuse into stable helium nuclei in the stellar core. The temperature at the core is very high, typically 10^8 K or greater! Here, a process known as the proton-proton cycle begins, releasing energy. This three-stage process can be summarised in a single equation:

$$4\,{}^1_1\mathrm{H} \rightarrow {}^4_2\mathrm{He} + 2\,{}^0_1\mathrm{e} + 2\upsilon + \text{energy}\,.$$

Our Sun is 1.51×10^{11} m from Earth, and it radiates energy uniformly through space with a mean intensity of radiation reaching the Earth's atmosphere of 1.34 kW m^{-2}. Hence, the Sun radiates a power of 3.8×10^{26} W. This is also equal to its luminosity, which is defined as the total power radiated by a star.

While hydrogen fusion supplies the energy stars require to maintain energy balance over its life span, this has little effect to the change in mass of the star. Even after five billion years, the Sun is very nearly the same mass as it is now!

We can estimate the surface temperature of a star from its colour. A body that is at a higher temperature than its surroundings emit electromagnetic radiation. The variation of intensity of the emitted radiation with wavelength λ is shown in Fig. 8.1.

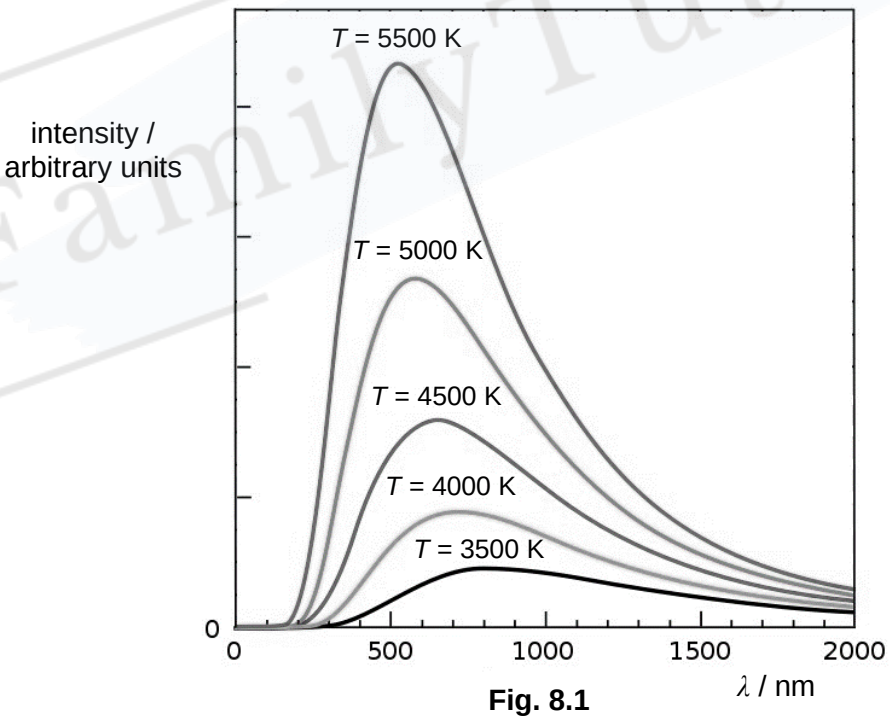

Fig. 8.1

The intensity distribution is different at different surface temperatures. At any temperature T, there is a peak corresponding to a wavelength λ_{max} for maximum intensity. Theory states that

$$\lambda_{max} T = \text{constant}\,.$$

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For example, at $T = 3500$ K, the intensity distribution spans the visible and infra-red wavelengths, with λ_{max} occurring at the red end of the visible spectrum. Since our eyes can only see in the visible spectrum, the object appears red-hot.

As the temperature of a body increases, the total emitted power also increases. It is known that the luminosity L of a star is related to its surface area A and its temperature T (in kelvins) as follows:

$$L \propto AT^4 .$$

When observing stars, astronomers rely on a phenomenon called the Doppler effect of light. The Doppler effect is more relatable to us with sound waves. Whenever there is relative motion between a wave source and an observer, the frequency noted by the observer is different from the actual frequency of the waves. We would have experienced the Doppler effect, such as when the frequency of the sirens change from higher pitch to lower pitch as an ambulance passes by. The higher pitch heard in front of the moving source is due to the 'bunching up' of wave crests as shown in Fig. 8.2. The reverse occurs for the observer behind the source.

Fig. 8.2

When light emitted from a distant star is passed through a diffraction grating, it is found that each line in the absorption spectrum from hydrogen gas occurs at a different wavelength from that of the corresponding line in the spectrum obtained in the laboratory. The Doppler effect is evident in Fig. 8.3. With some stars, all the spectral lines are shifted to longer wavelengths (red shifted), while with other stars, the lines are shifted to shorter wavelengths (blue shifted). Thus, hydrogen spectral lines provide important information about the motion of a star.

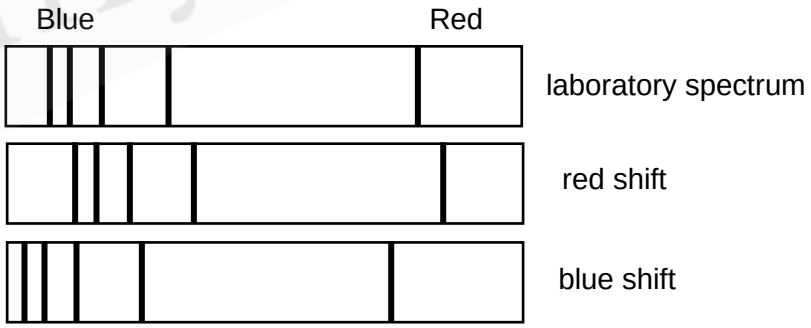

Fig. 8.3

Using the Doppler effect together with the hydrogen spectral lines is extremely important in the detection of binary stars. This method of detection is known as spectroscopic binary. Over four-fifths of the single spots of light we see in the night sky are two or more stars revolving around each other. Binary stars, which consist of only two stars, are the most common star systems. An example would be Sirius-A and Sirius-B. However, when two stars are close together, they appear visually as a single star when viewed with a telescope.

Since binary stars rotate about their common centre of mass, when one star is approaching Earth, the other must be moving away. Analysis of the spectral lines could reveal information that there are, in fact, two stars.

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(a) Suggest one advantage of placing telescopes in space to observe new stars.

Radiation / light not absorbed or scattered by the atmosphere / no turbulence of atmosphere [B1]

so image not distorted [A0]

[1]

(b) Explain why very high temperatures are necessary for fusion reactions to occur in stars.

Protons / Nuclei will repel each other [B1]

At high temperatures, particles have large kinetic energies to do work against (electrostatic) repulsion and get close (and fuse) [B1]

[2]

(c) **(i)** Show that the total power radiated by the Sun is 3.8×10^{26} W.

$P = I \times A$

$= 1340 \times 4\pi \left(1.51 \times 10^{11}\right)^2$ [C1]

$= 3.839 \times 10^{26}$ W

$\approx 3.8 \times 10^{26}$ W [A0]

[1]

(ii) Use the data below to calculate the number of fusion reactions occurring in the Sun each second. Assume all the radiated energy from the Sun comes from the fusion reaction.

mass of electron = 0.000549 *u*

mass of proton = 1.007276 *u*

mass of helium-4 nucleus = 4.001506 *u*

$$\text{energy released per reaction} = \left(\sum M_{\text{reactants}} - \sum M_{\text{products}}\right) \times c^2$$
$$= \left(4 \times 1.007276u - 4.001506u - 2 \times 0.000549u\right) \times c^2 \quad \text{[M1]}$$
$$= 0.0265u \times c^2$$
$$= 3.9591 \times 10^{-12} \text{ J}$$

$$\text{No. of reactions per second} = \frac{3.8 \times 10^{26}}{3.9591 \times 10^{-12}} \quad \text{[M1]}$$
$$= 9.60 \times 10^{37} \quad \text{[A1]}$$

number of reactions per second = 9.60×10^{37} [3]

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(iii) The present mass of the Sun is 2.0×10^{30} kg. In about another five billion years, the core of the Sun will be depleted of hydrogen.

Calculate the percentage decrease in the mass of the Sun when the core is depleted of hydrogen. Justify whether your calculation agrees with the claim in the passage.

mass lost per second $= 9.60 \times 10^{37} \times 0.0265u = 4.22 \times 10^{9}$ kg s^{-1} [M1] ecf their no. of reaction

OR $\Delta m = \dfrac{3.8 \times 10^{26}}{\left(3.0 \times 10^{8}\right)^2} = 4.22 \times 10^{9}$ kg s^{-1}

$$\text{percentage decrease} = \frac{\left(4.22 \times 10^{9}\right) \times \left(5 \times 10^{9}\right) \times \left(365 \times 24 \times 3600\right)}{2.0 \times 10^{30}} \times 100\%$$

$= 0.033\%$ [A1]

percentage decrease = 0.033 %

As the percentage decrease in mass is very small, hydrogen fusion has little effect on the mass of the Sun [A0]

[2]

(d) Fig. 8.4 shows some data about our Sun and Sirius-A, one of the binary stars mentioned.

	Sun	Sirius-A
Radius / m	R	1.7R
Luminosity / W	L	25L
Surface temperature / K	5800	
Wavelength λ_{max} at maximum intensity / nm	500	

Fig. 8.4

(i) Calculate the surface temperature T of Sirius-A.

$L \propto AT^4$

$\dfrac{L}{25L} = \dfrac{4\pi R^2 \times 5800^4}{4\pi \left(1.7R\right)^2 \times T^4}$ [C1]

$T^4 = 9.79 \times 10^{15}$

$T = 9950$ K [A1]

T = 9950 K [2]

(ii) Use data from Fig. 8.1 to verify the theory that

$$\lambda_{max} T = \text{constant}.$$

At least 3 results verified [B2], if only 2 results [B1]

$k_1 = \left(775 \times 10^{-9}\right)(3500) = 0.0027$

$k_2 = \left(700 \times 10^{-9}\right)(4000) = 0.0028$

$k_3 = \left(650 \times 10^{-9}\right)(4500) = 0.0029$

$k_4 = \left(575 \times 10^{-9}\right)(5000) = 0.0029$

$k_5 = \left(500 \times 10^{-9}\right)(5500) = 0.0028$

Since the constants are about the same value, the theory is verified.

[2]

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(iii) Use information from Fig. 8.4 and your answer in **(d)(i)** to determine the wavelength λ_{max} for which maximum intensity occurs from Sirius-A.

$\lambda_{max} T = \text{constant}$

$500 \times 5800 = \lambda_{max} \times 9950$ [C1]

$\lambda_{max} = 291 \text{ nm}$ [A1]

λ_{max} = 291 nm [2]

(iv) By considering your answer in **(d)(iii)**, suggest why Sirius-A appears as a bluish star to an astronomer using an optical telescope.

Wavelength for maximum intensity (band) closer to the blue end of visible spectrum [B1]

NOT 291 nm is blue light.

[1]

(e) Fig. 8.5 shows the visible part of the absorption spectrum from hydrogen gas in a laboratory on the Earth and the same part of the absorption spectrum observed in light from a star in a distant galaxy. The numbers indicate the wavelengths in nanometres (nm).

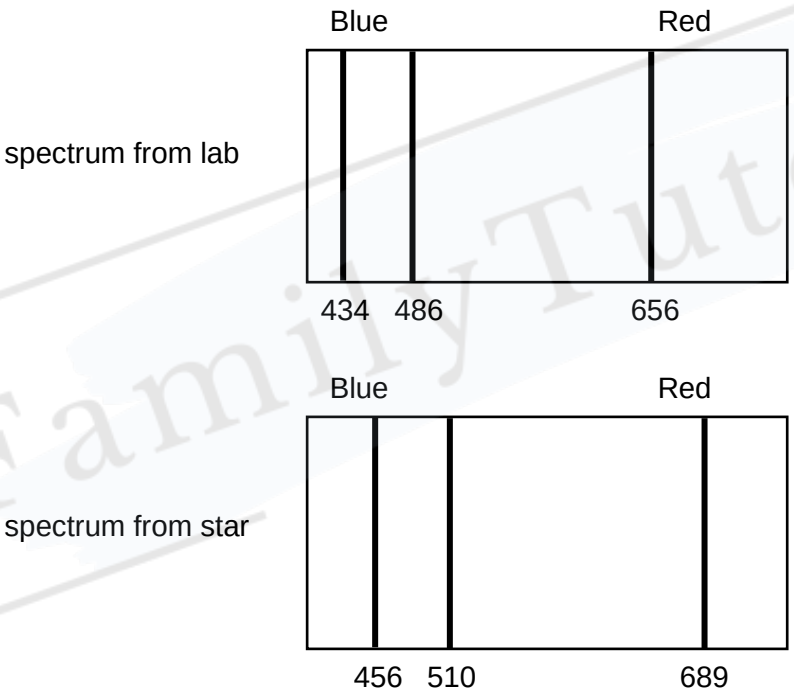

Fig. 8.5 (not to scale)

(i) Compare the line spectra and state what this shows about the motion of the star.

Spectral lines show evidence of red shift OR shifts to longer wavelengths [B1]

so star must be moving away from Earth/observer [B1]

[2]

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(ii) Use Fig. 8.5 to calculate the percentage change in the wavelength of a spectral line observed with light from the star compared with a corresponding spectral line observed in the laboratory.

Any corresponding % change calculated [A1]

$$\frac{\Delta\lambda}{\lambda}\times 100\% = \frac{689-656}{656}\times 100\% = 5.0\%$$
$$\frac{\Delta\lambda}{\lambda}\times 100\% = \frac{510-486}{486}\times 100\% = 4.9\%$$
$$\frac{\Delta\lambda}{\lambda}\times 100\% = \frac{456-434}{434}\times 100\% = 5.1\%$$

percentage change = 4.9 to 5.1 % [1]

(f) (i) Apart from two binary stars being too close together, use Rayleigh's criterion to state another reason why the stars could appear as a single image as seen with a telescope.

Stars are too far away from Earth / telescope diameter is too small [B1]

.....[1]

(ii) Suggest how hydrogen spectral lines might provide astronomers with information that a star is part of a binary star system.

Assume that the observed star has similar brightness as its binary counterpart and viewed from Earth in the plane of their orbits.

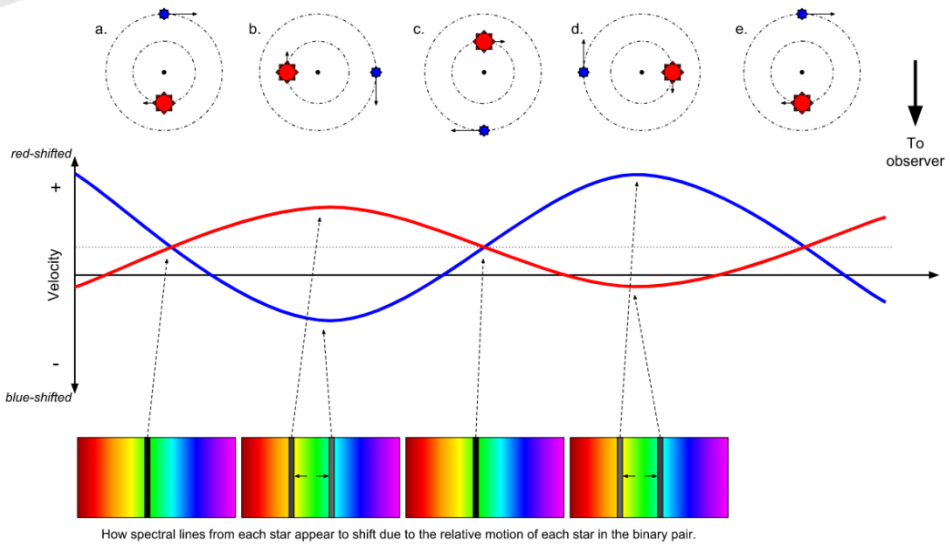
There would be 2 sets of spectral lines (one for each star) [B1]

Lines would have periodic shifts in wavelengths (as each star moves periodically towards and then away from Earth) [B1]

.....[2]

[Total: 22]

End of Paper



How spectral lines from each star appear to shift due to the relative motion of each star in the binary pair.

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Paper 2 Structured Questions **14 September 2023**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

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

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

For Examiner's Use	
1	/ 8
2	/ 9
3	/ 8
4	/ 7
5	/ 8
6	/ 8
7	/ 10
8	/ 22
Total	/ 80

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Data

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

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / ^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 Fig. 1.1 shows the variation of velocity v with time t for a fuel-propelled model rocket travelling upwards.

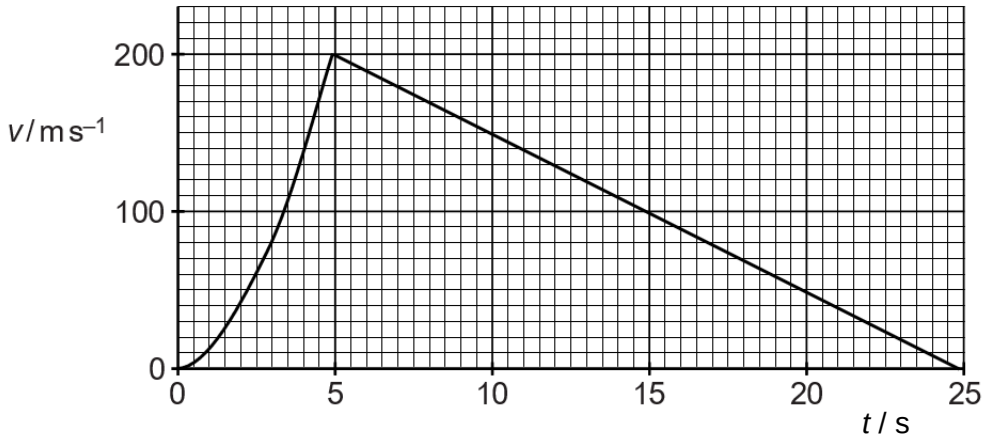

Fig. 1.1

(a) (i) Define *acceleration*.

.....[1]

(ii) State the time interval when the rocket has the greatest acceleration.

between t = ... s to t = ... s [1]

(iii) Explain why the acceleration of the rocket increases between t = 0 to t = 5.0 s.

.....

.....

.....[1]

(b) (i) Suggest a reason for the abrupt change in the motion of the rocket at t = 5.0 s.

.....

.....[1]

(ii) Explain how it can be deduced from Fig. 1.1 that air resistance has a negligible effect on the motion of the rocket.

.....

.....

.....

.....[2]

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(c) Use Fig. 1.1 to determine the maximum height reached by the rocket.

height = ... m [2]

[Total: 8]

2 **(a)** State the *principle of moments*.

.....

.....[1]

(b) Fig. 2.1 shows part of a cable-stayed bridge. Each section of the bridge is supported by eight equally spaced cables that pass through a central supporting pillar.

