Raffles Institution
Year 5-6 Physics Department

2022 H2 Physics Preliminary Examination Solution
Paper 1

Qn	Ans	Solution
1	D	$\Delta v = \frac{4.5}{100} \times 335.61 = 15.1 = 20$ (1 s.f.) $v \pm \Delta v = (340 \pm 20)$ m s^{-1} v is rounded off to the nearest tens place.
2	A	unit of σ = unit of $\left(\frac{P}{AeT^4}\right)$ = unit of $\left(\frac{W/t}{AeT^4}\right)$ = unit of $\left(\frac{F \times d}{tAeT^4}\right)$ = unit of $\left(\frac{m \times a \times d}{tAeT^4}\right)$ $= \left(\frac{\text{kg m s}^{-2}\text{ m}}{\text{s m}^2\text{ K}^4}\right) = \text{kg s}^{-3}\text{ K}^{-4}$
3	C	Take direction to the right and upwards as positive. $s_x = u_x t$ $t = \frac{s_x}{u_x} = \frac{3.4\cos 30°}{5.0\cos 60°}$ $v_y = u_y + a_y t = 5.0\sin 60° + (-9.81)\left(\frac{3.4\cos 30°}{5.0\cos 60°}\right) = -7.2240$ m s^{-1} $\tan\beta = \frac{v_y}{v_x}$, where β is the angle that the final velocity makes with the horizontal $\beta = \tan^{-1}\left(\frac{7.2240}{5.0\cos 60°}\right) = 70.911°$ $\theta = 70.911° - 30° = 40.911° = 41°$ OR ${v_y}^2 = {u_y}^2 + 2a_y s_y$ $v_y = \pm\left[(5.0\sin 60°)^2 + 2(-9.81)(-3.4\sin 30)\right]^{1/2} = -7.2183$ m s^{-1} or 7.2183 m s^{-1} (reject) $\tan\beta = \frac{v_y}{v_x}$, where β is the angle that the final velocity makes with the horizontal $\beta = \tan^{-1}\left(\frac{7.2183}{5.0\cos 60°}\right) = 70.897°$ $\theta = 70.897° - 30° = 40.897° = 41°$

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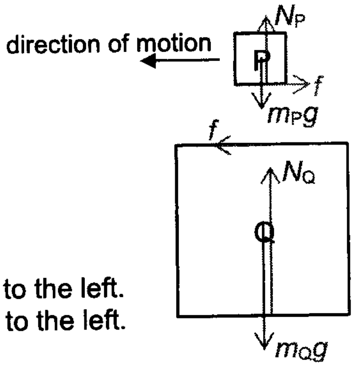
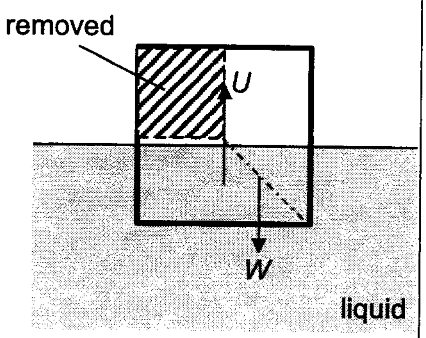
4	A	Based on the given graph, the direction upwards is positive. At time t, the ball is at its maximum height, and its displacement is +S1 (or +S2). At time $2t$, the ball is back at its initial point and is accelerating as it moves downwards (negative velocity). Hence its displacement is zero (S1 = S2) and the gradient of the displacement-time graph is negative. At time $3t$, the ball hits the ground since its velocity is $-2u$ and acceleration is constant at $-g$. Its displacement is –S3 from the initial point. From $2t$ to $3t$, since the ball is accelerating as it moves downwards, its speed increases. Hence the gradient of the displacement-time graph should be negative with increasing magnitude.
5	C	When P starts to slide: Consider block P: $-f = m_P a_P$ Consider block Q: $f = m_Q a_Q$ $-m_P a_P = m_Q a_Q$ Since $m_P < m_Q$, $\lvert a_P \rvert > \lvert a_Q \rvert$ Friction on Block P causes it to decelerate as it moves to the left. Friction on Block Q causes it to accelerate as it moves to the left. 
6	A	from the time the column is dropped to when it just reaches the surface of the soil, increase in K.E. = decrease in G.P.E $\frac{1}{2}Mv^2 - 0 = MgH$ $v = \sqrt{2gH}$ from the time the column enters the soil to the time when it comes to a stop, by Newton's second law and taking direction downwards as positive, $F_R = \frac{dp}{dt}$ $Mg - f = \frac{\Delta p}{\Delta t}$ where f is the average resistive force $Mg - f = \frac{p_f - p_i}{\Delta t}$ $Mg - f = \frac{0 - Mv}{t}$ $f = Mg + \frac{Mv}{t} = Mg + \frac{M\sqrt{2gH}}{t} = Mg\left(1 + \sqrt{\frac{2H}{gt^2}}\right)$

7	B	When a quarter of the cube is removed, the C.G. changes to the new geometrical centre and the weight decreases. Upthrust remains unchanged initially. Hence $U > W$ and there is a resultant force upwards. Since the upthrust and the weight are now not acting along the same line of action, there will be a resultant clockwise moment. 
8	B	$E_k = \frac{1}{2}m(v_x^2 + v_y^2)$ where $v_x = u_x$ and $v_y = u_y - gt$ $E_k = \frac{1}{2}m\left(u_x^2 + (u_y - gt)^2\right)$ $E_p = mgh = mg(u_y t - \frac{1}{2}gt^2)$ From the above equations, the variation with time of the energies is a quadratic relationship. By the conservation of energy, the increase in G.P.E. is equal to the decrease in K.E. as the ball moves upwards to its highest point and the decrease in G.P.E. is equal to the increase in K.E. as the ball moves downwards back to the ground. At $t = 0$ and when ball is back to the ground, $E_k = \frac{1}{2}m(u_x^2 + u_y^2)$ and $E_p = 0$ At maximum height, $v_y = 0$, $t = \frac{u_y}{g}$ $E_k = \frac{1}{2}mu_x^2$, $E_p = mgh = mg\left(\frac{u_y^2}{2g}\right) = \frac{1}{2}mu_y^2$
9	D	$F = ma = m\left(\frac{v-u}{t}\right) = \frac{mv}{t}$ since $u = 0$ $\text{K.E.} = \frac{1}{2}mv^2 = \frac{(mv)^2}{2m} = \frac{F^2t^2}{2m} \Rightarrow \text{K.E.} \propto \frac{t^2}{m}$ $\frac{\text{gain in kinetic energy of body A}}{\text{gain in kinetic energy of body B}} = \frac{\text{K.E.}_A - 0}{\text{K.E.}_B - 0}$ $= \frac{t_A^2}{m_A} \div \frac{t_B^2}{m_B}$ $= \frac{t_A^2 m_B}{t_B^2 m_A}$ $= \left(\frac{2t}{t}\right)^2 \left(\frac{2m}{m}\right)$ $= 8$