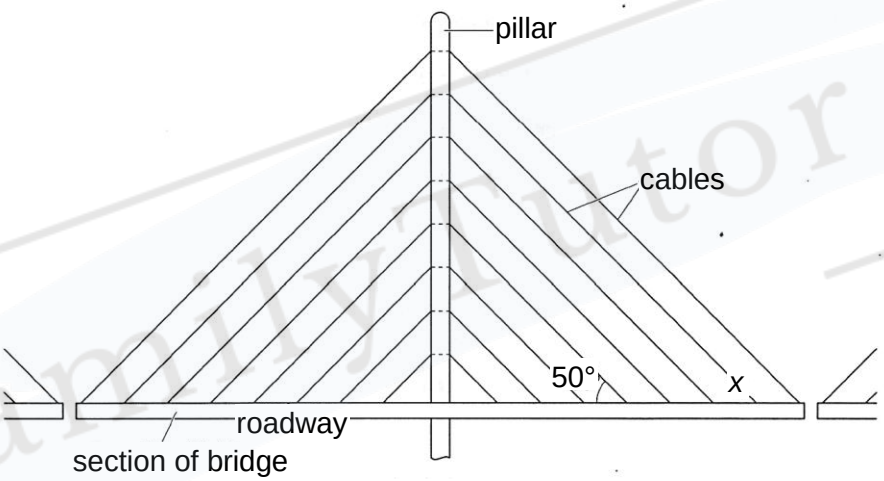

Fig. 2.1 (not to scale)

The cables are at an angle of 50° to the horizontal and the maximum tension allowed in each cable is 7.8×10^5 N.

(i) The mass of the roadway in this section is 350 tonnes (1 tonne = 1000 kg).
Calculate the maximum mass of traffic that is allowed on this section of the roadway.

mass = ... kg [2]

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(ii) Suggest a reason why the maximum tension allowed in each cable is well below the breaking tension.

.....

.....

.....[1]

(c) Fig. 2.2 shows a suspension bridge. The cables of the bridge are anchored into large free-standing anchor blocks of concrete.

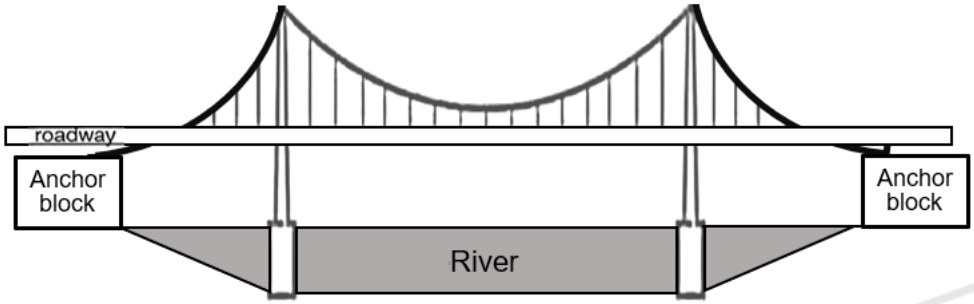

Fig. 2.2

The anchor block on the right is shown on a larger scale in Fig. 2.3. It has a length of 30.0 m and its cross-section and density are uniform.

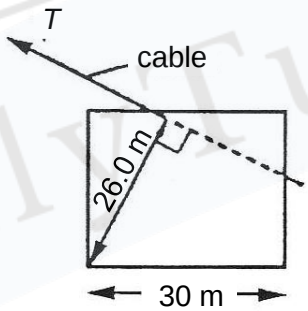

Fig. 2.3

This block is standing on the ground. The maximum force which the cables could exert on this block is 5.50×10^8 N for a particular bridge. This force acts in the direction shown so that its line of action is 26.0 m from the point about which the block might possibly rotate.

(i) Calculate the minimum mass of the block needed to prevent rotation, when the force exerted by the cable has its maximum value.

minimum mass = ... kg [2]

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(ii) Draw on Fig. 2.4 the two other forces acting on the block under normal operating conditions (i.e. when the maximum force of the cable on the block is not at the maximum value). [3]

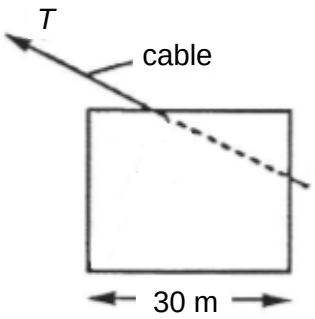

Fig. 2.4

[Total: 9]

3 **(a)** **(i)** By reference to the direction of propagation of energy, state how plane-polarised light differs from unpolarised light.

.....

.....

.....[2]

(ii) Explain why sound waves cannot be polarised.

.....

.....[1]

(b) Light from a laser incident normally on an ideal polarising filter. The polarising filter is slowly rotated about a horizontal axis that is parallel to the incident light as shown in Fig. 3.1.

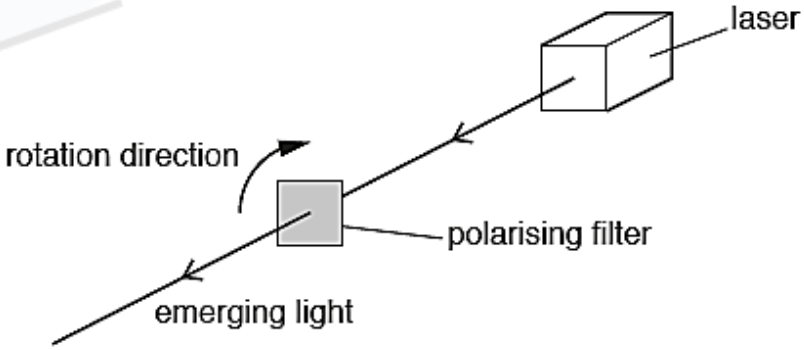

Fig. 3.1

It was observed that the intensity of the emerging light varies from I_o to 0.

(i) State what may be deduced from this observation.

.....[1]

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(ii) On Fig. 3.2, sketch a graph to show how the intensity of the emerging light may vary with the angle θ which the filter is rotated. [2]

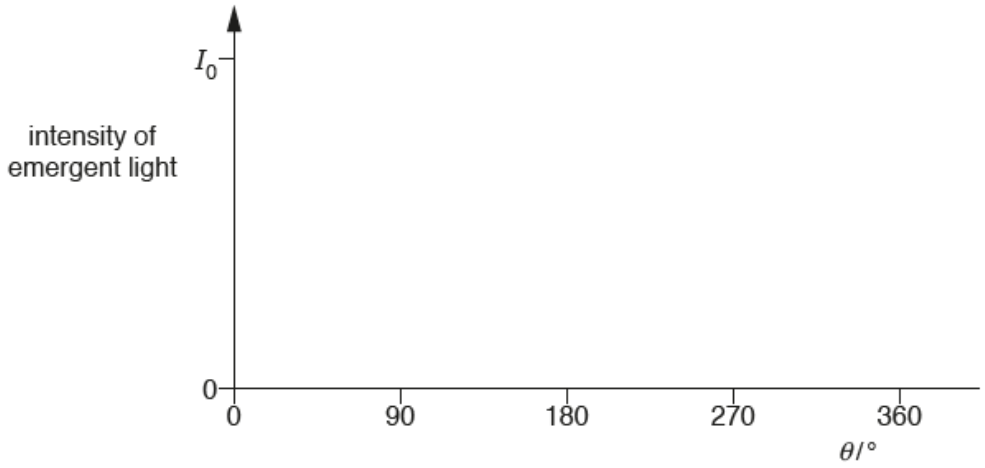

Fig. 3.2

(c) Fig. 3.3 shows a beam of sunlight that is reflected from a surface and passes through a vertical polarising filter.

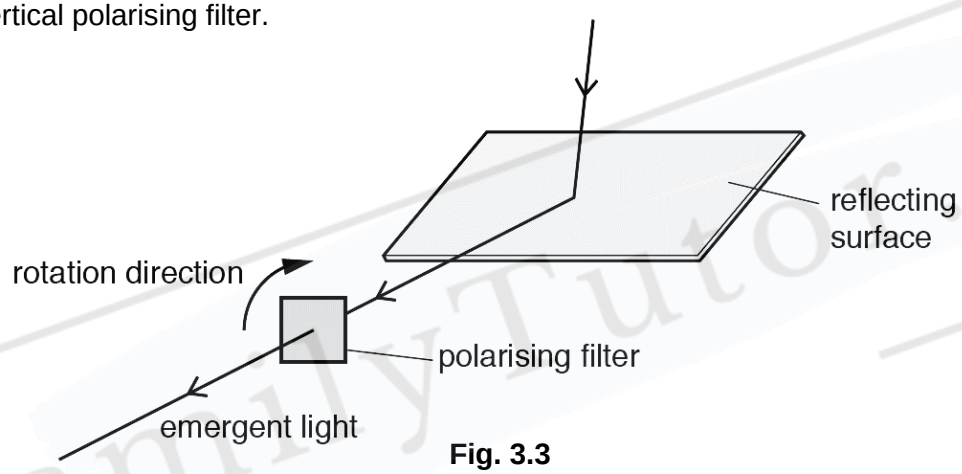

Fig. 3.3

The light that reflects from the surface is an unequal mixture of vertically polarised and horizontally polarised light.

When the polarising direction of the filter is vertical, the intensity of the emergent light is 0.262 I_o. When the polarising direction of the filter is horizontal, the intensity is 0.850 I_o.

Determine the intensity of the emergent light when the polarising direction of the filter is 30° from the vertical.

intensity = ... I_o [2]

[Total: 8]

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4 **(a)** Explain what is meant by a *field of force*.

.....

.....[1]

(b) State **one** similarity and **one** difference between the fields produced by an isolated point charge and by an isolated point mass.

similarity: .....

.....

difference: .....

.....

[2]

(c) An isolated solid metal sphere A of radius *R* has charge +*Q*, as illustrated in Fig. 4.1.

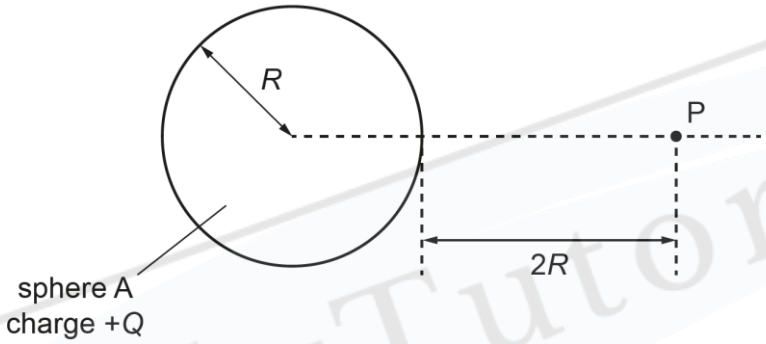

Fig. 4.1

A point P is distance 2*R* from the surface of the sphere.

Determine an expression that includes the terms *R* and *Q* for the electric field strength *E* at point P.

E = ... [1]

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(d) A second identical solid metal sphere B is now placed near sphere A. The centres of the spheres are separated by a distance 6*R*, as shown in Fig. 4.2.

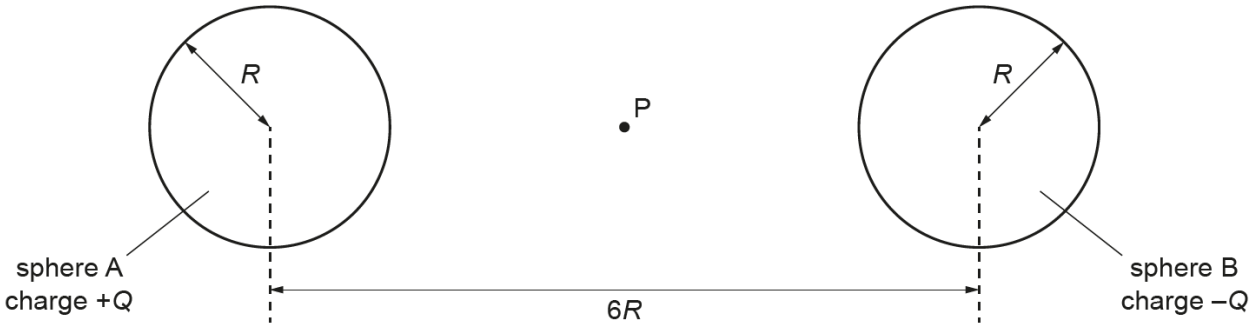

Fig. 4.2

Point P lies midway between spheres A and B.

Sphere B has charge –*Q*.

Explain why

(i) the magnitude of the electric field strength at P is given by the sum of the magnitudes of the field strengths due to each sphere.

.....

.....[1]

(ii) the electric field strength at point P due to the charged metal spheres is not, in practice, equal to 2*E*, where *E* is the electric field strength determined in **(c)**.

.....

.....

.....

.....[2]

[Total: 7]

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5 A battery of electromotive force (e.m.f.) 8.0 V and internal resistance 2.0 Ω is connected to a resistor X and a wire Y, as shown in Fig. 5.1.

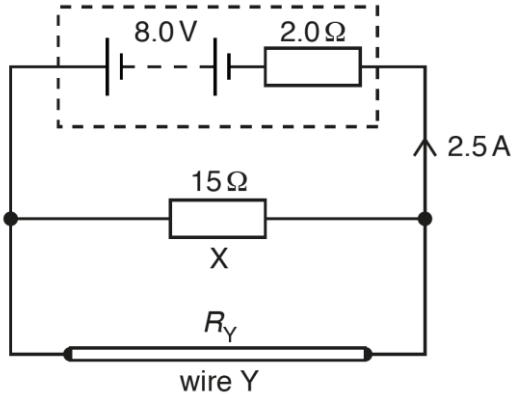

Fig. 5.1

The resistance of X is 15 Ω. The resistance of Y is R_Y. The current in the battery is 2.5 A.

(a) Calculate

(i) the thermal energy dissipated in the battery in a time of 5.0 minutes,

energy = ... J [2]

(ii) the terminal potential difference of the battery.

terminal potential difference = ... V [1]

(b) Determine the resistance R_Y.

R_Y = ... Ω [3]

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(c) Wire Y is replaced in the circuit by a new wire Z which has less resistance than wire Y. By considering the current in the battery, state and explain the effect of changing the wires on the total power produced by the battery.

.....

.....

.....[2]

[Total: 8]

6 **(a)** Define *magnetic flux*.

.....

.....

.....[2]

(b) A solenoid has a coil C of wires wound tightly about its centre, as shown in Fig. 6.1.

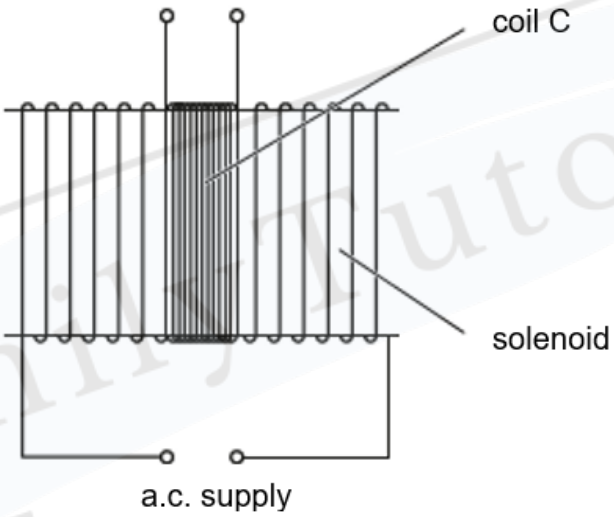

Fig. 6.1

Coil C has 86 turns.

The uniform magnetic flux Φ (in weber) in the solenoid is given by the expression

$$\Phi = 6.8 \times 10^{-6} \times I$$

where I is the current in the solenoid.

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The variation with time t of the current I in the solenoid by the a.c. supply is shown in Fig. 6.2.

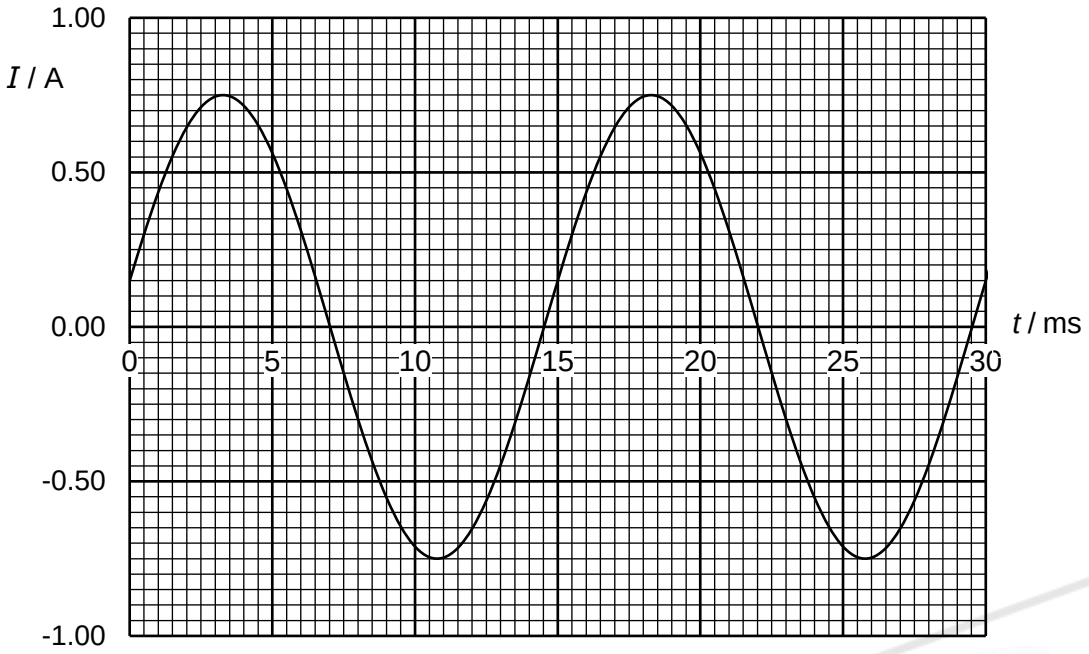

Fig. 6.2

(i) Explain how electromotive force (e.m.f.) is induced in coil C.

.....

.....

.....

.....[2]

(ii) Use Fig. 6.2 to determine the maximum e.m.f. induced in coil C.

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

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(iii) The a.c supply is changed to a non-sinusoidal periodic wave as shown in Fig. 6.3.

On Fig. 6.3, draw the corresponding e.m.f. that is induced in coil C.

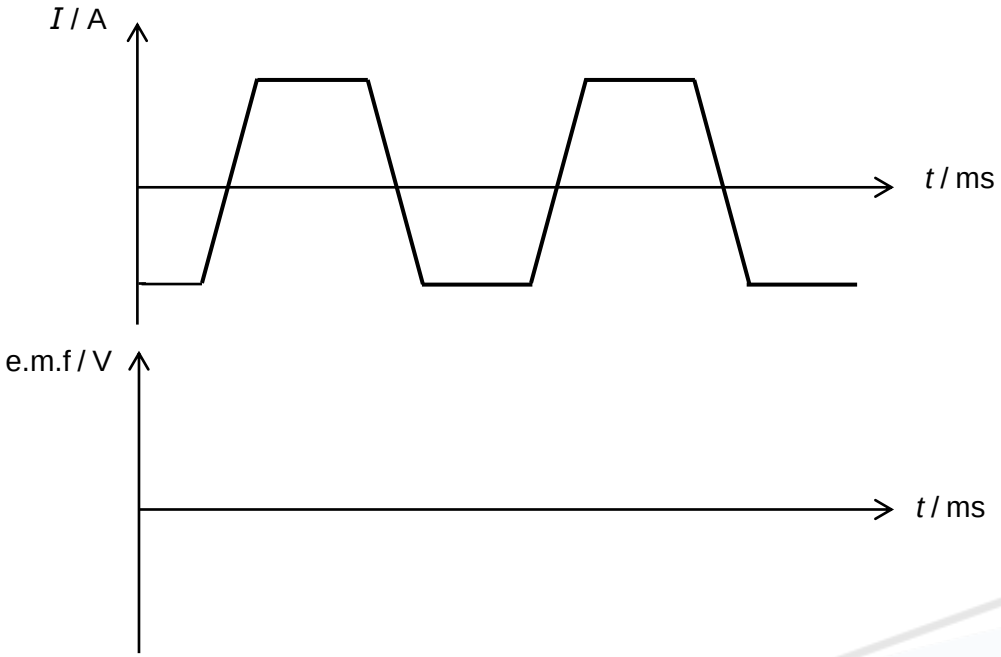

Fig. 6.3

[2]

[Total: 8]

7 **(a)** The radioactive isotope of Bismuth $^{210}_{83}Bi$ decays into Polonium (chemical symbol: Po) with the emission of a beta particle.

(i) State the origin of the beta particle.

.....

.....[1]

(ii) Write down the equation representing the beta decay of $^{210}_{83}Bi$.

.....[1]

(iii) State two quantities that are conserved in any radioactive decay process.

1. .....

2. .....

[2]

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(iv) The mass of a $^{210}_{83}Bi$ nucleus is 209.939 *u*. Show that its mass defect is 1.767 *u*.
(mass of proton, m_p = 1.00729 *u*; mass of neutron, m_n = 1.00867 *u*)

[2]

(v) Calculate the binding energy per nucleon, in MeV, of $^{210}_{83}Bi$.

binding energy per nucleon = ... MeV [2]

(b) Fig. 7.1 shows the energy spectrum for beta particles emitted during the decay of $^{210}_{83}Bi$. The intensity indicates the number of beta particles emitted with each particular kinetic energy.

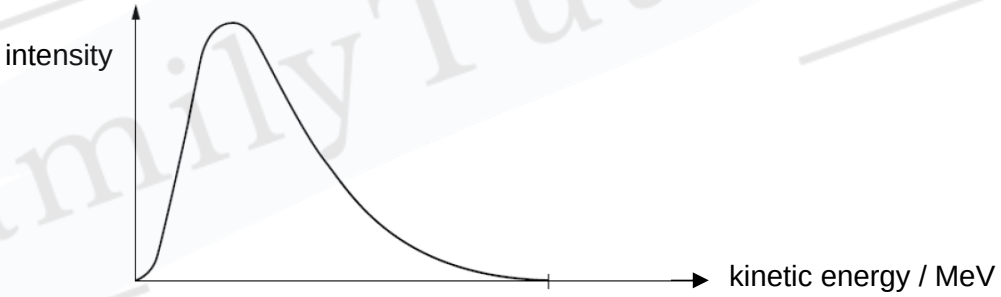

Fig. 7.1

Explain how a consideration of this kinetic energy spectrum provide evidence for the prediction of the existence of the antineutrino.

.....

.....

.....

.....

.....[2]

[Total: 10]

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

Stars

Stars are formed from the gravitational collapse of gas clouds called nebulae. Gravitational potential energy is converted to internal energy of hot gases which emit electromagnetic radiation. Thus, the search for new stars usually involves the use of infra-red telescopes in space.

Once the core of a young star is hot enough to initiate hydrogen fusion, it is called a main sequence star. Such stars are stable, lasting for millions or billions of years. One example is our Sun, which produces energy when hydrogen nuclei fuse into stable helium nuclei in the stellar core. The temperature at the core is very high, typically 10^8 K or greater! Here, a process known as the proton-proton cycle begins, releasing energy. This three-stage process can be summarised in a single equation:

$$4\,{}^1_1\mathrm{H} \rightarrow {}^4_2\mathrm{He} + 2\,{}^0_1\mathrm{e} + 2\upsilon + \text{energy}\,.$$

Our Sun is 1.51×10^{11} m from Earth, and it radiates energy uniformly through space with a mean intensity of radiation reaching the Earth's atmosphere of 1.34 kW m^{-2}. Hence, the Sun radiates a power of 3.8×10^{26} W. This is also equal to its luminosity, which is defined as the total power radiated by a star.

While hydrogen fusion supplies the energy stars require to maintain energy balance over its life span, this has little effect to the change in mass of the star. Even after five billion years, the Sun is very nearly the same mass as it is now!

We can estimate the surface temperature of a star from its colour. A body that is at a higher temperature than its surroundings emit electromagnetic radiation. The variation of intensity of the emitted radiation with wavelength λ is shown in Fig. 8.1.

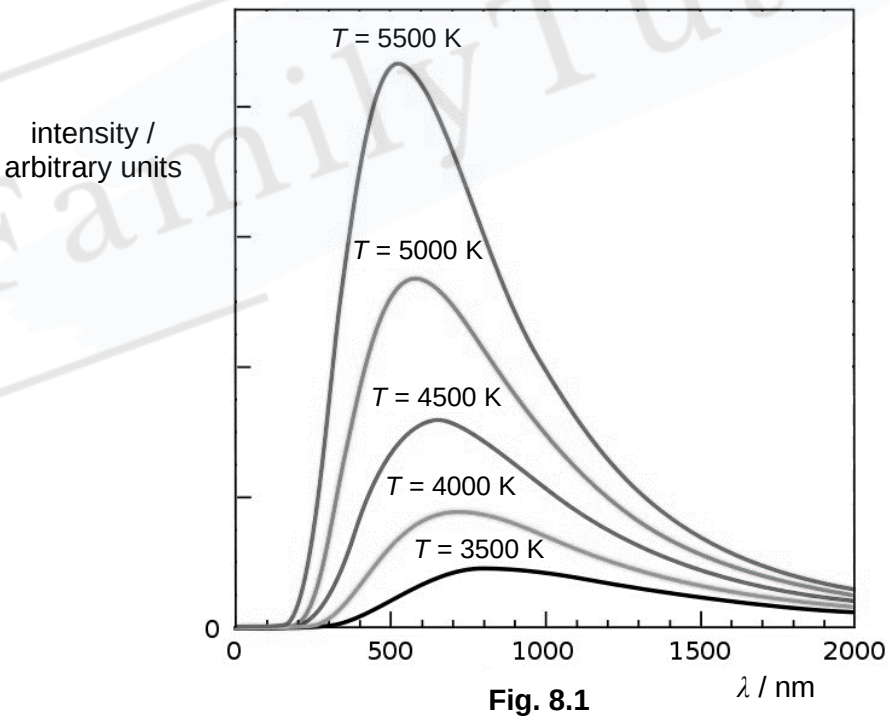

Fig. 8.1

The intensity distribution is different at different surface temperatures. At any temperature T, there is a peak corresponding to a wavelength λ_{max} for maximum intensity.
Theory states that

$$\lambda_{max} T = \text{constant}\,.$$

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For example, at T = 3500 K, the intensity distribution spans the visible and infra-red wavelengths, with λ_{max} occurring at the red end of the visible spectrum. Since our eyes can only see in the visible spectrum, the object appears red-hot.

As the temperature of a body increases, the total emitted power also increases. It is known that the luminosity L of a star is related to its surface area A and its temperature T (in kelvins) as follows:

$$L \propto AT^4 .$$

When observing stars, astronomers rely on a phenomenon called the Doppler effect of light. The Doppler effect is more relatable to us with sound waves. Whenever there is relative motion between a wave source and an observer, the frequency noted by the observer is different from the actual frequency of the waves. We would have experienced the Doppler effect, such as when the frequency of the sirens change from higher pitch to lower pitch as an ambulance passes by. The higher pitch heard in front of the moving source is due to the 'bunching up' of wave crests as shown in Fig. 8.2. The reverse occurs for the observer behind the source.

Fig. 8.2

When light emitted from a distant star is passed through a diffraction grating, it is found that each line in the absorption spectrum from hydrogen gas occurs at a different wavelength from that of the corresponding line in the spectrum obtained in the laboratory. The Doppler effect is evident in Fig. 8.3. With some stars, all the spectral lines are shifted to longer wavelengths (red shifted), while with other stars, the lines are shifted to shorter wavelengths (blue shifted). Thus, hydrogen spectral lines provide important information about the motion of a star.

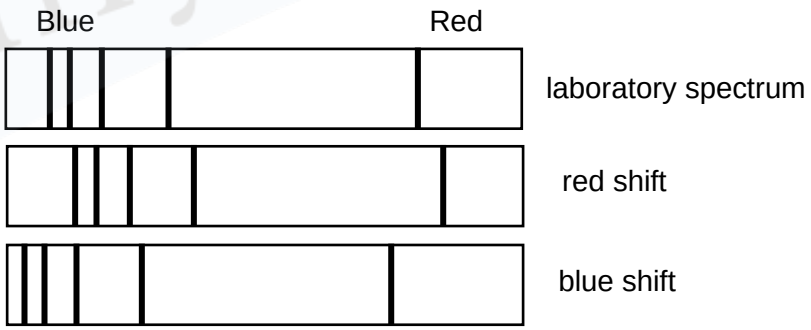

Fig. 8.3

Using the Doppler effect together with the hydrogen spectral lines is extremely important in the detection of binary stars. This method of detection is known as spectroscopic binary. Over four-fifths of the single spots of light we see in the night sky are two or more stars revolving around each other. Binary stars, which consist of only two stars, are the most common star systems. An example would be Sirius-A and Sirius-B. However, when two stars are close together, they appear visually as a single star when viewed with a telescope.

Since binary stars rotate about their common centre of mass, when one star is approaching Earth, the other must be moving away. Analysis of the spectral lines could reveal information that there are, in fact, two stars.

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(a) Suggest one advantage of placing telescopes in space to observe new stars.

.....

.....[1]

(b) Explain why very high temperatures are necessary for fusion reactions to occur in stars.

.....

.....

.....[2]

(c) **(i)** Show that the total power radiated by the Sun is 3.8×10^{26} W.

[1]

(ii) Use the data below to calculate the number of fusion reactions occurring in the Sun each second. Assume all the radiated energy from the Sun comes from the fusion reaction.

mass of electron = 0.000549 *u*

mass of proton = 1.007276 *u*

mass of helium-4 nucleus = 4.001506 *u*

number of reactions per second = ... [3]

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(iii) The present mass of the Sun is 2.0×10^{30} kg. In about another five billion years, the core of the Sun will be depleted of hydrogen.

Calculate the percentage decrease in the mass of the Sun when the core is depleted of hydrogen. Justify whether your calculation agrees with the claim in the passage.

percentage decrease = ... %

.....

.....[2]

(d) Fig. 8.4 shows some data about our Sun and Sirius-A, one of the binary stars mentioned.

	Sun	Sirius-A
Radius / m	R	1.7R
Luminosity / W	L	25L
Surface temperature / K	5800	
Wavelength λ_{max} at maximum intensity / nm	500	

Fig. 8.4

(i) Calculate the surface temperature T of Sirius-A.

T = ... K [2]

(ii) Use data from Fig. 8.1 to verify the theory that

$$\lambda_{max} T = \text{constant}.$$

[2]

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(iii) Use information from Fig. 8.4 and your answer in **(d)(i)** to determine the wavelength λ_{max} for which maximum intensity occurs from Sirius-A.

λ_{max} = ... nm [2]

(iv) By considering your answer in **(d)(iii)**, suggest why Sirius-A appears as a bluish star to an astronomer using an optical telescope.

.....

.....[1]

(e) Fig. 8.5 shows the visible part of the absorption spectrum from hydrogen gas in a laboratory on the Earth and the same part of the absorption spectrum observed in light from a star in a distant galaxy. The numbers indicate the wavelengths in nanometres (nm).

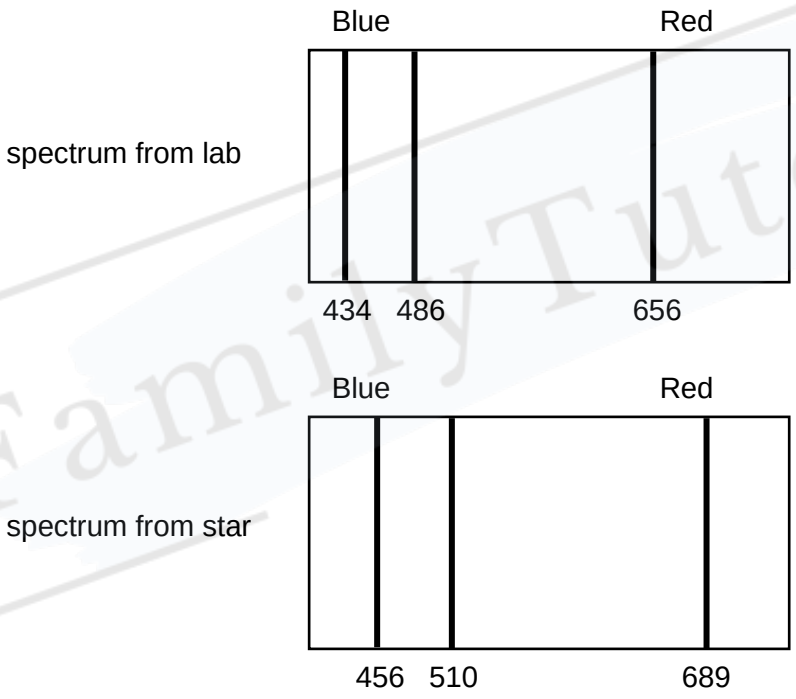

Fig. 8.5 (not to scale)

(i) Compare the line spectra and state what this shows about the motion of the star.

.....

.....

.....[2]

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(ii) Use Fig. 8.5 to calculate the percentage change in the wavelength of a spectral line observed with light from the star compared with a corresponding spectral line observed in the laboratory.

percentage change = ... % [1]

(f) **(i)** Apart from two binary stars being too close together, use Rayleigh's criterion to state another reason why the stars could appear as a single image as seen with a telescope.

.....

.....[1]

(ii) Suggest how hydrogen spectral lines might provide astronomers with information that a star is part of a binary star system.

Assume that the observed star has similar brightness as its binary counterpart and viewed from Earth in the plane of their orbits.

.....

.....

.....

.....[2]

[Total: 22]

End of Paper

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PHYSICS 9749/03

Paper 3 Longer Structured Questions **20 September 2023**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

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

For Examiner's Use	
Section A	
1	/ 8
2	/ 8
3	/ 8
4	/ 8
5	/ 8
6	/ 9
7	/ 11
Section B	
8	/ 20
9	/ 20
Total	/ 80

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Data

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

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / ^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

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

1 **(a)** A student sets up the circuit shown in Fig. 1.1 to determine the resistivity of the metal of a resistance wire. He reads the current I from the ammeter and the potential difference V from the voltmeter.

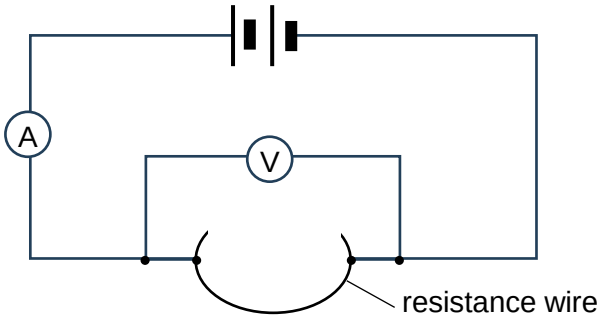

Fig. 1.1

(i) Determine the base units for resistance.

$$P = I^2R$$

$$[R] = \left[\frac{P}{I^2}\right] = \left[\frac{Fd}{I^2t}\right]$$

$$= \frac{\text{kg m s}^{-2}\ \text{m}}{\text{sA}^2}$$

$$= \text{kg m}^2\ \text{s}^{-3}\ \text{A}^{-2}$$

base units for resistance: ..... [2]

(ii) The following readings were obtained for the experiment:

Reading of voltmeter = 1.30 ± 0.01 V
Reading of ammeter = 0.76 ± 0.01 A
Length of wire = 75.4 ± 0.2 cm
Diameter of wire = 0.54 ± 0.02 mm

Calculate, with its associated uncertainty, the value of the resistivity of the metal of the resistance wire, expressing your results to an appropriate number of significant figures.

$$R = \frac{\rho L}{A}$$

$$\frac{V}{I} = \frac{\rho L}{\pi d^2/4}$$

$$\rho = \frac{V}{I}\frac{\pi d^2}{4L} = \frac{\pi(1.30)(0.54\times10^{-3})^2}{4(0.76)(75.4\times10^{-2})}$$

$$= 5.19\times10^{-7}\ \text{[C1]}\ \Omega\text{m}$$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta V}{V} + \frac{\Delta I}{I} + 2\frac{\Delta d}{d} + \frac{\Delta L}{L}$$

$$= \frac{0.01}{1.30} + \frac{0.01}{0.76} + 2\frac{0.02}{0.54} + \frac{0.2}{75.4}\ \text{[M1]}$$

$$\Delta\rho = 0.098\times(5.19\times10^{-7})$$

$$= 0.5\times10^{-7}\ \text{[A1]}$$

$$\rho = 5.2\ \text{[A1]} \pm 0.5\times10^{-7}\ \Omega\text{m}$$

ρ = ... ± ..... Ω m [4]

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(b) A second student repeated the experiment in **(a)** with the same length of the wire. In this new experiment, the supply voltage was varied and several pairs of corresponding readings on the voltmeter and ammeter were tabulated. A graph showing the variation of the current in the wire with potential difference across the wire was then plotted.

Discuss how this procedure reduces the random error and systematic error that could have occurred.

The graph of best fit will reduce the scatter caused by random errors in the experiment. [B1]

If the line of best fit does not pass through the origin, there is a systematic error present in the experiment. [B1] ..... [2]

[Total: 8]

2 An object of mass 1.5 kg is released from a stationary hot air balloon. Fig. 2.1 shows how the vertical displacement of the object varies with time.