10	**D**	As the sphere moves from highest to lowest point, increase in K.E. = decrease in G.P.E. $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mg(2L)$ $v^2 = 2\left(2gL + \frac{1}{2}u^2\right)$ When the sphere is at the lowest point, $T - mg = \frac{mv^2}{L}$ $T = \frac{mv^2}{L} + mg$ $= \frac{2m\left(2gL + \frac{1}{2}u^2\right)}{L} + mg$ $= \frac{2(0.40)\left(2(9.81)(0.50) + 0.5(2.5)^2\right)}{0.50} + (0.40)(9.81)$ $= 24.62 = 25\ \text{N}$
11	**B**	Since the total energy $E_T = -\frac{GMm}{2R}$ of the satellite decreases due to work done against drag forces, its orbital radius R decreases. As R decreases, kinetic energy $E_k = \frac{GMm}{2R}$ increases, hence orbital speed increases. Since $\frac{GMm}{R^2} = m\omega^2 R = m\left(\frac{2\pi}{T}\right)^2 R \Rightarrow T^2 \propto R^3$ The orbital period T decreases as R decreases.
12	**A**	Gravitational force provides the centripetal force. $\frac{GMm}{R^2} = m\frac{v^2}{R}$ $v = \sqrt{\frac{GM}{R}} = \sqrt{\frac{G\rho\left(\frac{4}{3}\pi R^3\right)}{R}} = \sqrt{\frac{4}{3}\pi\rho G R^2} \Rightarrow v \propto \sqrt{\rho R^2}$ $\frac{v_M}{v_E} = \sqrt{\frac{\rho_M {R_M}^2}{\rho_E {R_E}^2}} = \sqrt{\frac{\rho_M {R_M}^2}{(1.25\rho_M)(4R_M)^2}}$ $v_M = \left(\sqrt{\frac{1}{1.25 \times 16}}\right)(7.90)$ $= 1.7665 = 1.77\ \text{km s}^{-1}$

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13	**D**	$pV = nRT$ $p = \frac{nRT}{V}$ $= \frac{mRT}{M_R V}$ $= \frac{(1.5)(8.31)(273.15+25)}{\left(\frac{20}{1000}\right)(3.7)}$ $= 50222 \text{ Pa} = 50 \text{ kPa}$
14	**D**	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ $\sqrt{\langle c^2 \rangle} = \sqrt{\frac{3pV}{Nm}} = \sqrt{\frac{3kT}{m}}$ $c_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.38\times10^{-23})(273.15+100)}{18(1.66\times10^{-27})}} = 719.04 = 720 \text{ m s}^{-1}$
15	**D**	Using $Q = mc\Delta\theta$ heat gained by metal = heat lost by liquid $mc(\theta_f - 20) = (3m)(2.5c)(100 - \theta_f)$ $\theta_f - 20 = 750 - 7.5\theta_f$ $8.5\theta_f = 750 + 20$ $\theta_f = 90.59 = 91$ °C
16	**A**	$E = \frac{1}{2}m\omega^2 x_0^2$ $E_p = \frac{1}{2}m\omega^2 x^2 = \frac{1}{2}m\omega^2\left(\frac{x_0}{3}\right)^2 = \frac{1}{9}E$
17	**B**	At $T/4$, the mass is at the equilibrium position where $d = 25$ cm. At $T/2$, the mass is at the highest point of its oscillation. Hence the amplitude of the oscillations is 15 cm.
18	**C**	After passing through the first polariser, intensity is halved, i.e. 20 W m^{-2}. Subsequently, the intensity after passing through the 2nd and 3rd polarisers is $I_f = \frac{1}{2}I_0\cos^2\theta\cos^2(90° - \theta) = \frac{1}{2}I_0\cos^2\theta\sin^2\theta$ $\cos\theta\sin\theta = \sqrt{\frac{2I_f}{I_0}}$ $\sin 2\theta = 2\sqrt{\frac{2I_f}{I_0}} = 2\sqrt{\frac{2\times2.5}{40}} = \frac{1}{\sqrt{2}}$ $\theta = 22.5°$

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19	B	Table shows $\sin\theta = \dfrac{n\lambda}{d}$ <table><tr><td>order</td><td>violet (400 nm)</td><td>red (700 nm)</td></tr><tr><td>1</td><td>$\dfrac{400\text{ nm}}{d}$</td><td>$\dfrac{700\text{ nm}}{d}$</td></tr><tr><td>2</td><td>$\dfrac{800\text{ nm}}{d}$</td><td>$\dfrac{1400\text{ nm}}{d}$</td></tr><tr><td>3</td><td>$\dfrac{1200\text{ nm}}{d}$</td><td>$\dfrac{2100\text{ nm}}{d}$</td></tr></table> Since $\dfrac{1200\text{ nm}}{d} < \dfrac{1400\text{ nm}}{d}$, 3rd order spectrum overlaps with the 2nd order spectrum.
20	B	The constant electric force on the electron is pointing vertically downwards, in the direction of increasing potential. $\lvert E\rvert = \left\lvert -\dfrac{\Delta V}{\Delta x}\right\rvert = \dfrac{2V}{d} \Rightarrow \lvert\Delta V\rvert = \lvert E\rvert(\Delta x) = \dfrac{2V}{d}(\Delta x)$ where Δx is the vertical distance work done by external force, $W = q(\Delta V) = -e(V_f - V_i)$ From X to Y: This is along an equipotential line. Since there is no change in potential, the work done is zero. From Y to Z: decrease in potential energy $W_{YZ} = (-e)(V_Z - V_Y) = (-e)\left(\dfrac{2V}{d}(\Delta x)\right) = -\dfrac{2V}{d} er\cos 30° = -\dfrac{2V}{d} er\sin 60°$ From Z to X: increase in potential energy $W_{ZX} = (-e)(V_X - V_Z) = (-e)\left(-\dfrac{2V}{d}(\Delta x)\right) = \dfrac{2V}{d} er\cos 30° = \dfrac{2V}{d} er\sin 60°$
21	B	increase in K.E. = decrease in E.P.E. $\dfrac{1}{2}mv^2 - 0 = q\lvert\Delta V\rvert$ $v = \sqrt{\dfrac{2q\lvert\Delta V\rvert}{m}} = \sqrt{\dfrac{2qEd}{m}} \Rightarrow v \propto \sqrt{Ed}$ for the same charge to mass ratio $\dfrac{v_2}{v_1} = \sqrt{\dfrac{E_2 d_2}{E_1 d_1}}$ $v_2 = \left(\sqrt{\dfrac{2E(2d)}{Ed}}\right)v$ $= 2v$

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22	C	$I_T = I_1 + I_2$ $\frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2}$ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ Since the resistors are in parallel, the p.d. across each resistor is the same.
23	C	$V_X = R_X I$ The graph for X is a straight line with positive gradient and it passes through the origin. $V_Y = E - R_X I$ The graph for Y is a straight line with negative gradient and positive vertical intercept, *E*. The current through the 2 resistors is always the same at any time. The total p.d. across the 2 resistors is always *E*. Hence as the reading of Y decreases, the reading of X increases.
24	D	For a long straight wire, $B = \frac{\mu_0 I}{2\pi d}$ At Q, $B_Q = B_{\text{earth}} - (B_{\text{due to P}} + B_{\text{due to R}})$ $= (2.0 \times 10^{-5}) - 2\left(\frac{(4\pi \times 10^{-7})(1.0)}{2\pi(0.30)}\right)$ $= 1.8667 \times 10^{-5}$ T (northwards) $\frac{F}{L} = B_Q I_Q = (1.8667 \times 10^{-5})(2.0)$ $= 3.7334 \times 10^{-5} = 3.7 \times 10^{-5}$ N m^{-1} Using Fleming's Left Hand Rule, the direction of the force is towards the West.
25	A	In field Y, the magnetic forces on the sides QR and PS of the coil are constant in magnitude, and they always act perpendicularly to the area of the coil, even as the coil rotates. This means the distance between the forces remains the same. Hence the torque on the coil is constant in magnitude throughout its rotation.
26	B	The p.d. induced between the centre and the edge of the disc is $V = BAf$, where *A* is the area of the disc, πr^2. Hence, $V = B(\pi r^2)\left(\frac{\omega}{2\pi}\right) = \frac{1}{2}Br^2\omega$, where $\omega = 2\pi f$. Since XY $= \frac{r}{2}$, $V_{XY} = \frac{1}{2}B\left(\frac{r}{2}\right)^2 \omega = \frac{1}{4}V$.
27	C	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$ $N_p = \frac{V_p}{V_s} N_s = \frac{120\sqrt{2}}{8.0}(250) = 5303 = 5300$