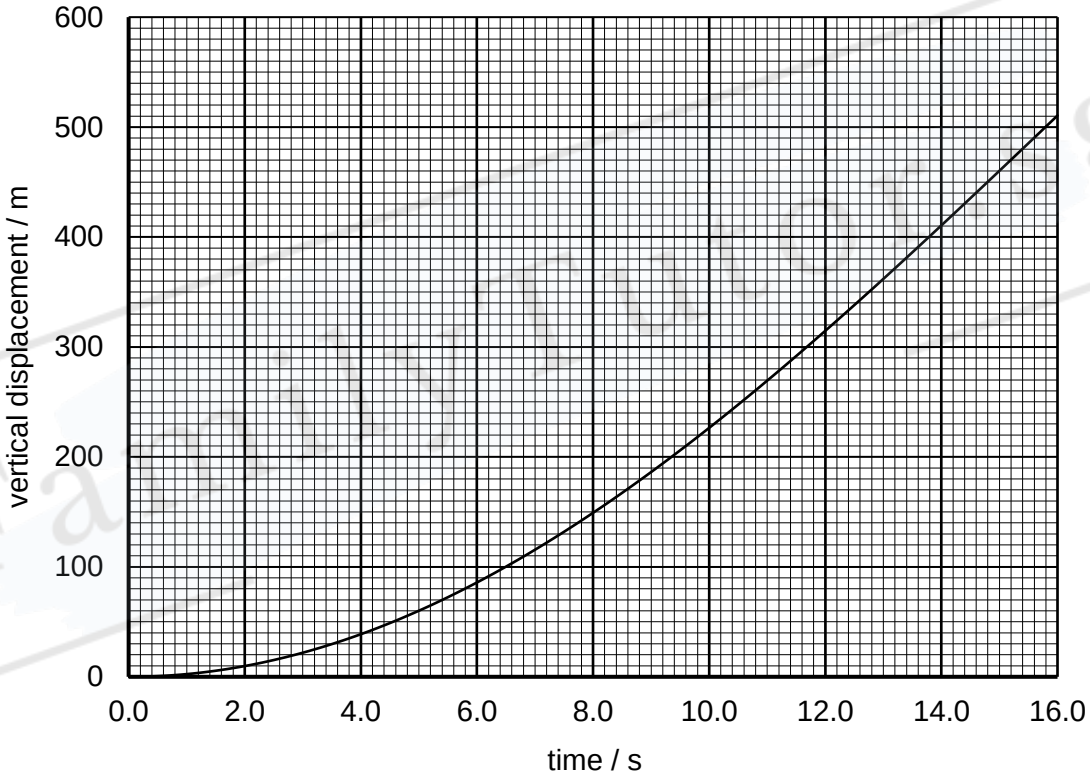

Fig. 2.1

(a) Calculate the change in gravitational potential energy ΔE_p of the object that occurred during the 16 s after it was released.

ΔE_p = mgh
= 1.5 (9.81)(-510)
= (-) 7500 J [A1]

ΔE_p = ... J [1]

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(b) Using Fig. 2.1, determine the speed of the object at t = 16 s.

speed = gradient of tangent to the graph at t = 16 s [M1]
= 50 m s^{-1} (acceptable range: 49 m s^{-1} to 52 m s^{-1}) [A1]

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

(c) Calculate the change in kinetic energy ΔE_k of the object during the same period.

$\Delta E_K = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$
$= \frac{1}{2}(1.5)(50)^2 - 0$
$= 1880$ J [A1]

ΔE_k = ... J [1]

(d) Explain why ΔE_p and ΔE_k are not equal to one another.

Work is done (by object) against/to overcome air resistance. [B1]

..... [1]

(e) The object strikes the ground 16 s after it was released and penetrates 0.85 m into the ground. Determine the average resistive force acting on the object as it penetrates the ground.

Work done against resistive force = Loss of E_K (and E_P)

$F(0.85) = 1880$ [M1] (+ 1.5×9.81×0.85 [B1])

$F = 2210$ N (or 2230 N) [A1]

$f - mg = ma$

$\left(-1.5(9.81)^{[B1]}\right) + f = 1.5\left(\frac{50.0^2}{2\times 0.85}\right)^{[M1]}$

$= 2210$ N (or 2230 N) [A1]

average resistive force = ... N [3]

[Total: 8]

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3 Fig. 3.1 shows a 0.45 kg mass held on a horizontal air track by two identical springs that are initially unstretched. The mass is pulled 5.0 cm to the left and released. The mass oscillates horizontally on a cushion of air.

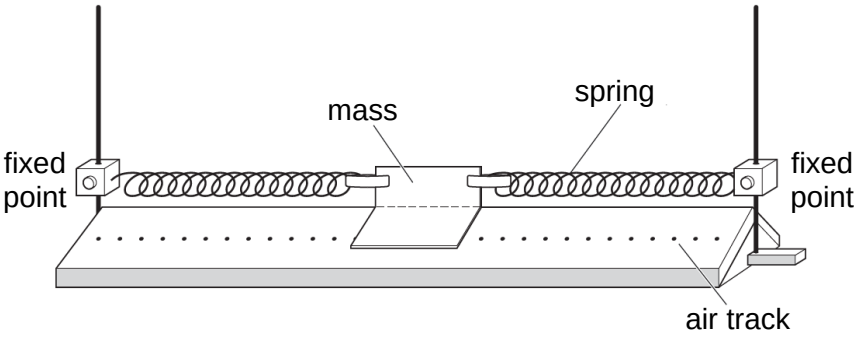

Fig. 3.1

(a) Explain why the mass oscillates with simple harmonic motion when displaced horizontally.

Resultant force on mass is proportional to displacement from equilibrium position / fixed point (as springs obey Hooke's law) so acceleration of mass is proportional to displacement from equilibrium position / fixed point [B1] and acceleration is directed towards equilibrium position/ opposite in direction to displacement from equilibrium position. [B1] [2]

The variation of kinetic energy with displacement x of the mass is shown in Fig. 3.2.

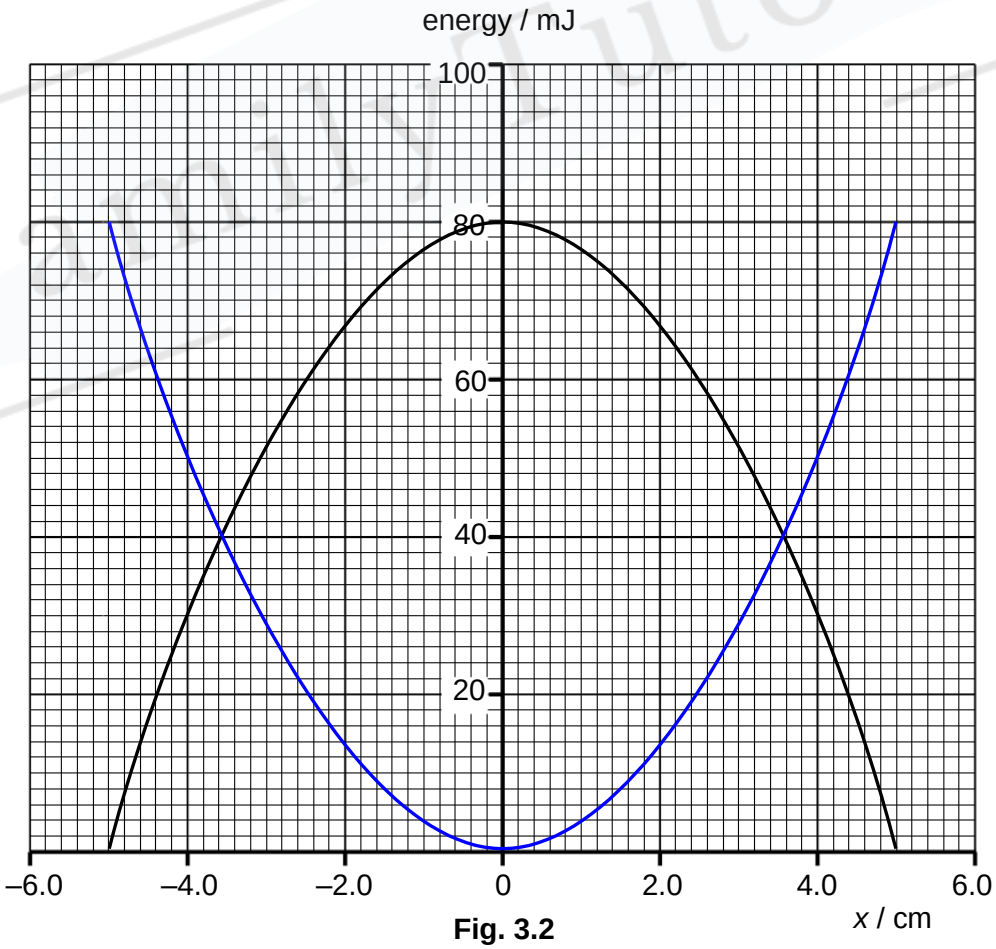

Fig. 3.2

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(b) (i) Use Fig. 3.2 to determine the frequency of the oscillations.

$$E_{k,max} = \frac{1}{2}m\omega^2 x_0^2$$

$$80\times10^{-3} = \frac{1}{2}(0.45)(0.050)^2(2\pi f)^2$$ [M1 - ignore POT error in substitution]

$$f = 1.90 \text{ Hz}$$ [A1]

frequency = ... Hz [2]

(ii) Draw, on Fig. 3.2, a graph to show the variation of potential energy stored in the springs with displacement x of the mass. [1]

correct shape, end points (5.0 cm) and intersection points (40 mJ) [1]

(c) The blower of the air track is switched off so that the mass is in direct contact with the track. One end of the spring is attached to a driver (oscillator) shown in Fig. 3.3. The amplitude of oscillation of the driver is kept constant.

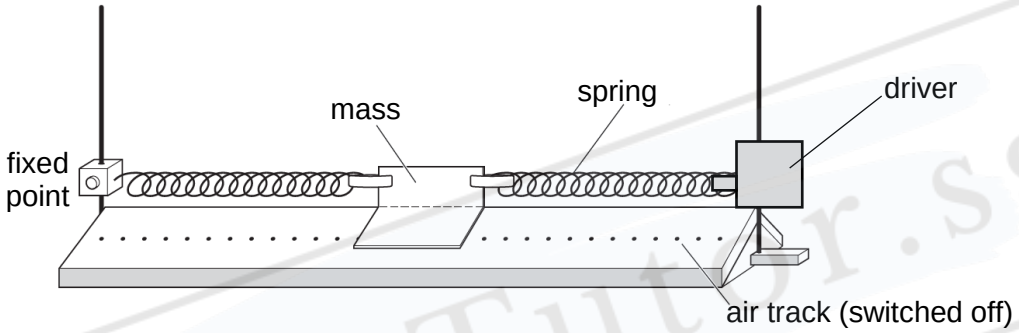

Fig. 3.3

The frequency of oscillations is gradually increased from zero. The variation of the amplitude of oscillation of the mass with driving frequency is shown in Fig. 3.4.

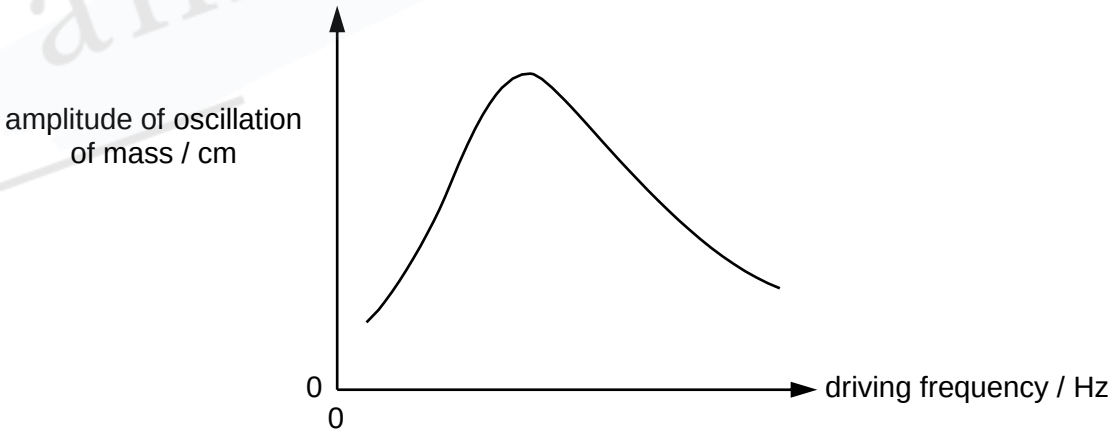

Fig. 3.4

(i) State how Fig. 3.4 shows that the mass is undergoing damped oscillations.

Peak is not infinitely high / not very sharp [B1]

..... [1]

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(ii) The model in Fig. 3.3 and result in Fig. 3.4 can be applied to a practical situation.

Tall buildings, such as the Taipei 101 tower as shown in Fig. 3.5, are equipped with a damping system to reduce movement of the tower in strong winds. A mass in the form of a huge sphere on support cables oscillates with the tower to reduce the effect of the wind. The oscillations of the sphere are damped with oil-filled hydraulic pistons connected to the sphere.

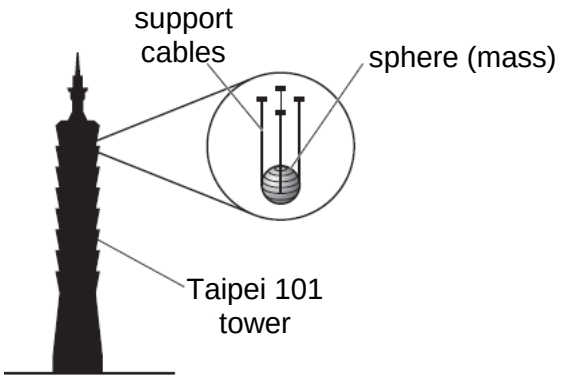

Fig. 3.5

Strong winds set the tower in oscillation. The natural frequency of oscillations of the tower is 0.15 Hz.

Suggest, by reference to energy transfer, why the frequency of the sphere-damping system must be close to 0.15 Hz to help reduce the motion of the tower.

Key points: 1) Recognise that when wind drives the tower, having similar natural frequencies allow maximum transfer of energy from tower to sphere, 2) so that this energy can be dissipated in the oil to reduce motion

- When frequency of sphere-damping system is equal/close to natural frequency of tower, sphere will resonate and there is maximum transfer of energy from tower to sphere [B1] [2]
- where oil/piston dissipates the energy from the sphere to reduce the motion [B1]

[Total: 8]

4 Coherent light of wavelength 590 nm is incident normally on a double slit, as shown in Fig. 4.1.

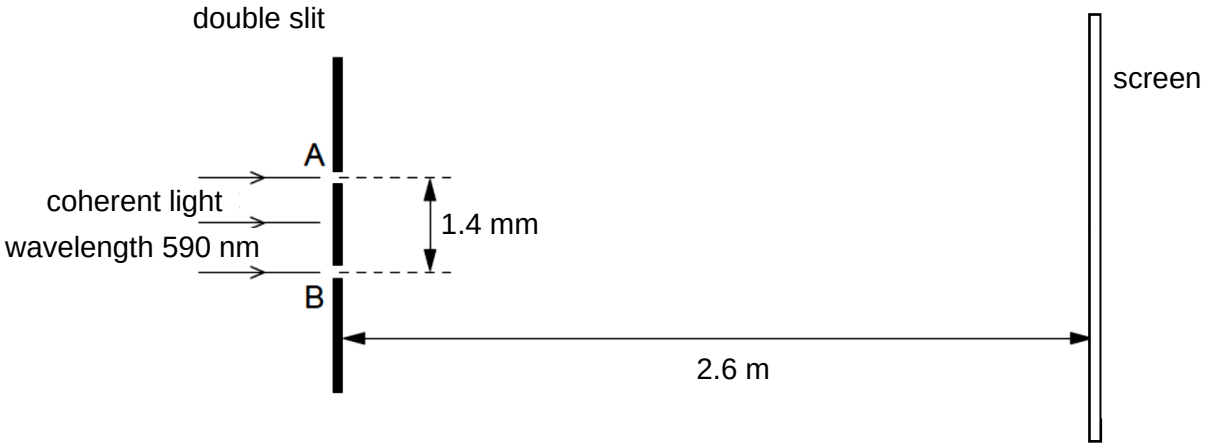

Fig. 4.1

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The separation of the slits A and B is 1.4 mm and the width of each slit is 0.15mm. A screen is placed parallel to the slits at a distance 2.6 m away.

(a) One of the slits is covered.

Calculate the width of the central maximum formed on the screen by diffraction through the uncovered slit.

$$\sin\theta_{min} = \frac{\lambda}{b}$$
$$= \frac{5.90\times10^{-7}}{0.15\times10^{-3}}$$
$$= 0.00393 \text{ [M1]}$$
$$\theta_{min} = 0.225°$$

$$\tan 0.225° = \frac{\frac{1}{2}w}{2.6} \text{ [M1]}$$
$$w = 2(2.6\times\tan 0.225°)$$
$$= 0.0204 \text{ m [A1]}$$

width = ... cm [3]

(b) Now, both slits are uncovered.

(i) State Rayleigh's criterion.

Rayleigh's criterion says that the images of two-point sources can just be distinguished/ resolved [B1] from each other if the central maximum of one diffraction pattern falls on the first minimum of the other one. [B1] [2]

(ii) Use Rayleigh's criterion to explain whether the diffraction pattern produced by the two slits are seen as on the screen as separate.

Since the separation of the double slits is 1.4 mm, the central maxima of the two diffraction patterns will be 1.4 mm apart. [B1]

From (a) the first minimum of each pattern is at a distance of 10.2 mm away from the central maximum of the pattern. [B1]

Hence, the maximum of the first diffraction will fall within the 1st minimum of other diffraction pattern. The two patterns are not distinguished/ resolved and will not be seen as separate. [B1] [3]

[Total: 8]

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5 Fig. 5.1 shows the arrangement of the apparatus used in the measurement of the magnetic flux density between the poles of a U-shaped magnet. The magnet rests on top of an electronic balance. A stiff rectangular frame measuring 8.0 cm by 5.0 cm carries a current I between the magnetic poles. The bottom edge of the frame is lowered into the region between the poles of the U-shaped magnet and is entirely within the uniform magnetic field.

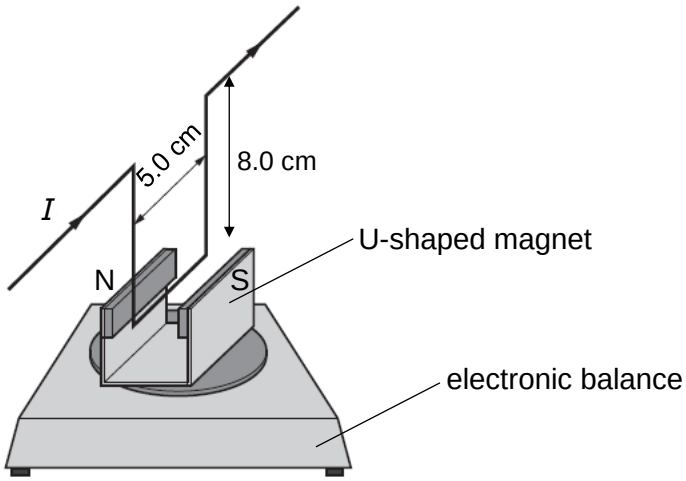

Fig. 5.1

Fig. 5.2 shows the apparatus when viewed from the front. The poles of the U-shaped magnet have been indicated.

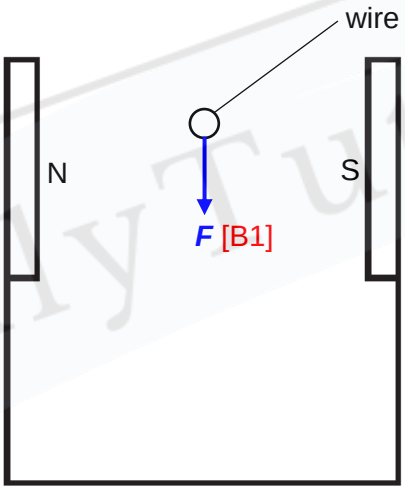

Fig. 5.2

(a) (i) Draw, on Fig. 5.2, a vertical force acting on the wire when current passes through it. Label the force *F*. [1]

(ii) When current passes through the wire, the balance reading changes.

Explain why there is a change in reading, and whether the change is an increase or decrease.

By Newton's 3rd Law, the interaction between wire and magnet causes an upward force on magnet [M1] which causes balance reading to decrease.[A1 – allow e.c.f. from (a)(i)] [2]

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(b) The current I is varied and the change in the balance reading is recorded as shown in Fig. 5.3.

	Change in balance reading / g				
I / A	Trial 1	Trial 2	Trial 3	Mean change / g	F / × 10^{-3} N
0.5	0.08	0.05	0.06	0.06	0.6
1.0	0.14	0.16	0.16	0.15	1.5
1.5	0.22	0.20	0.23	0.22	2.2
2.0	0.31	0.29	0.31	0.30	2.9
2.5	0.38	0.39	0.34	0.37	3.6
3.0	0.44	0.48	0.48	0.47	4.6

Fig. 5.3

(i) Complete the table in Fig. 5.3. [1]

(ii) On Fig. 5.4, plot the missing data point from the table in Fig. 5.3 and draw a line of best fit. [1]

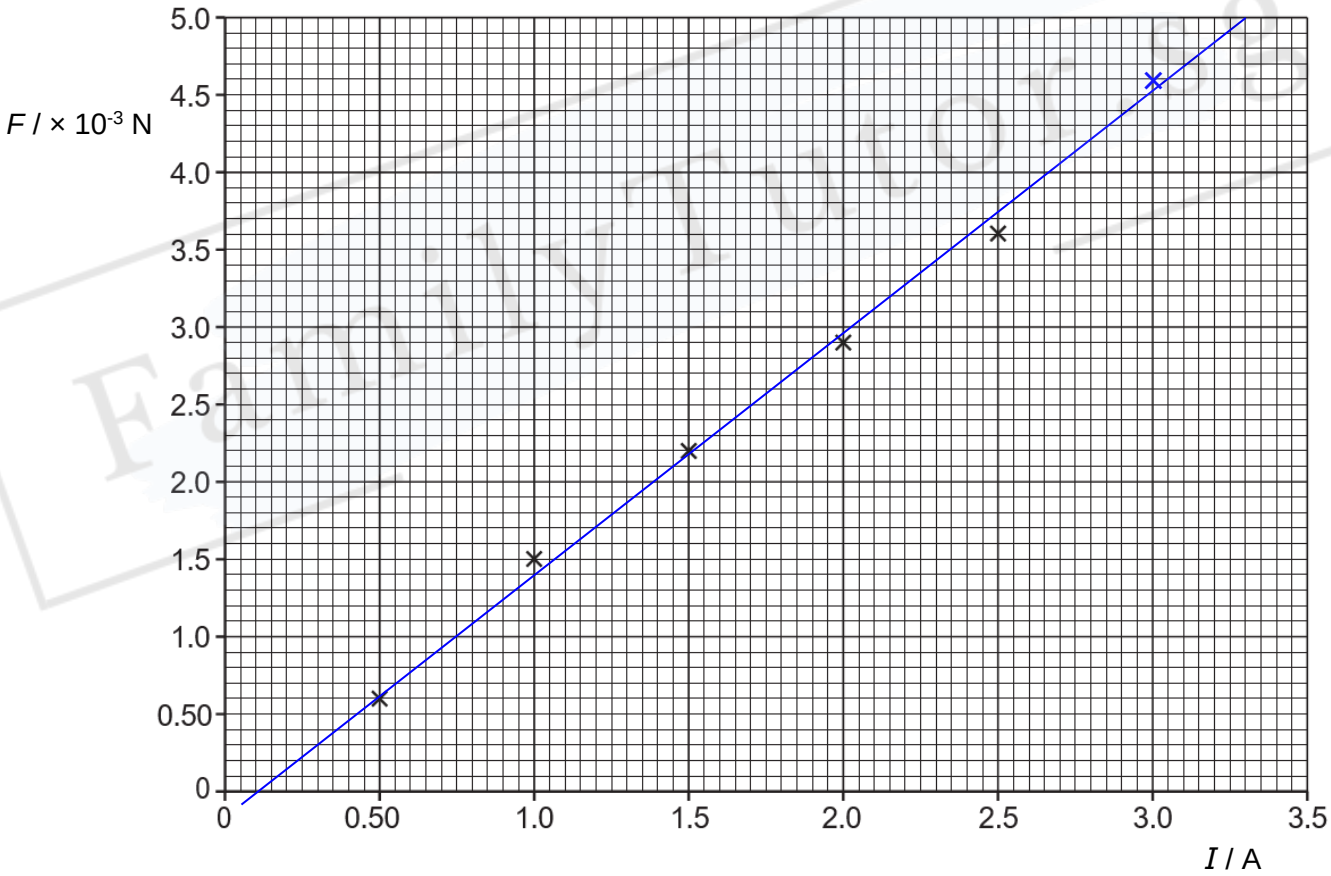

Fig. 5.4

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(iii) Use your graph to determine the value of the magnetic flux density B, in mT, between the U-shaped magnet.

$$\text{gradient} = \frac{5.0\times10^{-3} - 0}{3.3 - 0.10}$$
$$= 0.00156 \text{ [M1 - ignore POT error]}$$

$$BL = 0.00156$$
$$B = \frac{0.00156}{0.050}$$
$$= 0.0312 \text{ T}$$
$$= 31 \text{ mT (acceptable range: 28 mT to 34 mT) [A1]}$$

B = ... mT [2]

(iv) The value of the magnetic flux density in **(b)(iii)** is slightly inaccurate for a reason which has nothing to do with human error or meter inaccuracies.

Suggest one reason that might be the cause of this inaccuracy.

Effect of the Earth's magnetic field / Presence of external magnetic field [B1]

..... [1]

[Total: 8]

6 An a.c. power supply is connected to a resistor R, as shown in Fig. 6.1.

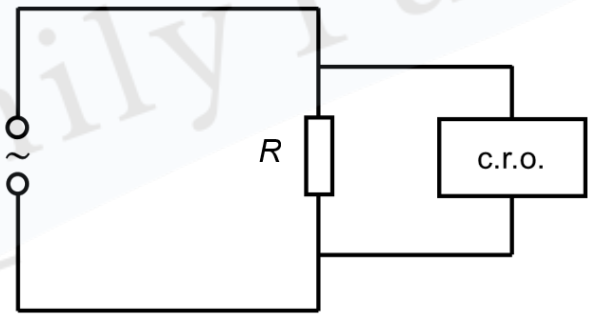

Fig. 6.1

A cathode ray oscilloscope (c.r.o.) is used to show the potential difference (p.d.) across R. The screen of the c.r.o. displays the variation with time of the p.d. across R, as shown in Fig. 6.2.

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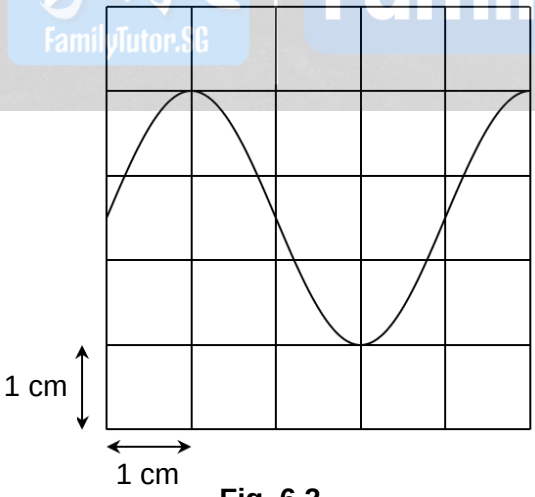

Fig. 6.2

(a) Explain, by reference to direct current, what is meant by the *root-mean-square* (r.m.s.) value of an alternating current.

The r.m.s. value of an alternating current is the value of the steady current that will dissipate heat at the same average rate as the alternating current in a resistive load [B1].

..... [2]

(b) The voltage V of the power supply is given by the expression

$$V = 6.0\sin(100\pi t)$$

V is measured in volts and the time t is measured in seconds.

Determine the Y-gain and time-base of the c.r.o.

12.0 V corresponds to 3 cm.

$12 \div 3 = 4.0$ V/cm [A1]

$\frac{2\pi}{T} = 100\pi$

$T = 20$ ms

20 ms corresponds to 4 cm.

$20 \div 4 = 5$ ms [A1]

Y-gain = ... V / cm

time-base = ... ms / cm

[2]

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(c) A diode is then connected in series with the resistor *R*, as shown in Fig. 6.3.

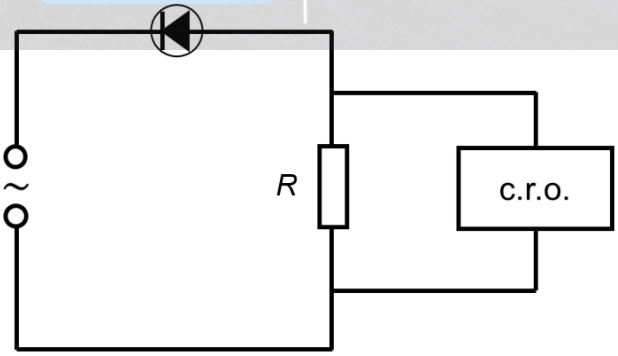
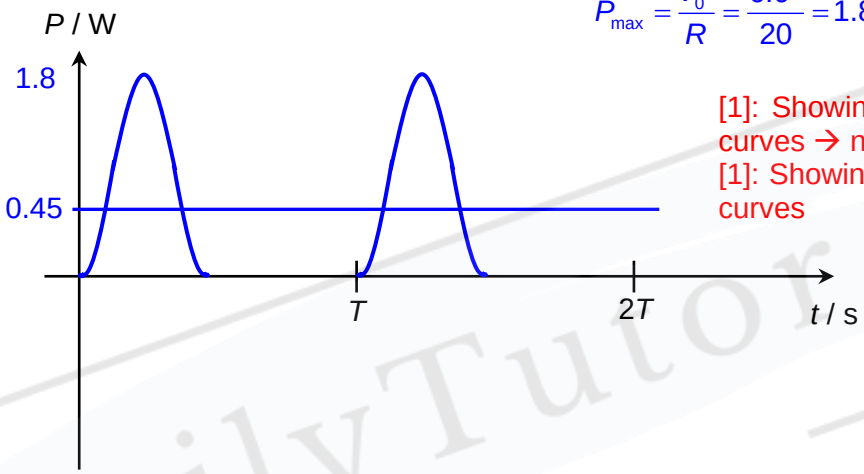


Fig. 6.3

(i) Sketch in Fig. 6.4, for 2 periods of the alternating p.d., the variation with time of the power *P* dissipated in *R* when *R* is 20 Ω, where *T* is the period. Indicate the peak power value in your sketch. [2]

$$P_{max} = \frac{V_0^2}{R} = \frac{6.0^2}{20} = 1.8 \text{ W}$$



[1]: Showing sinusoidal square curves → not McDonald curves
[1]: Showing half wave rectified curves

Fig. 6.4

(ii) Draw a line in Fig. 6.4 to represent the average power dissipated in *R*. Indicate its value on the y-axes. [1]

(iii) Calculate the root-mean-square current in *R*.

$$\langle P \rangle = I_{rms}^2 R$$
$$0.45 = I_{rms}^2 (20)$$
$$I_{rms} = 0.15 \text{ A}$$

root-mean-square current = ... A [2]

[Total: 9]

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7 Fig. 7.1 shows what is observed when a parallel beam of electrons, accelerated by a potential difference V, is incident on a fluorescent screen.

Fig. 7.1

A carbon film is then placed perpendicularly to the path of the electron beam as shown in Fig. 7.2.

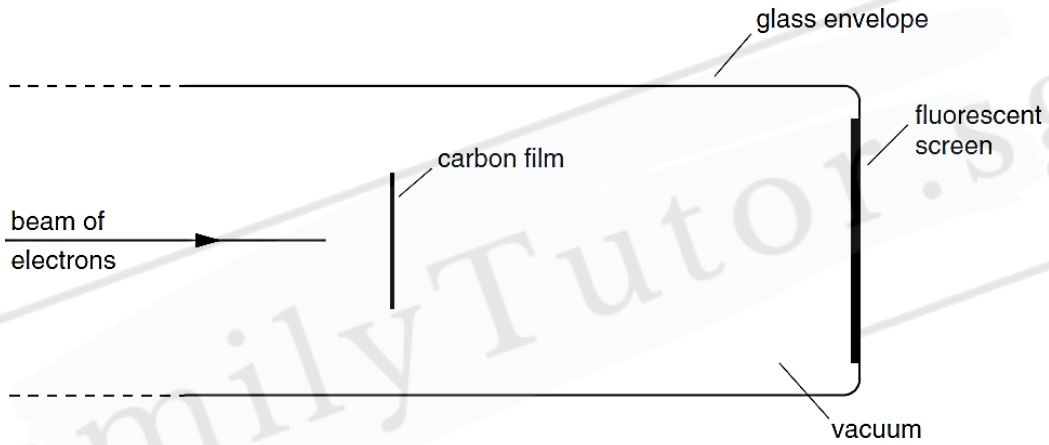

Fig. 7.2

The pattern observed on the screen is shown in Fig. 7.3.

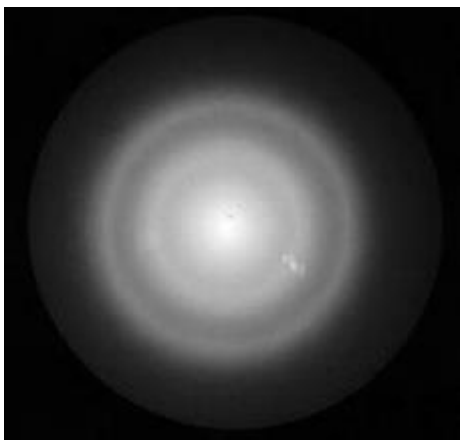

Fig. 7.3

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(a) Identify and explain two key features in Fig. 7.3 that provide evidence for the wave nature of the electrons.

Pattern spreading/occupy over a large area demonstrates diffraction of the beam. [B1] (don't accept diffract w/o explanation)

Bright rings (with alternating with dark regions between them) indicates regions of constructive and destructive interference. [B1] (don't accept interference w/o explanation)

Since both interference & diffraction are behaviours exhibited by waves, hence the electrons which are usually treated as particles, have wave-like behaviours. [B1] ..... [3]

(b) The electrons were accelerated through a potential difference of 2000 V.

(i) Calculate the momentum of an electron after being accelerated through a potential difference of 2000 V.

E_k of electron = $\frac{p^2}{2m}$

By conservation of energy,

Loss in electric potential energy = Gain in kinetic energy

$$2000 \times 1.60 \times 10^{-19} = \frac{p^2}{2(9.11\times10^{-31})} \text{ [M1]}$$

$$p = 2.41 \times 10^{-23} \text{ N s [A1]}$$

momentum = ... N s [2]

(ii) Hence, calculate the de Broglie wavelength of the electrons.

$$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{2.41\times10^{-23}} \text{ [C1]}$$

$$= 2.75\times10^{-11} \text{ m [A1]}$$

wavelength = ... m [2]

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(c) State and explain the changes, if any, that is observed in the pattern on the screen when the following changes are made separately.

(i) The potential difference used to accelerate the electrons is increased.

With a larger potential difference used, the kinetic energy/speed of the electrons will become larger and hence momentum becomes larger. With a larger momentum, the de Broglie wavelengths of the electrons become smaller. [M1] The rings will now have a smaller diameter/ closer together. [A1] [2]

(ii) The current of the electron beam is increased.

A greater rate of electrons is incident on the fluorescent screen. [M1]

This will cause the bright rings to appear brighter/greater contrast. [A1] [2]

[Total: 11]

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Section B

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

8 **(a)** Fig. 8.1 shows the variation of the gravitational potential ϕ with distance d from the surface of Pluto along a line joining the centers of Pluto and Charon.

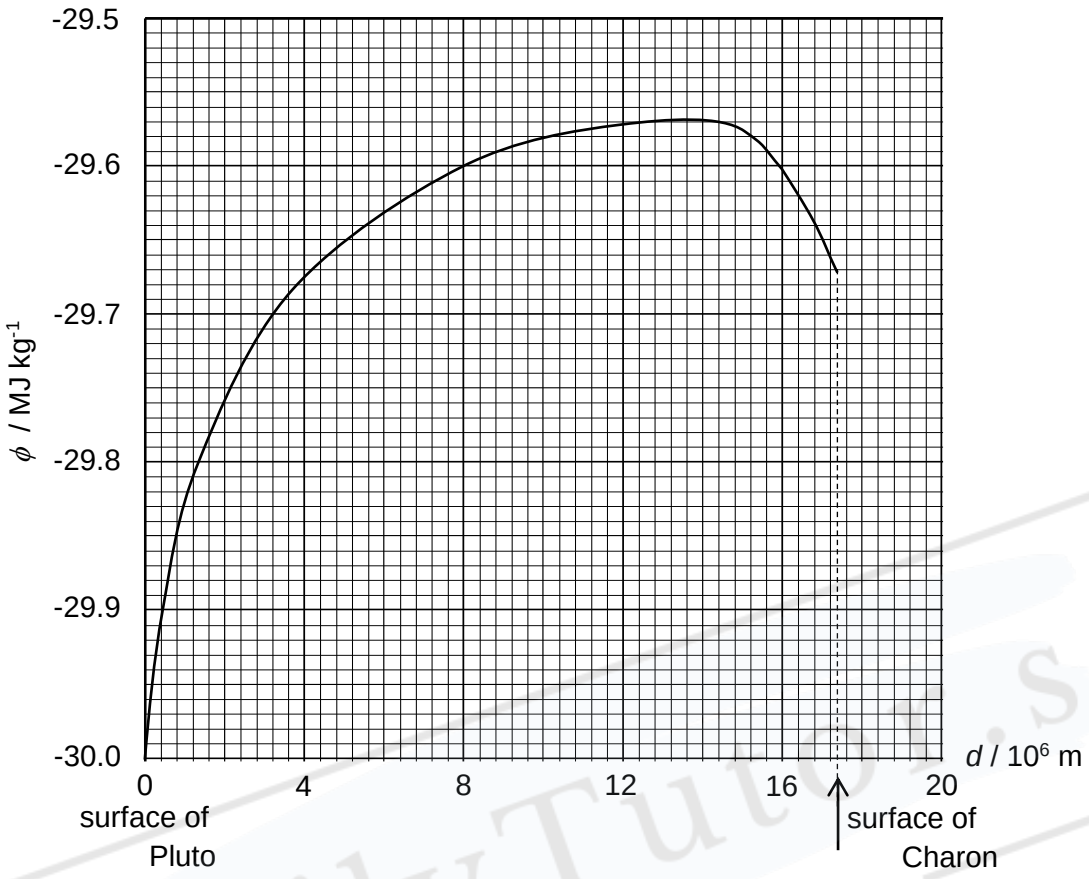

Fig. 8.1

The gravitational potential is taken as being zero at infinity.