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28	**C**	The range of wavelengths for visible light is 400 nm to 700 nm. Since $E=\frac{hc}{\lambda}$, the energies of these photons range from $\frac{(6.63\times10^{-34})(3.00\times10^{8})}{(700\times10^{-9})(1.60\times10^{-19})}=1.7759$ eV to $\frac{(6.63\times10^{-34})(3.00\times10^{8})}{(400\times10^{-9})(1.60\times10^{-19})}=3.1078$ eV. Only 3 transitions will result in emissions of such photons: $6.12-4.28=1.84$ eV $6.81-4.28=2.53$ eV $7.02-4.28=2.74$ eV
29	**D**	When each electron is accelerated through the electric field, increase in K.E = decrease in E.P.E. final K.E. of electron $-0=\lvert -e\Delta V\rvert$ The X-ray photon with the shortest wavelength is produced when an electron loses all its K.E. (maximum loss in K.E. possible) to form the highest energy X-ray photon. final K.E. of electron $-0=\frac{hc}{\lambda_{min}}$ $\lambda_{min}=\frac{hc}{\lvert -e\Delta V\rvert}=\frac{(6.63\times10^{-34})(3.00\times10^{8})}{(1.60\times10^{-19})(30\times10^{3})}=4.1438\times10^{-11}=4.1\times10^{-11}$ m
30	**C**	initial count rate of source alone, $C_0=100-20=80\text{ s}^{-1}$ no. of half-lives, $n=\frac{t}{t_{1/2}}=\frac{60}{20}=3$ $\frac{C}{C_0}=\left(\frac{1}{2}\right)^n$ $C=\left(\frac{1}{2}\right)^n C_0=\left(\frac{1}{2}\right)^3(80)$ recorded count rate $=\left(\frac{1}{2}\right)^3(80)+20=30\text{ s}^{-1}$

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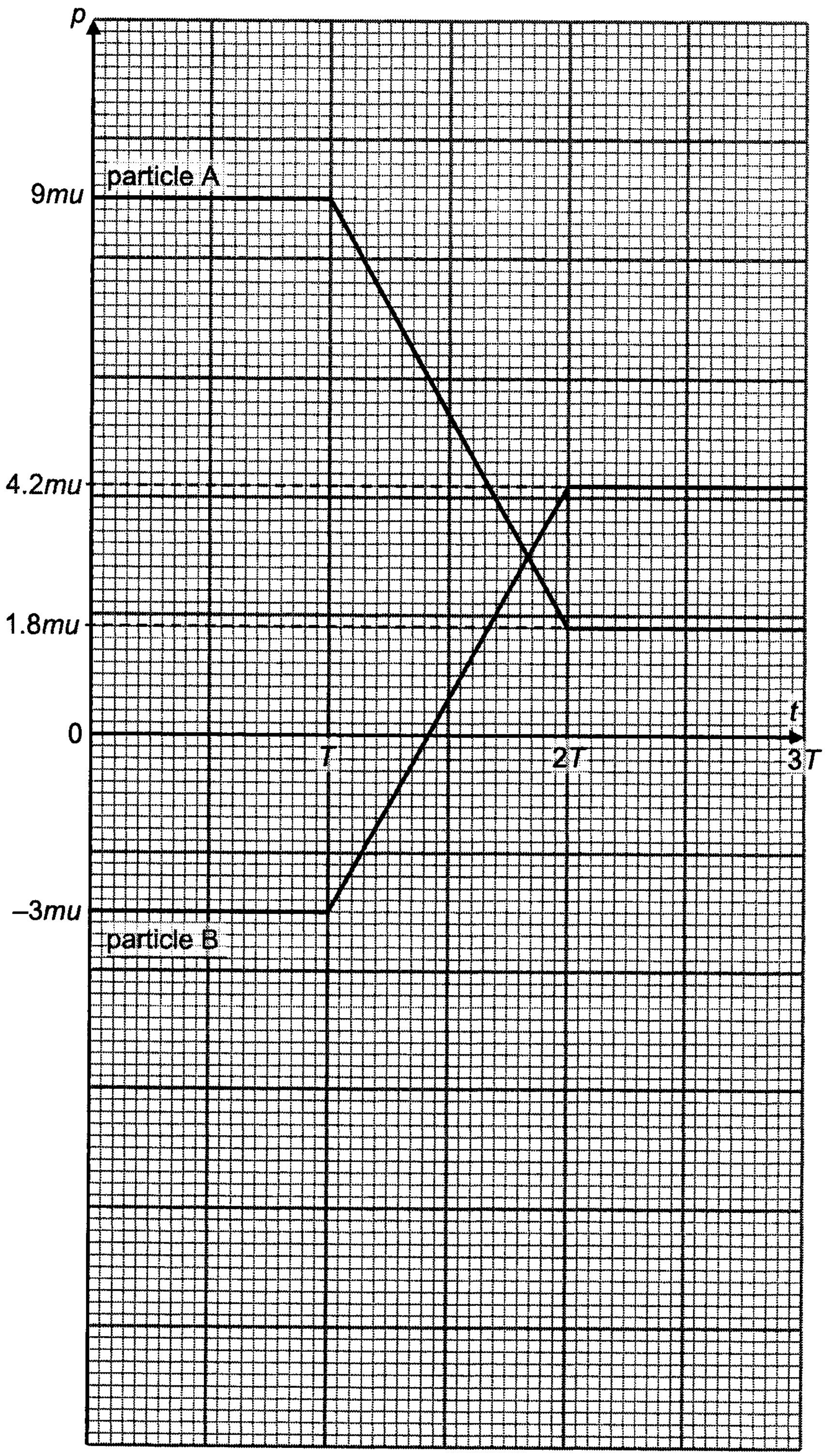
2022 H2 Physics Preliminary Examination Solution (JC)

Paper 2

1 (a) (i)



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(ii) As there are no **resultant** external forces acting in the horizontal direction on the system of particles A and B, total momentum of the system is conserved in the horizontal direction by the principle of conservation of momentum.

Since the momentum of particle A decreases by 7.2*mu* (36 small squares) after the collision, the momentum of particle B should increase by 7.2*mu* (36 small squares) so that the total momentum remains constant at all times.
OR
Since the momentum before the collision is 6.0*mu*, the total momentum of the system remains constant at 6.0*mu* at all times.

(b) Solution 1
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.

Solution 2
kinetic energy, $E_k = \frac{1}{2}mv^2 = \frac{1}{2}\frac{(mv)^2}{m} = \frac{p^2}{2m}$

before collision:
$$E_{k,before} = \frac{{p_{A,before}}^2}{2m_A} + \frac{{p_{B,before}}^2}{2m_B} = \frac{(9mu)^2}{2(9m)} + \frac{(-3mu)^2}{2m} = 9mu^2$$
after collision:
$$E_{k,after} = \frac{{p_{A,after}}^2}{2m_A} + \frac{{p_{B,after}}^2}{2m_B} = \frac{(1.8mu)^2}{2(9m)} + \frac{(4.2mu)^2}{2m} = 9mu^2$$

Since the kinetic energy of the system before and after the collision remains the same, the collision is elastic.

(c) By Newton's second law, **resultant** force $F_R = \frac{dp}{dt}$, which is given by the gradient of the graph in Fig. 1.1.

During collision, from $t = T$ to $t = 2T$, the gradient of the graph for particle A is $-\frac{7.2mu}{T}$. The gradient of the graph for particle B is $\frac{7.2mu}{T}$.

Hence the horizontal resultant force on particle A, which is the force on A by B has magnitude $\frac{7.2mu}{T}$ and the horizontal resultant force on particle B, which is the force on B by A also has the same magnitude of $\frac{7.2mu}{T}$.

Since the gradients have opposite signs, this imply that the two forces are opposite in direction.

This is consistent with Newton's third law as the force on A by B and the force on B by A are equal in magnitude and opposite in direction.

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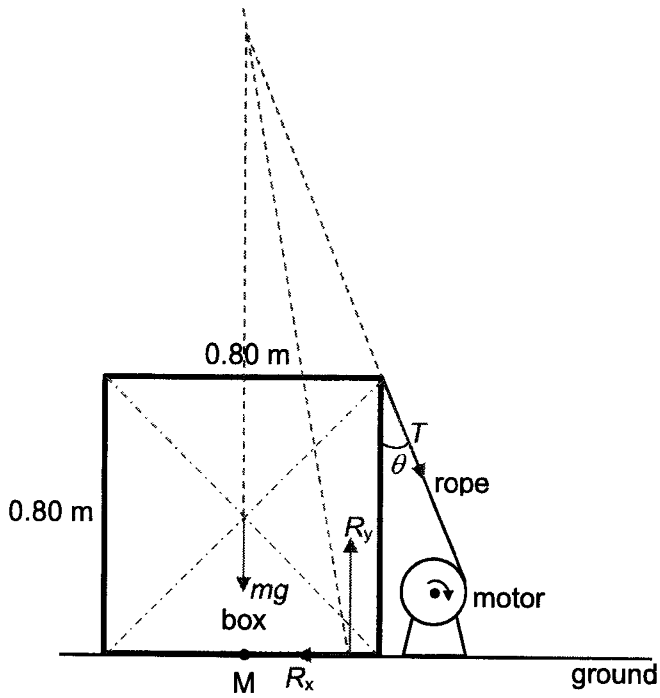
2



(a) Since the wheel is in rotational equilibrium,

$Tr = \tau$

$T = \dfrac{\tau}{r} = \dfrac{5.0}{0.20} = 25\text{ N}$

(b) Since the box is in equilibrium,
horizontally, (not required to answer this part)

$T_x - R_x = 0$

$R_x = T\sin 20°$

vertically,

$R_y - T_y - mg = 0$

$R_y = T\cos 20° + mg$

By the principle of moments, taking moments about point M,

$$R_y d = T_x h + T_y\left(\frac{h}{2}\right)$$

$$d = \frac{h}{R_y}\left(T_x + \frac{1}{2}T_y\right)$$

$$= \frac{0.80}{T\cos 20° + mg}\left(T\sin 20° + \frac{T\cos 20°}{2}\right)$$

$$= \frac{0.80T}{T\cos 20° + mg}(\sin 20° + 0.5\cos 20°)$$

$$= \frac{0.80(25)}{25\cos 20° + 2.0(9.81)}(\sin 20° + 0.5\cos 20°)$$

$$= 0.3766 = 0.377\text{ m}$$

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(c) Solution 1
As θ increases, the increased clockwise moment about point M due to the tension exceeds the maximum anticlockwise moment possible due to the normal contact force when the normal contact force is at the corner ($d = 0.40$ m) of the box. The box will rotate clockwise about the bottom right corner.

Solution 2
As θ increases, d increases to balance the increasing moment due to the tension and if $d > 0.40$ m, this implies that the contact force needs to act outside the box for the box to be in equilibrium. Since it is not possible for the contact force to act outside the box, there is a maximum value for θ.

Solution 3
As θ increases, the horizontal component of the tension in the rope increases. If the horizontal component exceeds the maximum friction on the box by the ground, the box will slide.

3 (a) $\omega = \frac{v}{r} = \frac{0.240}{0.080} = 3.0 \text{ rad s}^{-1}$

(b) (i) Consider vertical equilibrium of the bob,

$$T\cos\theta = mg$$

$$T = \frac{mg}{\cos\theta} = \frac{1.5 \times 9.81}{\cos 30°} = 16.991 = 17.0 \text{ N}$$

(ii) The horizontal component of tension provides the centripetal force for the bob's horizontal circular motion.

$$T\sin\theta = m\omega^2 R$$

$$T\sin\theta = m\omega^2 (d + L\sin\theta)$$

$$d = \left(\frac{T}{m\omega^2} - L\right)\sin\theta = \left(\frac{16.991}{1.5 \times 3.0^2} - 0.250\right)\sin 30° = 0.5043 = 0.504 \text{ m}$$

(c) The weight of the bob is always acting vertically downwards. Hence the tension in the string needs to have an upward vertical component to keep it in vertical equilibrium. So the string cannot be horizontal and θ must be smaller than 90°.

The statement is valid.

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4 (a) The gravitational force due to a mass is always attractive. Hence, the external force required to bring a small test mass from infinity to a point in the gravitational field of the mass always acts in the opposite direction to the displacement of the small test mass. The work done per unit mass by the external force is thus negative and gravitational potential is always negative.

The electric force due to a negative or positive source charge on a small positive test charge is attractive or repulsive respectively.

For a negative source charge, the external force required to bring the small (positive) test charge from infinity to a point in the electric field acts in the opposite direction to the displacement of the small test charge. The work done per unit positive charge by the external force is thus negative and electric potential is negative.

For a positive source charge, the external force required to bring the small (positive) test charge from infinity to a point in the electric field acts in the same direction as the displacement of the small test charge. The work done per unit positive charge by the external force is thus positive and electric potential is positive.

(b) (i) 1. The gravitational force on the moon by the planet provides the centripetal force.

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{GM}{r}} = \sqrt{-\phi} \qquad \text{since } \phi = -\frac{GM}{r}$$

when $r = 1.07 \times 10^6$ km $= 10.7 \times 10^8$ m, $\phi = -1.2 \times 10^8$ J kg^{-1}

$$v = \sqrt{-\phi}$$
$$= \sqrt{-(-1.2 \times 10^8)}$$
$$= 10954 = 1.10 \times 10^4 \text{ ms}^{-1}$$

2. total energy $= E_p + E_k$

$$= m\phi + \frac{1}{2}mv^2$$
$$= m\phi - \frac{1}{2}m\phi$$
$$= \frac{1}{2}m\phi$$
$$= \frac{1}{2}(1.48 \times 10^{23})(-1.2 \times 10^8)$$
$$= -8.88 \times 10^{30} \text{ J}$$

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(ii) **1.** at the surface of the planet: $r = 0.7\times10^8$ m, $\phi_i = -18.1\times10^8$ J kg^{-1}

when the K.E. of the rock is zero, by conservation of energy,

$$E_i = E_f$$

$$m\phi_i + \frac{1}{2}mv^2 = 0 + m\phi_f$$

$$\phi_f = \phi_i + \frac{1}{2}v^2$$

$$= (-18.1\times10^8) + \frac{1}{2}(45\times10^3)^2$$

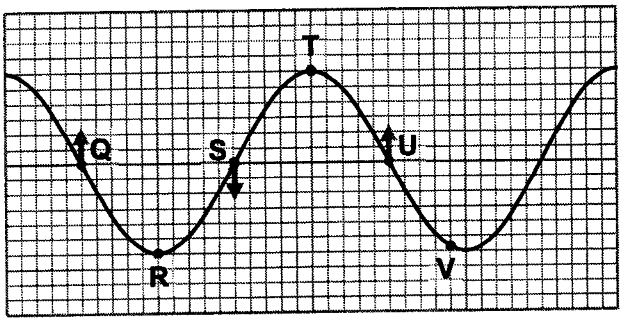
$$= -7.975\times10^8 = -7.98\times10^8 \text{ J kg}^{-1}$$

Since the gravitational potential of the rock is negative when its kinetic energy is zero, the rock cannot reach infinity to escape.