(i) By considering the definition of gravitational potential, suggest why all values of ϕ in Fig. 8.1 are negative and explain how they may be obtained.

The direction of the external force to bring a (test) mass from infinity to a point in the field without a change in kinetic energy is opposite in direction to displacement. [B1]

Hence the work done per unit mass (which is the gravitational potential) is negative.

The resultant gravitational potential at that point is the (numerical) sum of the individual negative values of gravitational potential due to each planet. [B1] [2]

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(ii) Explain how Fig. 8.1 can be used to determine the resultant gravitational force acting on an object with mass *m* placed at a point between Pluto and Charon.

The resultant gravitational force acting on an object at a point is the product of *m* [B1]
and the (negative of the) gradient of the tangent at that point [B1] on the graph.

[2]

(iii) A lump of rock of mass 5.0 kg is ejected from the surface of Charon such that it travels towards Pluto.

1. Using data from Fig. 8.1, determine the minimum speed of the rock as it hits the surface of Pluto.

Loss in gravitational potential energy = gain in kinetic energy

$$m(\phi_i - \phi_f) = \tfrac{1}{2} m v_{minimum}^2 - 0 \quad [M1]$$

$$5.0\,(-29.57 - (-30.00))\times 10^6 = \tfrac{1}{2}(5.0) \times v_{minimum}^2 \quad [C1]$$

$$v_{minimum} = 927 \text{ m s}^{-1} \quad [A1]$$

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

2. The rock is now projected from Pluto to Charon.

State and explain how its minimum speed when it hits the surface of Charon will be different from the answer in **(a)(iii)1**.

The loss in gravitational potential energy from the maximum gravitational potential energy point to the surface of Charon is less than that to the surface of Pluto. Thus, the gain in kinetic energy of the rock on impact on Charon will be lesser [M1] and the minimum speed of impact on Charon will be smaller. [A1]

[2]

(b) In another isolated planetary system, X and Y are two stars of equal mass *M* and separated by a distance 2*L*. The two stars rotate about their common centre of mass.

(i) State Newton's Law of Gravitation.

The gravitational force of attraction between any two point masses is directly proportional to the product of their masses and inversely proportional to the square of their separation. [B1]

[1]

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(ii) Explain why the two stars will not collide with each other even though the gravitation force acting on each other are attractive.

The gravitational force acts perpendicular to the motion of the star. [B1] Hence the gravitation force provides the centripetal force for circular motion. [B1]

..... [2]

(iii) Derive an expression, in terms of M, L and the gravitational constant G, for the period T of their rotation.

Gravitational force provides the centripetal force for circular motion.

$$\frac{GMM}{(2L)^2} = ML\left(\frac{2\pi}{T}\right)^2 \quad [B1]$$

$$T = \sqrt{\frac{16\pi^2 L^3}{GM}} \quad [B1]$$

[2]

(c) Fig. 8.2 shows three points A, B and C relative to the stars X and Y. All three points are equidistant from both X and Y and point B lies on the straight line joining the centres of mass of X and Y.

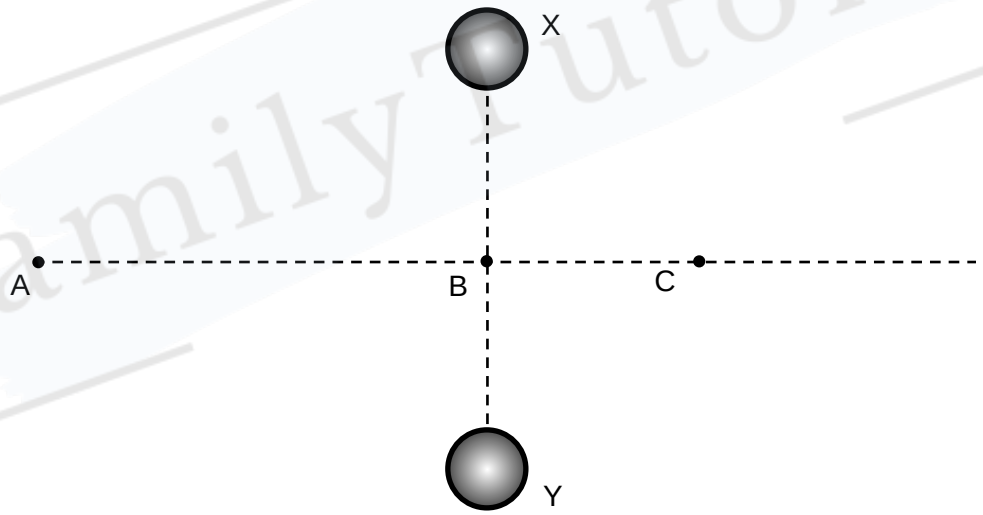

Fig. 8.2

(i) Draw arrows on Fig. 8.2 to represent the gravitational forces due to each star acting on a small mass placed separately at points A, B and C. The length of the arrow should be relative to their respective magnitudes. [2]

arrows directed towards centres of X and Y [B1]
shortest arrows for A and largest for B [B1]

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(ii) Fig. 8.3 shows another schematic of X and Y. P is a point equidistant from X and Y and is at a distance *s* from the straight line joining the centers of mass of X and Y.

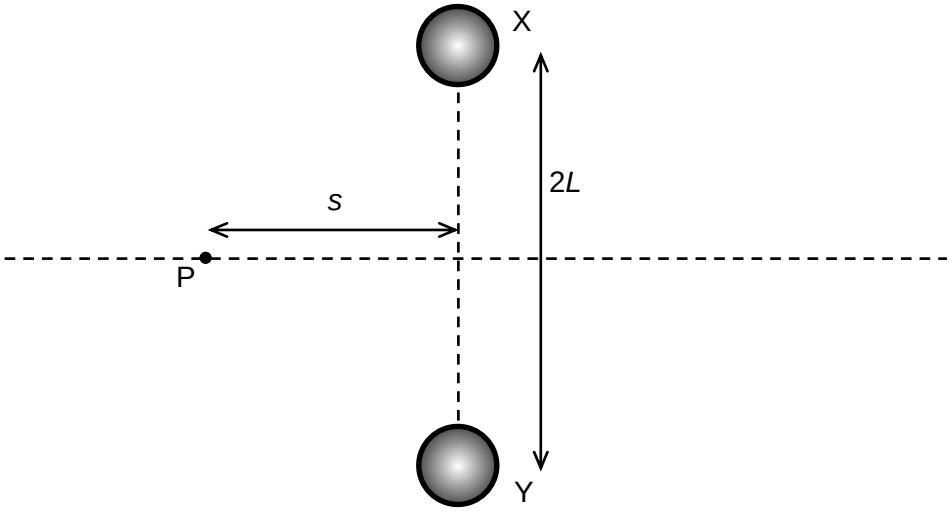

Fig. 8.3

1. Show that the magnitude of the resultant gravitational force acting on a mass *m* placed at P is

$$F_G = \frac{2GMms}{\left(s^2 + L^2\right)^{\frac{3}{2}}}$$

Components of forces along XY cancels each other [B1]

$$F_G = 2\frac{GMm}{\left(\sqrt{L^2+s^2}\right)^2}\left(\frac{s}{\sqrt{L^2+s^2}}\right) \quad [B1]$$

$$= \frac{2GMms}{\left(s^2+L^2\right)^{\frac{3}{2}}} \text{ (shown)}$$

[2]

2. Hence, state and explain if the subsequent motion of a mass placed at rest at point P is simple harmonic.

From the above equation, it may be deduced that the acceleration of the mass is not directly proportional to its displacement from equilibrium *s* [M1], the subsequent motion of the mass is not simple harmonic [B1] [2]

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9 (a) One assumption of the kinetic theory of gases is that the particles of the gas make perfectly elastic collisions among themselves and with the wall of the container. State two other assumptions of the kinetic theory of gases.

1. Any gas is made up of a large number of particles in constant and random motion.
2. The volume of each particle is negligible compared to the volume of the gas. This also means that any 2 particles are considered far apart (relative to their size).
3. The forces between the particles are negligible except during the time of collision. Having negligible forces between particles implies that the microscopic potential energy of the particles is constant and we can set it as 0 J.
4. The duration of collisions is negligible compared with the time interval between collisions.

(b) Consider a single molecule of mass *m* in a cuboidal container of internal side length L. The molecule is travelling with velocity *v* directly towards one of the walls W as shown in Fig 9.1.

Collisions between the molecule and the walls are elastic. This molecule makes multiple collisions in unit time. The pressure the molecule exerts on the wall is dependent on the frequency of the collisions with the wall.

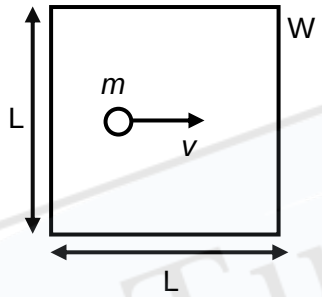

Fig. 9.1

Write expressions for

(i) the change in momentum of the molecule when it collides with wall W.

change in momentum $= p_f - p_i = -(mv) - (+mv) = -2mv$ ..... [1]

(ii) time between collisions of the molecule and the wall W.

time between collisions $= \dfrac{\text{distance}}{\text{speed}} = \dfrac{2L}{v}$ ..... [1]

(iii) the frequency of the collisions of the molecule with the wall W.

frequency of collisions $= \dfrac{1}{t} = \dfrac{v}{2L}$ ..... [1]

(iv) the average momentum change per unit time for this molecule.

total momentum change $= f(\Delta p) = \dfrac{v}{2L}(-2mv) = -\dfrac{mv^2}{L}$ ..... [1]

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(v) the average force on wall W as a result of impacts by the molecule.

from (iv) and according to Newton's second law, the average force on the molecule = $\frac{mv^2}{L}$ [B1]

according to Newton's Third Law, average force on wall = $\frac{mv^2}{L}$ [B1] [2]

(vi) the average pressure of wall W.

average pressure on wall = $\frac{\text{average force on wall}}{L^2} = \frac{mv^2}{L^3}$ [1]

(c) A cuboidal container contains *N* molecules of an ideal gas has volume V and pressure *p* given by the relation

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

where *m* is the mass of each molecule.

Explain briefly how the expression in **(b)(vi)** leads to this relation.

The volume of the container V is equal to L^3. [B1]

The equation was assuming every molecule was moving horizontally.

In a sample of gas of N molecules, each molecule could be moving randomly in any three directions within the container so that its actual velocity c is given by

$c^2 = c_x^2 + c_y^2 + c_z^2$

The molecules are moving with a range of velocities, $\langle c^2 \rangle$ is the mean square speed of the molecules, so $\langle c^2 \rangle = \langle c_x^2 \rangle + \langle c_y^2 \rangle + \langle c_z^2 \rangle$ [B1]

Since the number of particles is large and they are in random motion, the particles have an equal chance of being in any direction $\langle c_x^2 \rangle = \langle c_y^2 \rangle = \langle c_z^2 \rangle = \frac{1}{3}\langle c^2 \rangle$ [B1]

The expression in **(b)(vi)** for average pressure due to one molecule moving in one direction is modified to be an expression for the average pressure due to N molecules in all directions.

average pressure on wall $= N\frac{m}{V}\left(\frac{1}{3}\langle c^2 \rangle\right) = \frac{1}{3}\frac{Nm\langle c^2 \rangle}{V}$ [B1] [4]

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(d) (i) Use the equation of state for an ideal gas, together with the equation given in **(c)** to show that K, the average translational kinetic energy of a molecule is proportional to its absolute temperature [3]

$$pV = nRT$$

from (c) $$pV = \frac{1}{3}Nm\langle c^2\rangle$$

$$nRT = \frac{1}{3}Nm\langle c^2\rangle \quad [M1]$$

$$= \frac{1}{3}nN_A m\langle c^2\rangle$$

$$3RT = N_A m\langle c^2\rangle$$

$$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}\frac{R}{N_A}T \quad [M1]$$

$$pV = NkT$$

from (c) $$pV = \frac{1}{3}Nm\langle c^2\rangle$$

$$NkT = \frac{1}{3}Nm\langle c^2\rangle \quad [M1]$$

$$kT = \frac{1}{3}m\langle c^2\rangle$$

$$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT \quad [M1]$$

Since R and N_A are constants / Since k is constant [B1], the kinetic energy of a molecule is proportional to its absolute temperature. [A0]

(ii) Calculate , for oxygen and hydrogen at the same temperature, the ratio

$$\frac{\text{root mean square speed of a hydrogen molecule}}{\text{root mean square speed of an oxygen molecule}}.$$

The masses of the molecules are given the following table:

Mass of a hydrogen molecule = 3.34×10^{-27} kg

Mass of an oxygen molecule = 5.34×10^{-26} kg

Kinetic energy of a molecule is proportional to its absolute temperature.

So when temperature is the same, mean square speed is inversely proportional to mass

$$\frac{v_H^2}{v_O^2} = \frac{m_O}{m_H}$$

$$\frac{v_H}{v_O} = \sqrt{\frac{m_O}{m_H}} = \sqrt{\frac{5.34\times10^{-26}}{3.34\times10^{-27}}} \quad [M1]$$

$$= 3.98 \quad [A1]$$

ratio = = ... [2]

(iii) Suggest why the atmosphere of the Earth contains very little hydrogen.

Hydrogen molecules have higher speed [B1]

.....

So a greater proportion/fraction of hydrogen molecules have a speed greater than

.....

escape speed [B1]

.....

..... [2]

[Total: 20]

End of Paper

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PHYSICS 9749/03

Paper 3 Longer Structured Questions **20 September 2023**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

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

For Examiner's Use	
Section A	
1	/ 8
2	/ 8
3	/ 8
4	/ 8
5	/ 8
6	/ 9
7	/ 11
Section B	
8	/ 20
9	/ 20
Total	/ 80

This document consists of **24** printed pages.

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Data

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

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \mathrm{K} = T / ^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

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

1 **(a)** A student sets up the circuit shown in Fig. 1.1 to determine the resistivity of the metal of a resistance wire. He reads the current I from the ammeter and the potential difference V from the voltmeter.

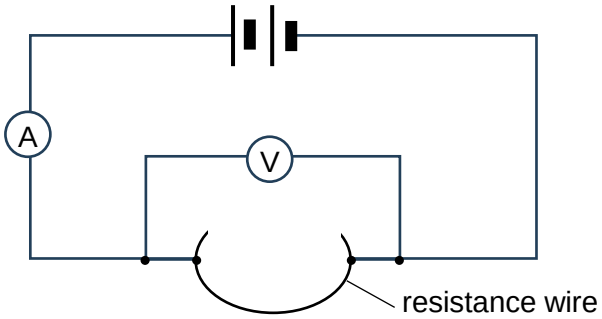

Fig. 1.1

(i) Determine the base units for resistance.

base units for resistance: ..... [2]

(ii) The following readings were obtained for the experiment:

Reading of voltmeter = 1.30 ± 0.01 V
Reading of ammeter = 0.76 ± 0.01 A
Length of wire = 75.4 ± 0.2 cm
Diameter of wire = 0.54 ± 0.02 mm

Calculate, with its associated uncertainty, the value of the resistivity of the metal of the resistance wire, expressing your results to an appropriate number of significant figures.

ρ = ... ± ..... [4]

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(b) A second student repeated the experiment in **(a)** with the same length of the wire. In this new experiment, the supply voltage was varied and several pairs of corresponding readings on the voltmeter and ammeter were tabulated. A graph showing the variation of the current in the wire with potential difference across the wire was then plotted.

Discuss how this procedure reduces the random error and systematic error that could have occurred.

.....

.....

..... [2]

[Total: 8]

2 An object of mass 1.5 kg is released from a stationary hot air balloon. Fig. 2.1 shows how the vertical displacement of the object varies with time.

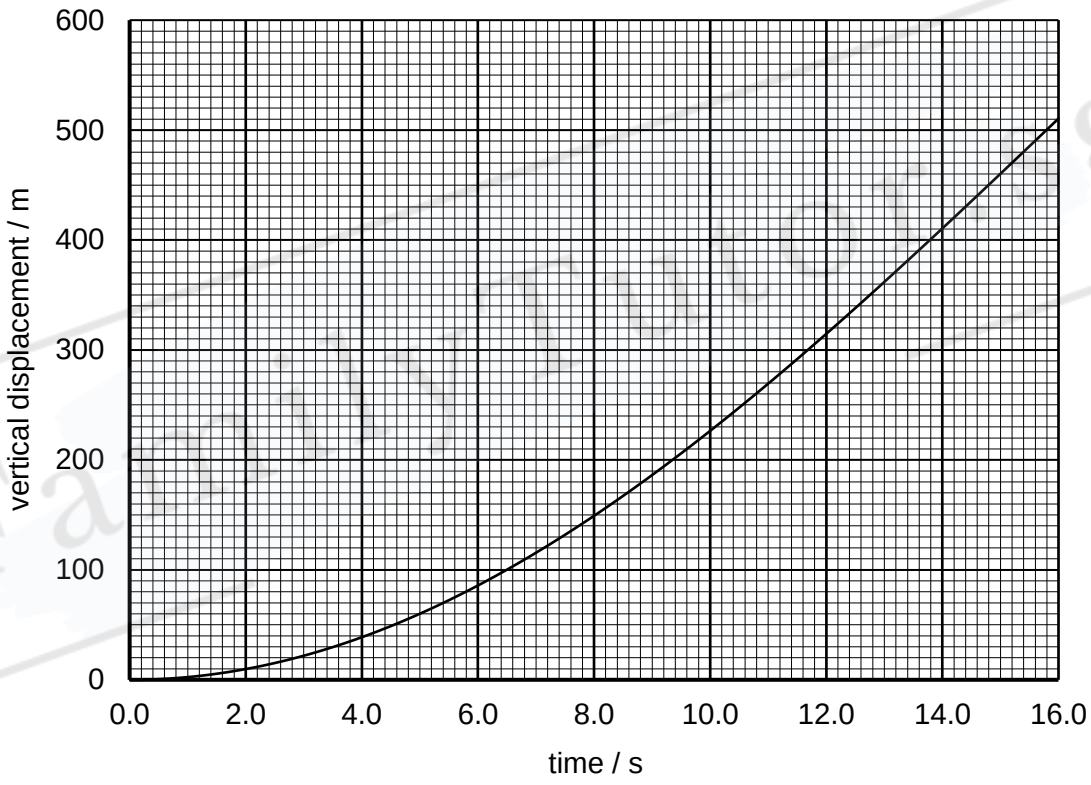

Fig. 2.1

(a) Calculate the change in gravitational potential energy ΔE_p of the object that occurred during the 16 s after it was released.

ΔE_p = ... J [1]

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(b) Using Fig. 2.1, determine the speed of the object at t = 16 s.

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

(c) Calculate the change in kinetic energy ΔE_k of the object during the same period.

ΔE_k = ... J [1]

(d) Explain why ΔE_p and ΔE_k are not equal to one another.