2. From Fig 4.1, when $\phi_f = -7.98\times10^8$ J kg^{-1}, $r = 1.6\times10^8$ m

max. distance from surface $= (1.6-0.7)\times10^8 = 9.0\times10^7$ m

5 **(a)**



(b) Particles R and T are momentarily at rest.

I **(i)** in phase: any pair of points a wavelength apart

(ii) In antiphase: any pair of points half-wavelength apart

(d) Particle U leads particle V by a phase of

$$\frac{\Delta x}{\lambda}\times 2\pi = \frac{\text{4 small squares}}{\text{20 small squares}}\times 2\pi = 0.4\pi \text{ rad}$$

Therefore, V leads U by a phase of $\phi = 2\pi - 0.4\pi = 5.0265 = 5.03$ rad

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6 (a) (i)

$$P=\frac{V^2}{R}$$

$$R=\frac{V^2}{P}=\frac{(6.0)^2}{3.0}=12\ \Omega$$

(ii)

$$R=\frac{\rho L}{A}$$

$$\rho=\frac{RA}{L}$$

$$=\frac{(12)\left(\pi\times\left(\frac{78\times10^{-6}}{2}\right)^2\right)}{0.020}$$

$$=2.8670\times10^{-6}=2.87\times10^{-6}\ \Omega\ \text{m}$$

(iii) The value of the resistivity calculated in (a)(ii) is about 50 times that stated in the table of constants.

The table of constants states the resistivity of tungsten at room temperature whereas the resistivity value in (a)(i) is the resistivity at a much higher temperature when the light bulb is in use.

When temperature increases, the lattice ions in tungsten gain thermal energy and vibrate with larger amplitudes. This increases the collisions between the free electrons and the lattice ions which hinder the movement of the electrons. Hence, resistivity increases with increasing temperature.

(b) (i)

p.d. across Y, $V_Y=\left(\frac{\frac{R}{2}}{\frac{R}{2}+\frac{R}{4}}\right)(6.0)=4.0\text{ V}$

current through Y, $I_Y=\frac{V_Y}{R}=\frac{4.0}{12}\text{ A}$

$$Q=I_Y t$$

$$=\left(\frac{4.0}{12}\right)(2\times60)$$

$$=40\text{ C}$$

(ii) Consider $I=Anvq=Anev$.

Since both filaments are identical, *Ane* is constant. Hence the current I through the filament is directly proportional to the mean drift velocity v of the electrons in the filament i.e. $I\propto v$.

The current through Y is twice the current through Z as the potential difference across Y is twice the potential difference across Z (OR the total current flowing through 2 bulbs and 4 bulbs in parallel are equal).

Therefore, the mean drift velocity of the electrons in Y is twice that of the electrons in Z.

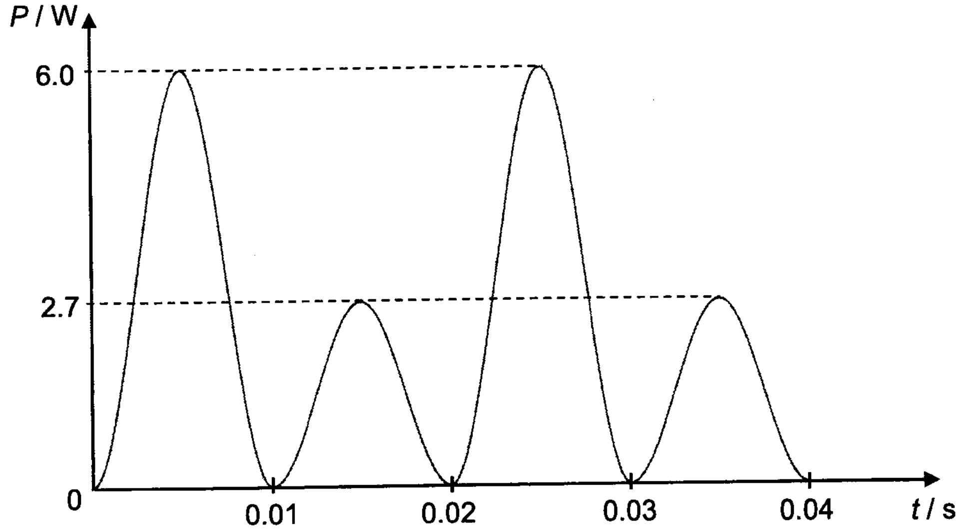
(c) **Diode in forward bias** *(current flows through the parallel arrangement of 2 bulbs on the left, and only through the diode on the right)* :

$V_Y = 6.0$ V , peak power in $Y = 2(3.0) = 6.0$ W

Diode in reverse bias *(current flows through the parallel arrangement of 4 bulbs on the right, and the parallel arrangement of 2 bulbs on the left)* :

$V_Y = 4.0$ V , peak power in $Y = 2\left(\frac{4.0^2}{12}\right) = 2.6667 = 2.7$ W

$T = \frac{1}{f} = \frac{1}{50} = 0.02$ s



7 (a) (i) Solution 1

$A_0 = \lambda N_0$

$= \left(\frac{\ln 2}{50.2 \times 60 \times 60}\right)\left(\frac{2.00 \times 10^{-9}}{240 \times 10^{-3}} \times (6.02 \times 10^{23})\right)$

$= 1.9241 \times 10^{10} = 1.92 \times 10^{10}$ Bq

Solution 2

$A_0 = \lambda N_0$

$= \left(\frac{\ln 2}{50.2 \times 60 \times 60}\right)\left(\frac{2.00 \times 10^{-9}}{240 \times 1.66 \times 10^{-27}}\right)$

$= 1.9254 \times 10^{10} = 1.93 \times 10^{10}$ Bq

(ii) number of decays required $= \frac{1140}{(5.71 \times 10^{6})(1.60 \times 10^{-19})}$

$= 1.2478 \times 10^{15} = 1.25 \times 10^{15}$

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(iii) Solution 1

$$N_{required} = N_i - N_f$$
$$= N_0 - N_0 e^{-\lambda t}$$
$$1.25\times10^{15} = \left(\frac{2.00\times10^{-9}}{240\times10^{-3}}\times\left(6.02\times10^{23}\right)\right)\left(1-e^{-\frac{\ln 2}{50.2}t}\right)$$
$$0.249 = 1-e^{-\frac{\ln 2}{50.2}t}$$
$$t = -\frac{50.2}{\ln 2}\times\ln 0.751$$
$$= 20.738 = 20.7 \text{ h}$$

Solution 2

$$N_{required} = N_i - N_f$$
$$= N_0 - N_0 e^{-\lambda t}$$
$$1.25\times10^{15} = \left(\frac{2.00\times10^{-9}}{240\times1.66\times10^{-27}}\right)\left(1-e^{-\frac{\ln 2}{50.2}t}\right)$$
$$0.249 = 1-e^{-\frac{\ln 2}{50.2}t}$$
$$t = -\frac{50.2}{\ln 2}\times\ln 0.751$$
$$= 20.738 = 20.7 \text{ h}$$

(b) The statement is incorrect because the activity of a radioactive sample is also proportional to the number of radioactive nuclei (besides being inversely proportional to its half-life).

So radioactive materials with a long half-life can have high activity if the number of radioactive nuclei is large.

8 (a) (i) 1.

$$d = \frac{\text{velocity of droplets}}{\text{frequency of droplet emission}}$$
$$= \frac{20}{110000}$$
$$= 1.8182\times10^{-4} \text{ m} = 182\,\mu\text{m}$$

2.

$$\text{mass of droplet} = \rho\left(\frac{4}{3}\pi r^3\right)$$
$$= \left(\frac{0.84\times10^{-3}}{10^{-6}}\right)\left(\frac{4}{3}\pi\right)\left(\frac{80\times10^{-6}}{2}\right)^3$$
$$= 2.2519\times10^{-10} = 2.25\times10^{-10} \text{ kg}$$

(ii) 1.

$$F = \frac{q^2}{4\pi\varepsilon_0 d^2}$$
$$= \frac{\left(-1.0\times10^{-13}\right)^2}{4\pi\left(8.85\times10^{-12}\right)\left(182\times10^{-6}\right)^2}$$
$$= 2.71\times10^{-9} \text{ N} = 2.7 \text{ nN (shown)}$$

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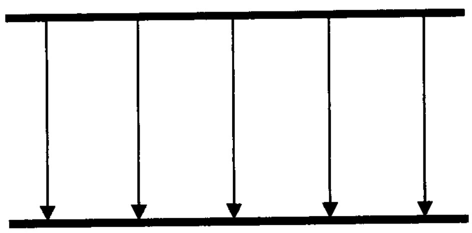
2. $a = \frac{F}{m}$

$= \frac{2.71 \times 10^{-9}}{2.25 \times 10^{-10}}$

$= 12.0444 = 12.0 \text{ m s}^{-2}$

(iii) The "guard droplets" increase the distance between the charged droplets, reducing the large accelerations due to the electrostatic forces, which could have caused uneven or irregular printing due to uneven spacing of the droplets / changing velocities of droplets / droplets colliding with one another.

(b) (i)



(ii) $E = \frac{\Delta V}{d} = \frac{10000}{0.010} = 1.0 \times 10^{6} \text{ N C}^{-1}$

(iii) 1. Perpendicularly out of the page.

2. The magnetic force provides the centripetal force.

$Bqv = \frac{mv^2}{r}$

$B = \frac{mv}{rq}$

$= \frac{(2.25 \times 10^{-10})(20)}{(0.260)(1.0 \times 10^{-13})}$

$= 1.7308 \times 10^{5} = 1.73 \times 10^{5} \text{ T}$

It is not practical / feasible to use a magnetic field to deflect an ink droplet as the required magnetic flux density is too large. (As a reference, MRI machines operate at around 1.5 T to 3 T, and those are already considered very strong magnetic fields that require many safety protocols during its operation!)

(c) (i) $Q = Pt$

$= I^2Rt$

$= (0.50)^2(30)(0.010 \times 10^{-6})$

$= 7.5 \times 10^{-8} \text{ J}$

(ii) $Q = mc\Delta\theta + ml_v = 7.5 \times 10^{-8} \text{ J}$

$m = \frac{7.5 \times 10^{-8}}{(2090)(80-25) + (444 \times 10^{3})}$

$= 1.3418 \times 10^{-13} = 1.34 \times 10^{-13} \text{ kg}$

(iii) $V = \frac{m}{\rho} = \frac{1.34 \times 10^{-13}}{\left(1.17 \times 10^{-3}\right)/10^{-6}} = 1.1453 \times 10^{-16}\ \text{m}^3$

$$x = \frac{1.1453 \times 10^{-16}}{\left(20 \times 10^{-6}\right)^2}$$
$$= 2.8632 \times 10^{-7}$$
$$= 0.286 \times 10^{-6}\ \text{m} = 0.286\,\mu\text{m}$$

(iv) There are significant heat losses to the surroundings and not all of the heat produced from the heating element goes into heating the ink layer.

(d) Advantage: Thermal inkjet printing has much higher resolution, resulting in better image quality, due to smaller droplet sizes for thermal inkjet printer at 10 μm compared to CIJ printer's at 80 μm.

Disadvantage: Thermal inkjet printing has much smaller printing speeds due to a lower frequency of droplet ejection for thermal inkjet printer at 18 kHz compared to CIJ printer's at 110 kHz.

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2022 H2 Physics Preliminary Examination Solution (JC)

Paper 3 – Section A

1 (a) The gas molecules exert no intermolecular forces on one another except during collisions.

(b) (i) 1. $p_B V_B = n_B R T_B$

$$n_B = \frac{p_B V_B}{R T_B}$$

$$= \frac{(2.0\times10^5)(3.0\times10^{-2})}{(8.31)(300)}$$

$$= 2.4067 = 2.4 \text{ mol (shown)}$$

2. Solution 1

total internal energy $= U_A + U_B$

$$= \frac{3}{2}p_A V_A + \frac{3}{2}p_B V_B$$

$$= \frac{3}{2}(3.0\times10^5)(2.0\times10^{-2}) + \frac{3}{2}(2.0\times10^5)(3.0\times10^{-2})$$

$$= 18000 \text{ J}$$

Solution 2

total internal energy $= U_A + U_B$

$$= \frac{3}{2}n_A R T_A + \frac{3}{2}n_B R T_B$$

$$= \frac{3}{2}(1.8)(8.31)(400) + \frac{3}{2}(2.4)(8.31)(300)$$

$$= 17949.6 = 17900 \text{ J}$$

(ii) 1. Total internal energy is conserved as this container is a closed system.

total internal energy $= U_A' + U_B' = 17900$

$$\frac{3}{2}n_A RT + \frac{3}{2}n_B RT = 17900$$

$$\frac{3}{2}RT(n_A + n_B) = 17900$$

$$T = (17900)\left(\frac{2}{3}\right)\left(\frac{1}{(8.31)(1.8+2.4)}\right)$$

$$= 341.91 = 342 \text{ K}$$

2. As gas A is at a higher pressure than gas B, it expands and does work against the pressure of gas B, hence work done W on gas A is negative.

As gas A is at a higher temperature than gas B, heat is transferred from gas A to gas B, hence heat supplied Q to gas A is negative.

Since $\Delta U = Q + W$, the increase in internal energy ΔU is negative which implies that the internal energy of gas A decreases. Since $\Delta U \propto \Delta T$ (or $U = \frac{3}{2}nRT$), the temperature of gas A decreases.

(iii) Vacuum does not contain any particles and has no pressure. Hence in expanding, gas A does no work and does not transfer heat to any other body. Hence by the first law of thermodynamics, there is no change in internal energy and no change in temperature.