…….....……

……...…….. [1]

(e) The object strikes the ground 16 s after it was released and penetrates 0.85 m into the ground. Determine the average resistive force acting on the object as it penetrates the ground.

average resistive force = ... N [3]

[Total: 8]

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3 Fig. 3.1 shows a 0.45 kg mass held on a horizontal air track by two identical springs that are initially unstretched. The mass is pulled 5.0 cm to the left and released. The mass oscillates horizontally on a cushion of air.

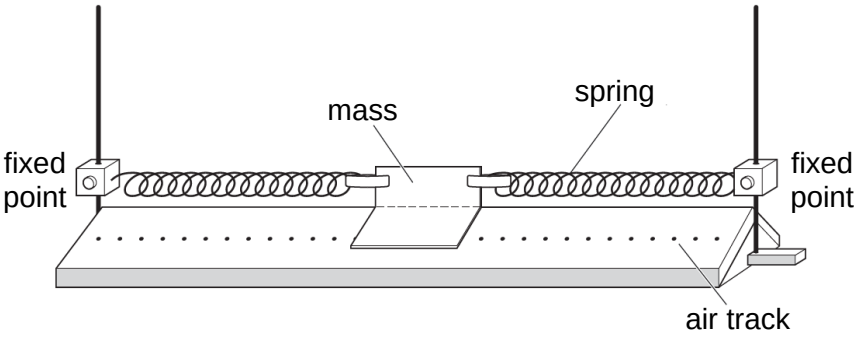

Fig. 3.1

(a) Explain why the mass oscillates with simple harmonic motion when displaced horizontally.

.....

.....

.....

..... [2]

The variation of kinetic energy with displacement *x* of the mass is shown in Fig. 3.2.

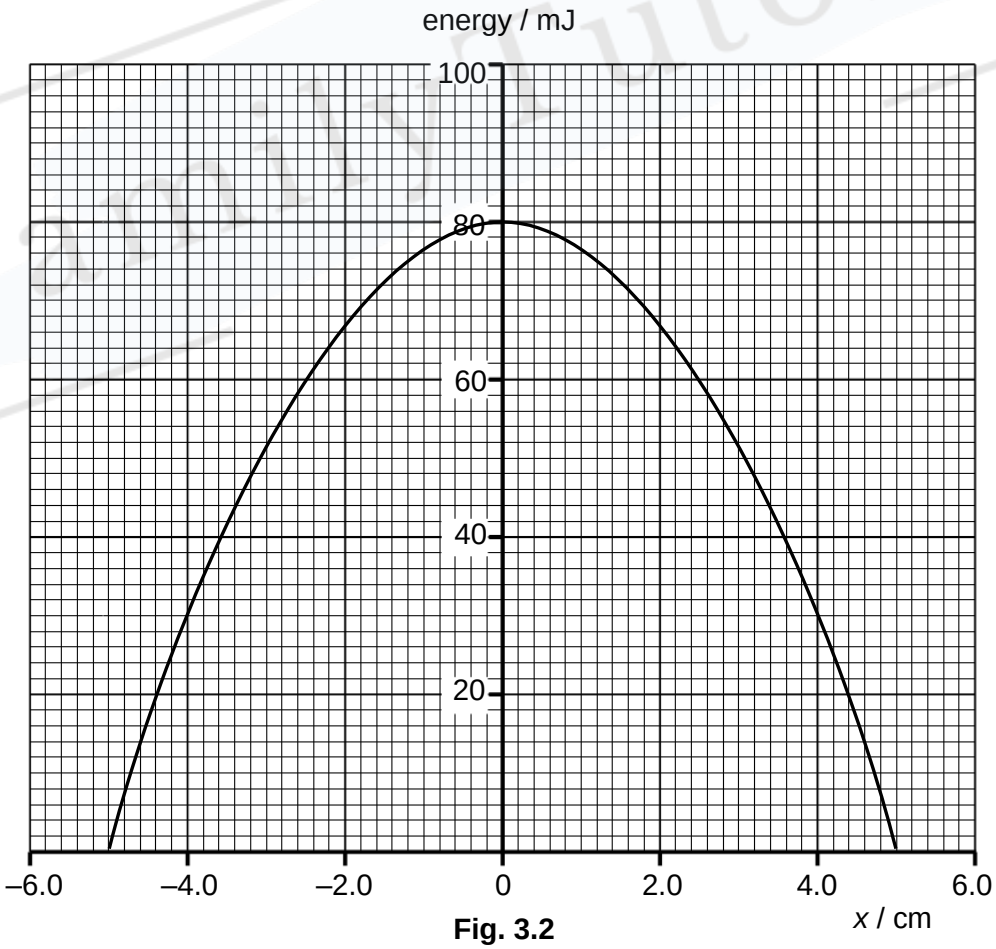

Fig. 3.2

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(b) (i) Use Fig. 3.2 to determine the frequency of the oscillations.

frequency = ... Hz [2]

(ii) Draw, on Fig. 3.2, a graph to show the variation of potential energy stored in the springs with displacement *x* of the mass. [1]

(c) The blower of the air track is switched off so that the mass is in direct contact with the track. One end of the spring is attached to a driver (oscillator) shown in Fig. 3.3. The amplitude of oscillation of the driver is kept constant.

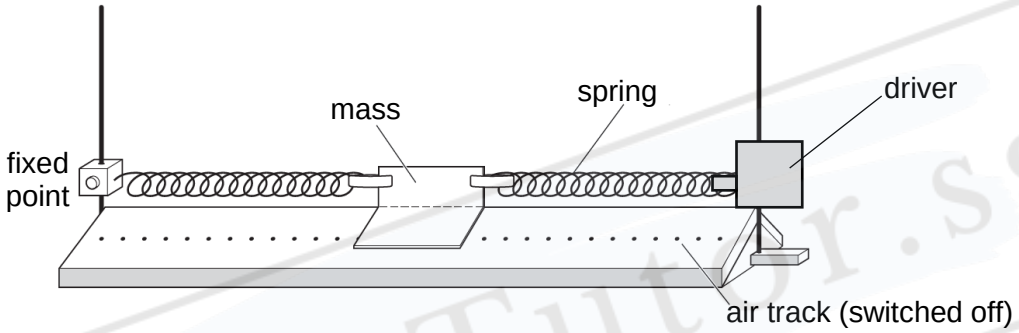

Fig. 3.3

The frequency of oscillations is gradually increased from zero. The variation of the amplitude of oscillation of the mass with driving frequency is shown in Fig. 3.4.

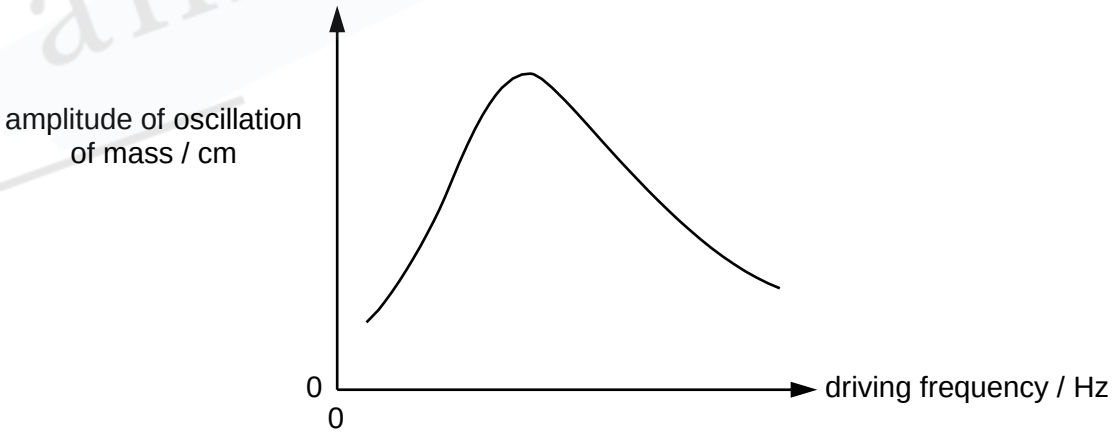

Fig. 3.4

(i) State how Fig. 3.4 shows that the mass is undergoing damped oscillations.

.....

..... [1]

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(ii) The model in Fig. 3.3 and result in Fig. 3.4 can be applied to a practical situation.

Tall buildings, such as the Taipei 101 tower as shown in Fig. 3.5, are equipped with a damping system to reduce movement of the tower in strong winds. A mass in the form of a huge sphere on support cables oscillates with the tower to reduce the effect of the wind. The oscillations of the sphere are damped with oil-filled hydraulic pistons connected to the sphere.

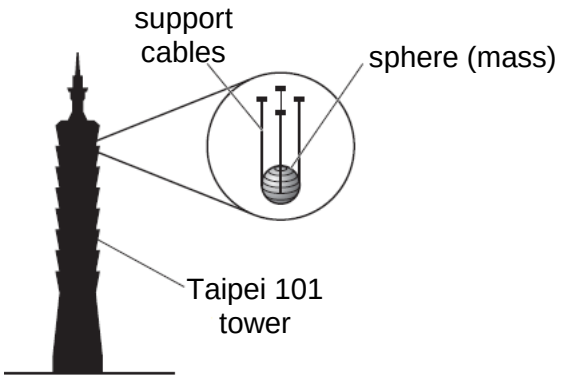

Fig. 3.5

Strong winds set the tower in oscillation. The natural frequency of oscillations of the tower is 0.15 Hz.

Suggest, by reference to energy transfer, why the frequency of the sphere-damping system must be close to 0.15 Hz to help reduce the motion of the tower.

.....

.....

.....

..... [2]

[Total: 8]

4 Coherent light of wavelength 590 nm is incident normally on a double slit, as shown in Fig. 4.1.

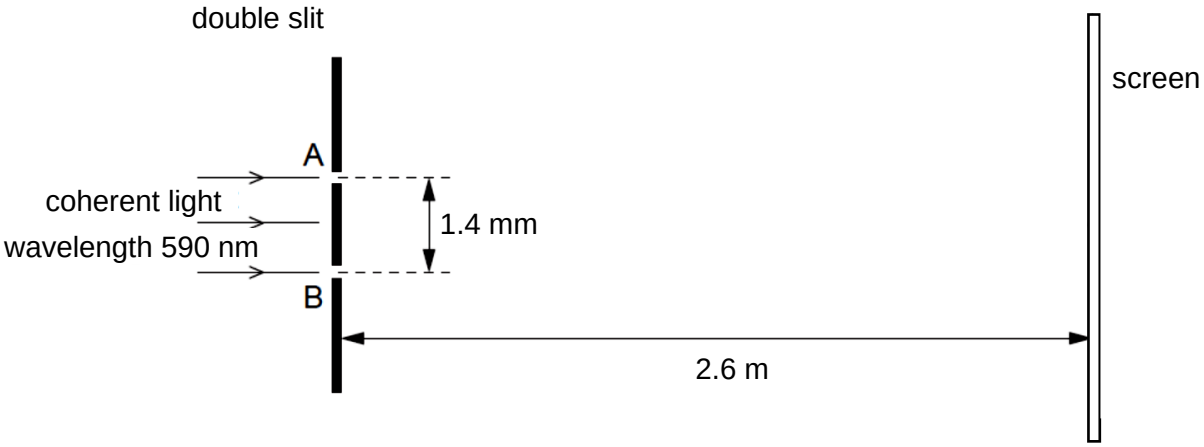

Fig. 4.1

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The separation of the slits A and B is 1.4 mm and the width of each slit is 0.15mm. A screen is placed parallel to the slits at a distance 2.6 m away.

(a) One of the slits is covered.

Calculate the width of the central maximum formed on the screen by diffraction through the uncovered slit.

width = ... cm [3]

(b) Now, both slits are uncovered.

(i) State Rayleigh's criterion.

.....

.....

..... [2]

(ii) Use Rayleigh's criterion to explain whether the diffraction pattern produced by the two slits are seen as on the screen as separate.

.....

.....

.....

.....

.....

.....

..... [3]

[Total: 8]

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5 Fig. 5.1 shows the arrangement of the apparatus used in the measurement of the magnetic flux density between the poles of a U-shaped magnet. The magnet rests on top of an electronic balance. A stiff rectangular frame measuring 8.0 cm by 5.0 cm carries a current I between the magnetic poles. The bottom edge of the frame is lowered into the region between the poles of the U-shaped magnet and is entirely within the uniform magnetic field.

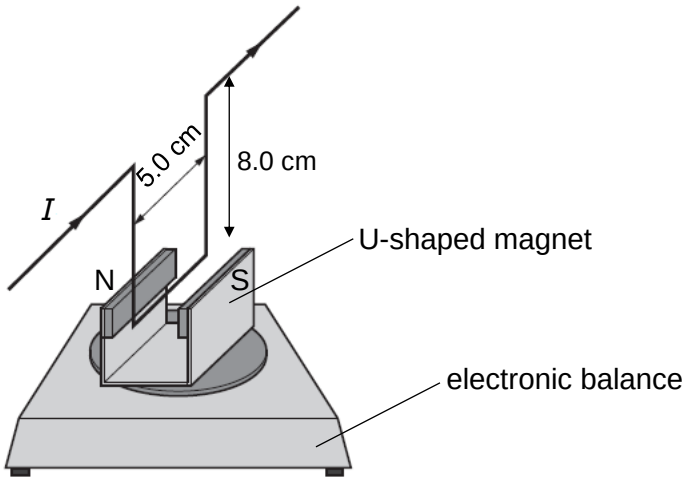

Fig. 5.1

Fig. 5.2 shows the apparatus when viewed from the front. The poles of the U-shaped magnet have been indicated.

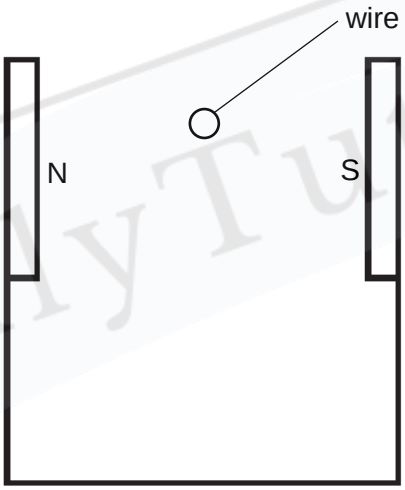

Fig. 5.2

(a) (i) Draw, on Fig. 5.2, a vertical force acting on the wire when current passes through it. Label the force *F*. [1]

(ii) When current passes through the wire, the balance reading changes.

Explain why there is a change in reading, and whether the change is an increase or decrease.

……

…… [2]

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(b) The current I is varied and the change in the balance reading is recorded as shown in Fig. 5.3.

	Change in balance reading / g				
I **/ A**	**Trial 1**	**Trial 2**	**Trial 3**	**Mean change / g**	***F*** **/ × 10^{-3} N**
0.5	0.08	0.05	0.06	0.06	0.6
1.0	0.14	0.16	0.16	0.15	1.5
1.5	0.22	0.20	0.23	0.22	2.2
2.0	0.31	0.29	0.31	0.30	2.9
2.5	0.38	0.39		0.37	3.6
3.0	0.44	0.48	0.48		

Fig. 5.3

(i) Complete the table in Fig. 5.3. [1]

(ii) On Fig. 5.4, plot the missing data point from the table in Fig. 5.3 and draw a line of best fit. [1]

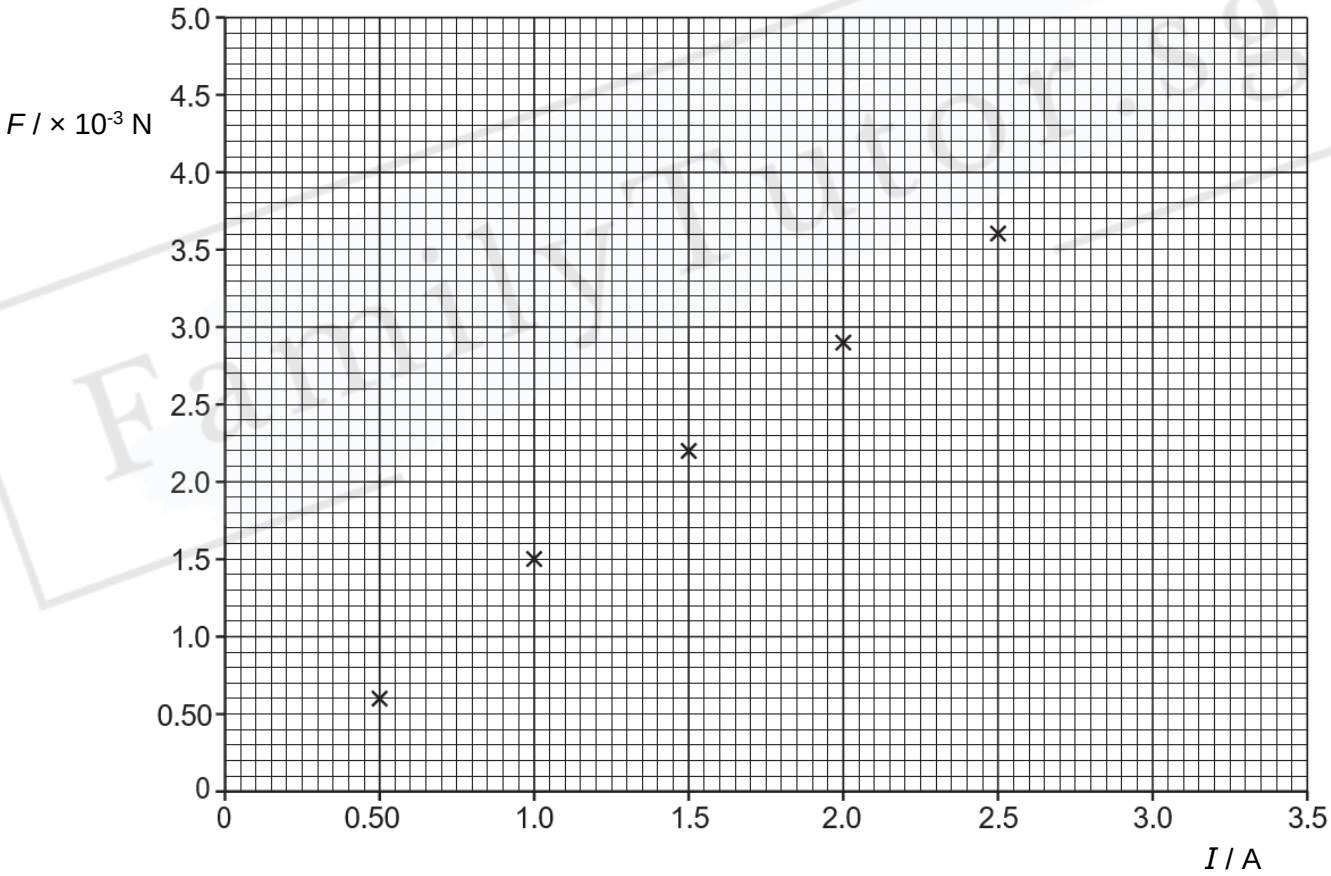

Fig. 5.4

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(iii) Use your graph to determine the value of the magnetic flux density B, in mT, between the U-shaped magnet.

B = ... mT [2]

(iv) The value of the magnetic flux density in **(b)(iii)** is slightly inaccurate for a reason which has nothing to do with human error or meter inaccuracies.