2 (a) (i) x_0 is the decrease in height of the load and is the extension of the spring when the load is at the equilibrium position.

decrease in G.P.E. $= mgx_0$

Solution 1

magnitude of the external force at the equilibrium position, $F = mg$

increase in E.P.E. $= \frac{1}{2}Fx_0 = \frac{1}{2}mgx_0$

Solution 2

increase in E.P.E. $= \frac{1}{2}kx_0^2 = \frac{1}{2}(kx_0)x_0 = \frac{1}{2}mgx_0$

where k is the spring constant and $kx_0 = mg$ at equilibrium

comparing the expressions for G.P.E. and E.P.E,
decrease in G.P.E. = 2 × increase in E.P.E. (shown)

(ii) The decrease in G.P.E. is greater than the increase in E.P.E. as there is negative work done by the external force in lowering the load slowly.

(b) (i) at equilibrium, $kx_0 = mg \Rightarrow k = \frac{mg}{x_0}$ where k is the spring constant

$$\text{E.P.E. at lowest point} = \frac{1}{2}ke^2 = \frac{1}{2}\left(\frac{mg}{x_0}\right)(2x_0)^2 = 2mgx_0$$

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(ii) **1.** $\text{G.P.E.} = mgh$ where h is the distance from the lowest point
G.P.E. varies linearly with distance.

at lowest point: $\text{G.P.E.} = 0$
at highest point: $\text{G.P.E.} = mg(2x_0) = 2mgx_0$
at equilibrium position: $\text{G.P.E.} = mgx_0$

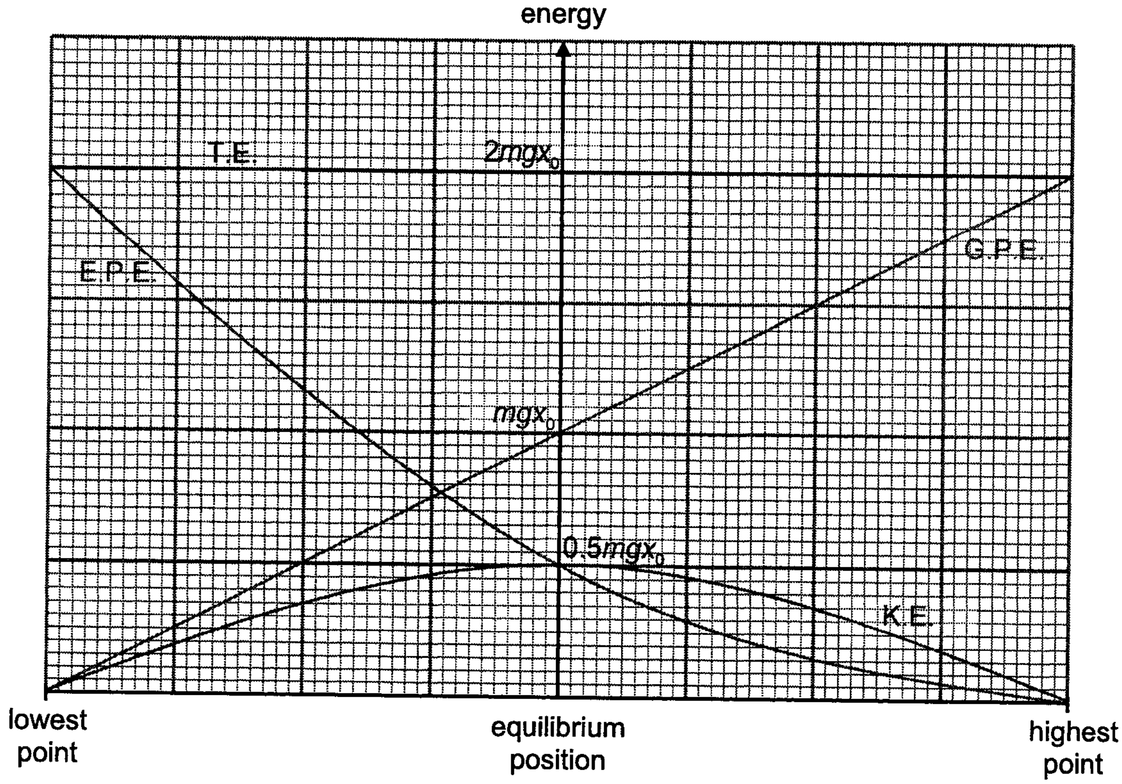
2. $\text{E.P.E.} = \frac{mg}{2x_0}e^2$ where e is the extension of the spring and the distance from the highest point.
E.P.E. and distance follows a quadratic relationship.

from (b)(i), at lowest point: $\text{E.P.E.} = 2mgx_0$
at highest point, spring is at its natural length: $\text{E.P.E.} = 0$
at equilibrium position: $\text{E.P.E.} = \frac{1}{2}mgx_0$

3. $\text{K.E.} = \frac{1}{2}m\left(\pm\omega\sqrt{x_0^{\,2} - x^2}\right)^2 = \frac{1}{2}m\omega^2\left(x_0^{\,2} - x^2\right) = -\frac{1}{2}m\omega^2x^2 + \frac{1}{2}m\omega^2x_0^{\,2}$
K.E. and displacement follows a quadractic relationship.

at lowest and highest points: $\text{K.E.} = 0$
at equilibrium position:
$\text{max. K.E.} = \frac{1}{2}m\omega^2x_0^{\,2} = \frac{1}{2}m\left(\frac{k}{m}\right)x_0^{\,2} = \frac{1}{2}\left(\frac{mg}{x_0}\right)x_0^{\,2} = \frac{1}{2}mgx_0$

4. Total energy at any position is the sum of the G.P.E. , E.P.E. and K.E. at that position.
Total energy remains constant for a system with no energy losses.