Suggest one reason that might be the cause of this inaccuracy.

.....

..... [1]

[Total: 8]

6 An a.c. power supply is connected to a resistor R, as shown in Fig. 6.1.

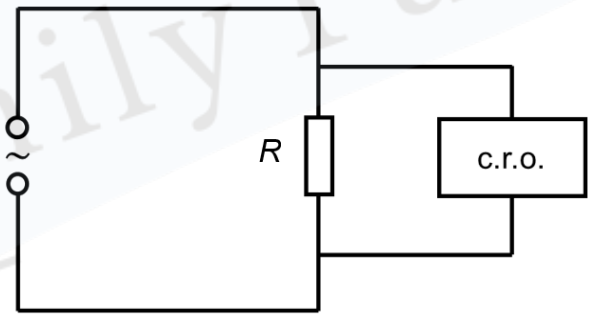

Fig. 6.1

A cathode ray oscilloscope (c.r.o.) is used to show the potential difference (p.d.) across R. The screen of the c.r.o. displays the variation with time of the p.d. across R, as shown in Fig. 6.2.

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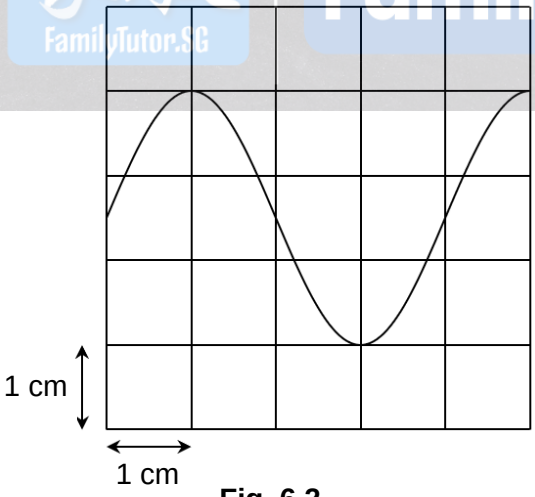

Fig. 6.2

(a) Explain, by reference to direct current, what is meant by the *root-mean-square* (r.m.s.) value of an alternating current.

……

……

…… [2]

(b) The voltage V of the power supply is given by the expression

$$V = 6.0\sin(100\pi t)$$

V is measured in volts and the time t is measured in seconds.

Determine the Y-gain and time-base of the c.r.o.

Y-gain = ... V / cm

time-base = ... ms / cm
[2]

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(c) A diode is then connected in series with the resistor *R*, as shown in Fig. 6.3.

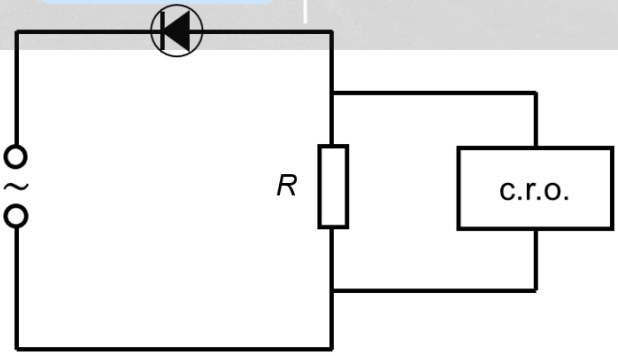

Fig. 6.3

(i) Sketch in Fig. 6.4, for 2 periods of the alternating p.d., the variation with time of the power *P* dissipated in *R* when *R* is 20 Ω, where *T* is the period. Indicate the peak power value in your sketch. [2]

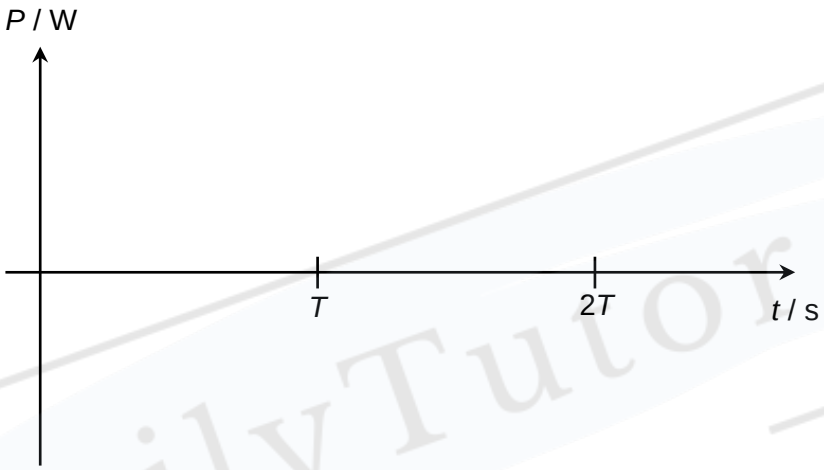

Fig. 6.4

(ii) Draw a line in Fig. 6.4 to represent the average power dissipated in *R*. Indicate its value on the y-axes. [1]

(iii) Calculate the root-mean-square current in *R*.

root-mean-square current = ... A [2]

[Total: 9]

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7 Fig. 7.1 shows what is observed when a parallel beam of electrons, accelerated by a potential difference V, is incident on a fluorescent screen.

Fig. 7.1

A carbon film is then placed perpendicularly to the path of the electron beam as shown in Fig. 7.2.

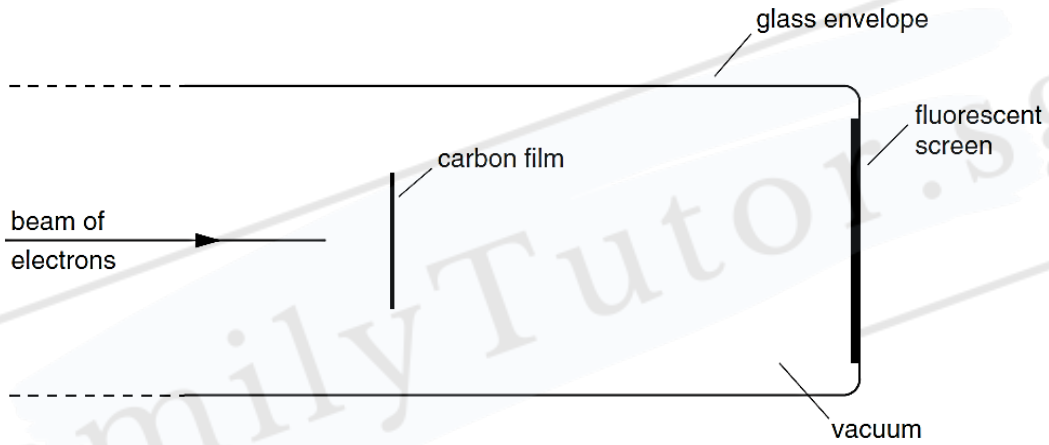

Fig. 7.2

The pattern observed on the screen is shown in Fig. 7.3.

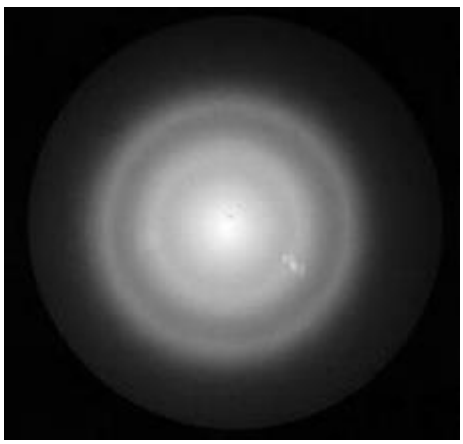

Fig. 7.3

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(a) Identify and explain two key features in Fig. 7.3 that provide evidence for the wave nature of the electrons.

……

……

……

……

……

…… [3]

(b) The electrons were accelerated through a potential difference of 2000 V.

(i) Calculate the momentum of an electron after being accelerated through a potential difference of 2000 V.

momentum = ... N s [2]

(ii) Hence, calculate the de Broglie wavelength of the electrons.

wavelength = ... m [2]

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(c) State and explain the changes, if any, that is observed in the pattern on the screen when the following changes are made separately.

(i) The potential difference used to accelerate the electrons is increased.

…….

…….

……. [2]

(ii) The current of the electron beam is increased.

…….

…….

……. [2]

[Total: 11]

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Section B

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

8 **(a)** Fig. 8.1 shows the variation of the gravitational potential ϕ with distance d from the surface of Pluto along a line joining the centers of Pluto and Charon.

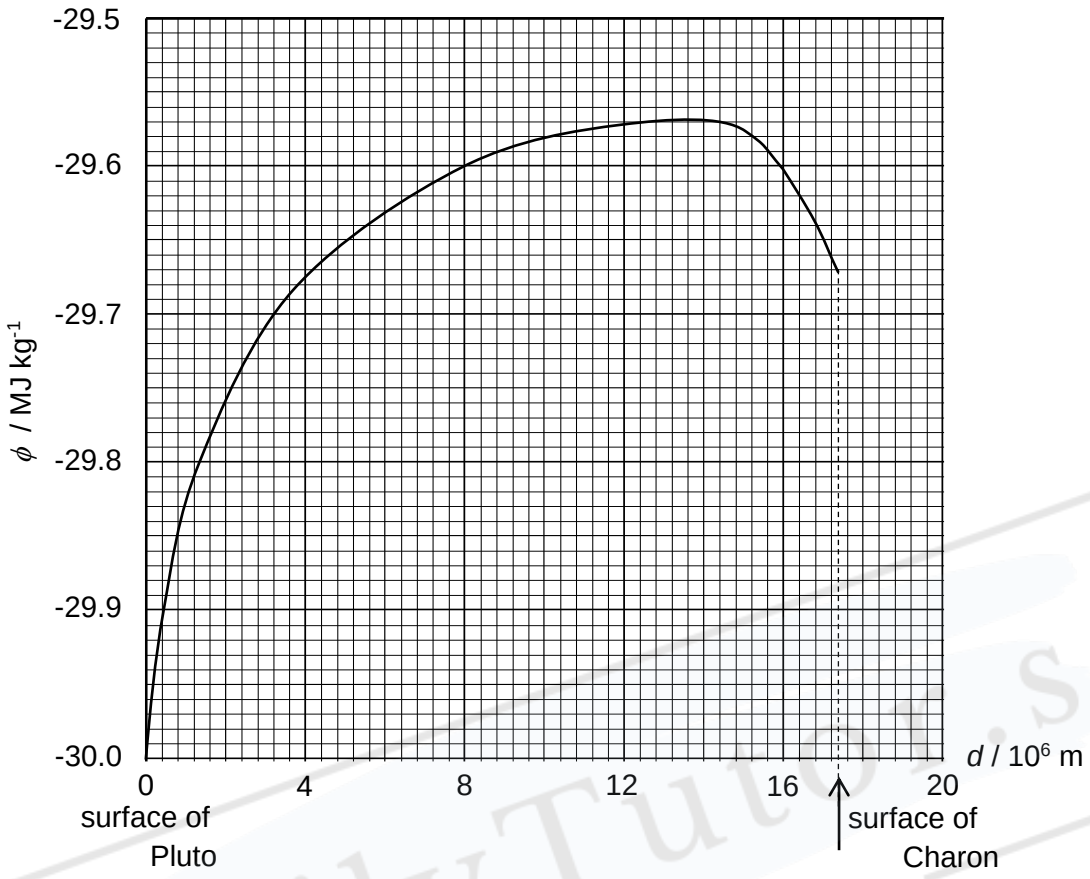

Fig. 8.1

The gravitational potential is taken as being zero at infinity.

(i) By considering the definition of gravitational potential, suggest why all values of ϕ in Fig. 8.1 are negative and explain how they may be obtained.

.....

.....

.....

.....

..... [2]

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(ii) Explain how Fig. 8.1 can be used to determine the resultant gravitational force acting on an object with mass *m* placed at a point between Pluto and Charon.

……

……

…… [2]

(iii) A lump of rock of mass 5.0 kg is ejected from the surface of Charon such that it travels towards Pluto.

1. Using data from Fig. 8.1, determine the minimum speed of the rock as it hits the surface of Pluto.

minimum speed = …… m s^{-1} [3]

2. The rock is now projected from Pluto to Charon.

State and explain how its minimum speed when it hits the surface of Charon will be different from the answer in **(a)(iii)1**.

……

……

……

……

…… [2]

(b) In another isolated planetary system, X and Y are two stars of equal mass *M* and separated by a distance 2*L*. The two stars rotate about their common centre of mass.

(i) State Newton's Law of Gravitation.

……

……

…… [1]

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(ii) Explain why the two stars will not collide with each other even though the gravitation force acting on each other are attractive.

……

……

…… [2]

(iii) Derive an expression, in terms of M, L and the gravitational constant G, for the period T of their rotation.

[2]

(c) Fig. 8.2 shows three points A, B and C relative to the stars X and Y. All three points are equidistant from both X and Y and point B lies on the straight line joining the centres of mass of X and Y.

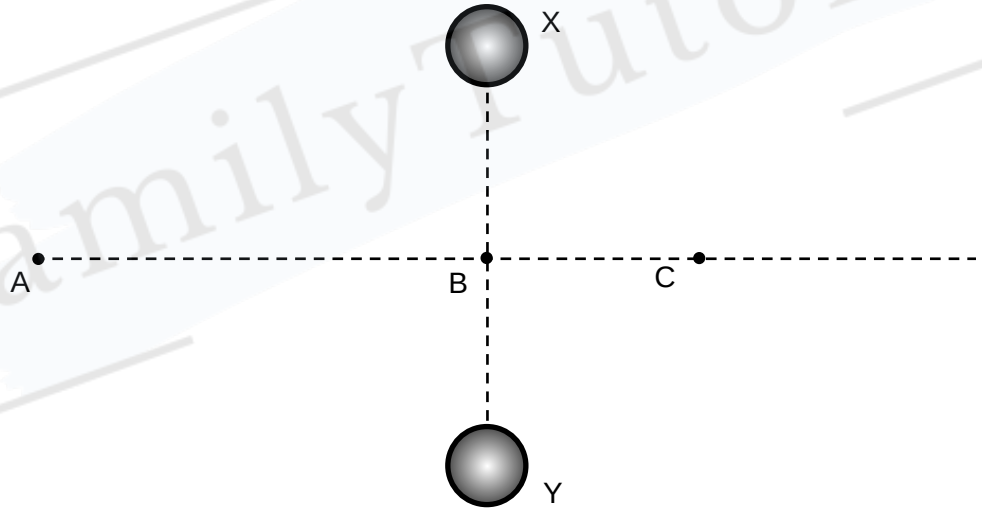

Fig. 8.2

(i) Draw arrows on Fig. 8.2 to represent the gravitational forces due to each star acting on a small mass placed separately at points A, B and C. The length of the arrow should be relative to their respective magnitudes. [2]

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(ii) Fig. 8.3 shows another schematic of X and Y. P is a point equidistant from X and Y and is at a distance *s* from the straight line joining the centers of mass of X and Y.

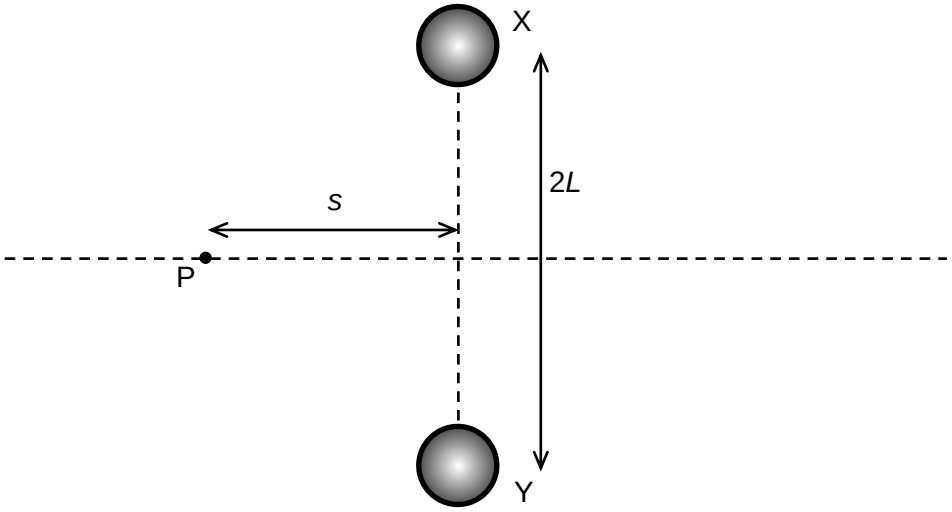

Fig. 8.3

1. Show that the magnitude of the resultant gravitational force acting on a mass *m* placed at P is

$$F_G = \frac{2GMms}{\left(s^2 + L^2\right)^{\frac{3}{2}}}$$

[2]

2. Hence, state and explain if the subsequent motion of a mass placed at rest at point P is simple harmonic.

……

……

…… [2]

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9 **(a)** One assumption of the kinetic theory of gases is that the particles of the gas make perfectly elastic collisions among themselves and with the wall of the container. State two other assumptions of the kinetic theory of gases.

……

……

……

…… [2]

(b) Consider a single molecule of mass *m* in a cuboidal container of internal side length L. The molecule is travelling with velocity *v* directly towards one of the walls W as shown in Fig 9.1.

Collisions between the molecule and the walls are elastic. This molecule makes multiple collisions in unit time. The pressure the molecule exerts on the wall is dependent on the frequency of the collisions with the wall.

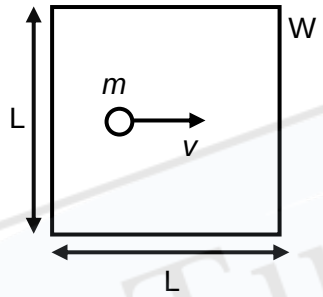

Fig. 9.1

Write expressions for

(i) the change in momentum of the molecule when it collides with wall W.

…… [1]

(ii) time between collisions of the molecule and the wall W.

…… [1]

(iii) the frequency of the collisions of the molecule with the wall W.

…… [1]

(iv) the average momentum change per unit time for this molecule.

…… [1]

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(v) the average force on wall W as a result of impacts by the molecule.

…… [2]

(vi) the average pressure of wall W.

…… [1]

(c) A cuboidal container contains *N* molecules of an ideal gas has volume V and pressure *p* given by the relation

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

where *m* is the mass of each molecule.

Explain briefly how the expression in **(b)(vi)** leads to this relation.

…… [4]

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(d) (i) Use the equation of state for an ideal gas, together with the equation given in **(c)** to show that K, the average translational kinetic energy of a molecule is proportional to its absolute temperature [3]

(ii) Calculate , for oxygen and hydrogen at the same temperature, the ratio

$$\frac{\text{root mean square speed of a hydrogen molecule}}{\text{root mean square speed of an oxygen molecule}}$$

The masses of the molecules are given the following table:

Mass of a hydrogen molecule = 3.34×10^{-27} kg
Mass of an oxygen molecule = 5.34×10^{-26} kg

Ratio = = ... N s [2]

(iii) Suggest why the atmosphere of the Earth contains very little hydrogen.

.....

.....

.....

..... [2]

[Total: 20]

End of Paper

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