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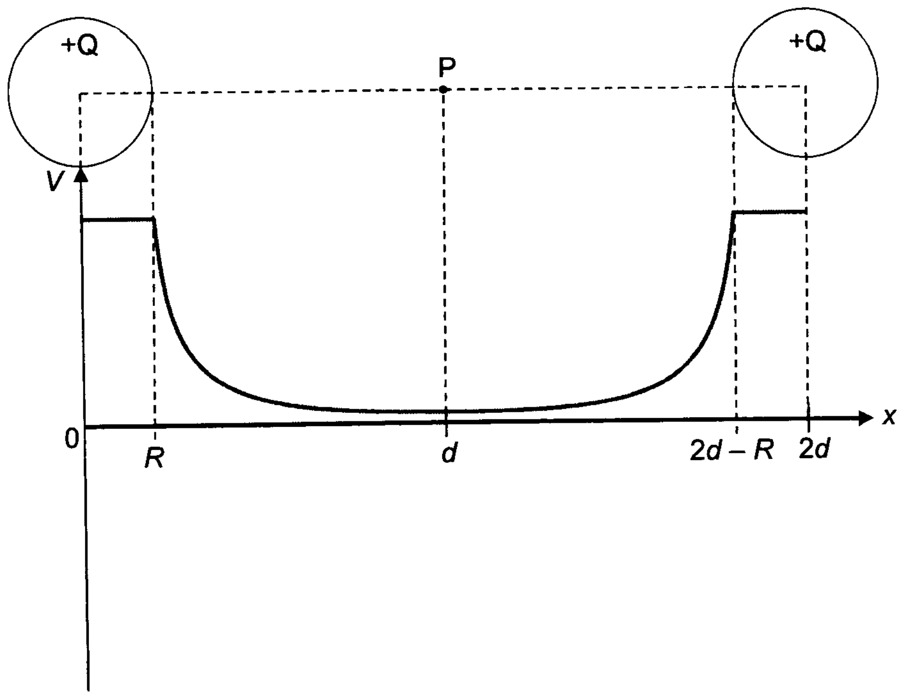
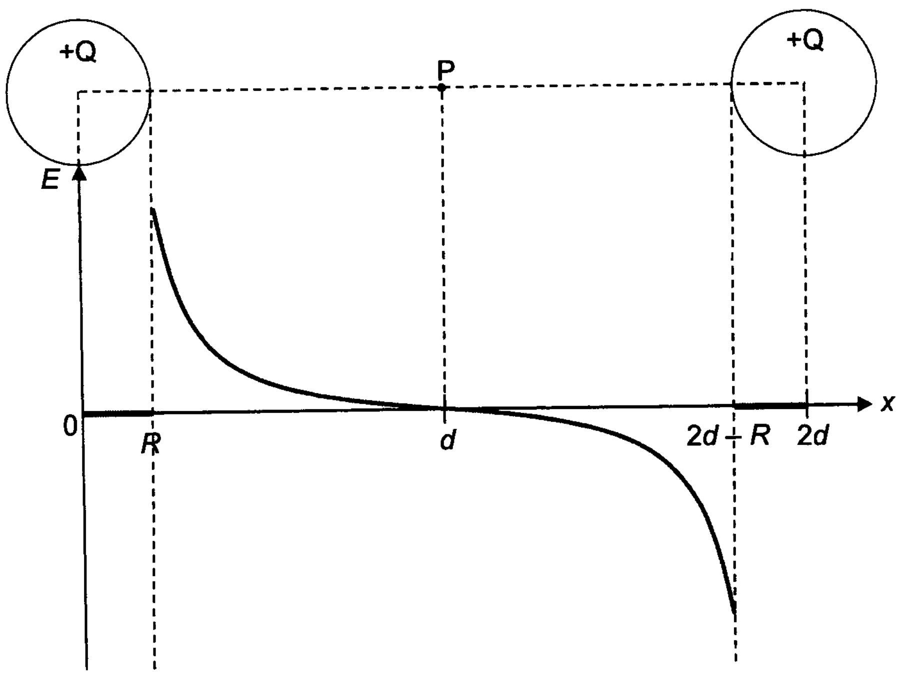
3 (a) (i)



(ii)



(b) (i) Solution 1

At point P, the electron is equidistant from each sphere and since each sphere carry the same amount of positive charge, the electric force acting on the electron due to sphere A is equal in magnitude and opposite in direction to the electric force on the electron due to sphere B.

Hence, the resultant electric force acting on the electron is zero.

(the force due to sphere A, $F_A = \dfrac{Qe}{4\pi\varepsilon_0 d^2}$ is acting to the left and the force due to sphere B, $F_B = \dfrac{Qe}{4\pi\varepsilon_0 d^2}$ is acting to the right)

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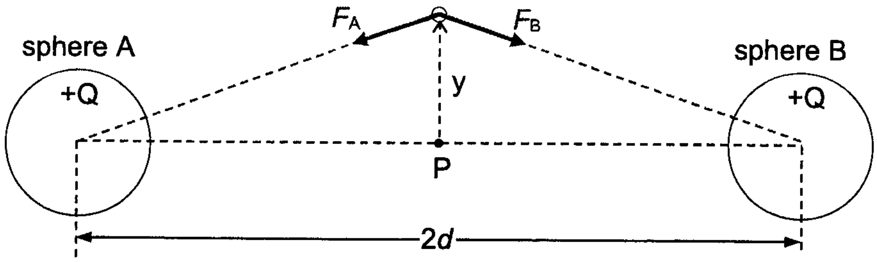
Solution 2
Point P is equidistant from each sphere and since each sphere carry the same amount of positive charge, the electric field strength at point P due to sphere A is equal in magnitude and opposite in direction to the electric field strength due to sphere B. Hence, the resultant electric field strength at point P is zero.

Since the resultant electric force on the electron at point P is the product of the resultant electric field strength at point P and the elementary charge, the resultant electric force is zero.

(ii) **1.**



2. The resultant force on the electron is acting vertically downwards, opposite to its upward displacement y.

$F_R = -F_A\cos\theta - F_B\cos\theta$
where θ is the angle that F_A or F_B makes with the vertical

Since $F_A = F_B = \dfrac{Qe}{4\pi\varepsilon_0}\dfrac{1}{\left(\sqrt{d^2+y^2}\right)^2} = \dfrac{Qe}{4\pi\varepsilon_0(d^2+y^2)}$

$$F_R = -2F_A\cos\theta$$
$$= -2\frac{Qe}{4\pi\varepsilon_0(d^2+y^2)}\left(\frac{y}{\sqrt{d^2+y^2}}\right)$$
$$= -\frac{Qe}{2\pi\varepsilon_0}\left(\frac{y}{(d^2+y^2)^{\frac{3}{2}}}\right)$$

3. Since Q, e, m_e, d and ε_0 are constants, $a \propto (-y)$.

The acceleration a of the electron is directly proportional to its displacement y from the equilibrium position P.

The negative sign implies that the acceleration a acts in the opposite direction to the displacement y from the equilibrium position P. Hence, the acceleration points towards the equilibrium position.

This satifies the condition for simple harmonic motion where $a = -\omega^2 y$. The electron will oscillate in simple harmonic motion along the vertical axis through point P with angular frequency $\omega = \sqrt{\dfrac{Qe}{2\pi\varepsilon_0 m_e d^3}}$.

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4 (a) (i) Using Fleming's left hand rule, the magnetic force acting on the electron is always perpendicular to the direction of its linear velocity. Hence the direction of the electron's velocity changes, but its speed remains constant.

Since magnetic flux density B, charge of electron e and speed of electron v are constant, the magnitude of the magnetic force Bev remains constant.

This magnetic force provides the centripetal force and hence the electron will be in uniform circular motion.

(ii) The magnetic force on the electron provides the centripetal force.

$$Bqv = mr\omega^2$$
$$Bq(r\omega) = mr\omega^2$$
$$Bq = m\omega$$
$$Bq = m(2\pi f)$$
$$f = \frac{Be}{2\pi m_e}$$
$$= \frac{(2.8\times10^{-5})(1.60\times10^{-19})}{2\pi(9.11\times10^{-31})}$$
$$= 7.8267\times10^5 = 7.83\times10^5 \text{ Hz}$$

(b) (i) $Bqv = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{Bq} \Rightarrow r \propto v$ (since B, m and q are constant)

The speed of the second electron is $\sqrt{2}$ times the speed of the first electron. Since $r \propto v$, the radius of its circular path is $\sqrt{2}$ times the radius of the circular path of the first eletron.

(ii) $T = \frac{2\pi r}{v} = \frac{2\pi}{v}\left(\frac{mv}{Bq}\right) = \frac{2\pi m}{Bq}$

The period of revolution is independent of the speed of the electron. The period of revolution for both electrons is the same.

(iii) The magnetic force is always perpendicular to the direction of the linear velocity / displacement of each electron. There is no displacement in the direction of the magnetic force and the work done by the magnetic force on each electron is always zero.

(c) The electric and magnetic fields are pointing perpendicularly into the paper. The electron experiences a constant electric force directed perpendicularly out of the paper while it undergoes uniform circular motion.

The electron will accelerate out of the paper in a helical path with increasing pitch.

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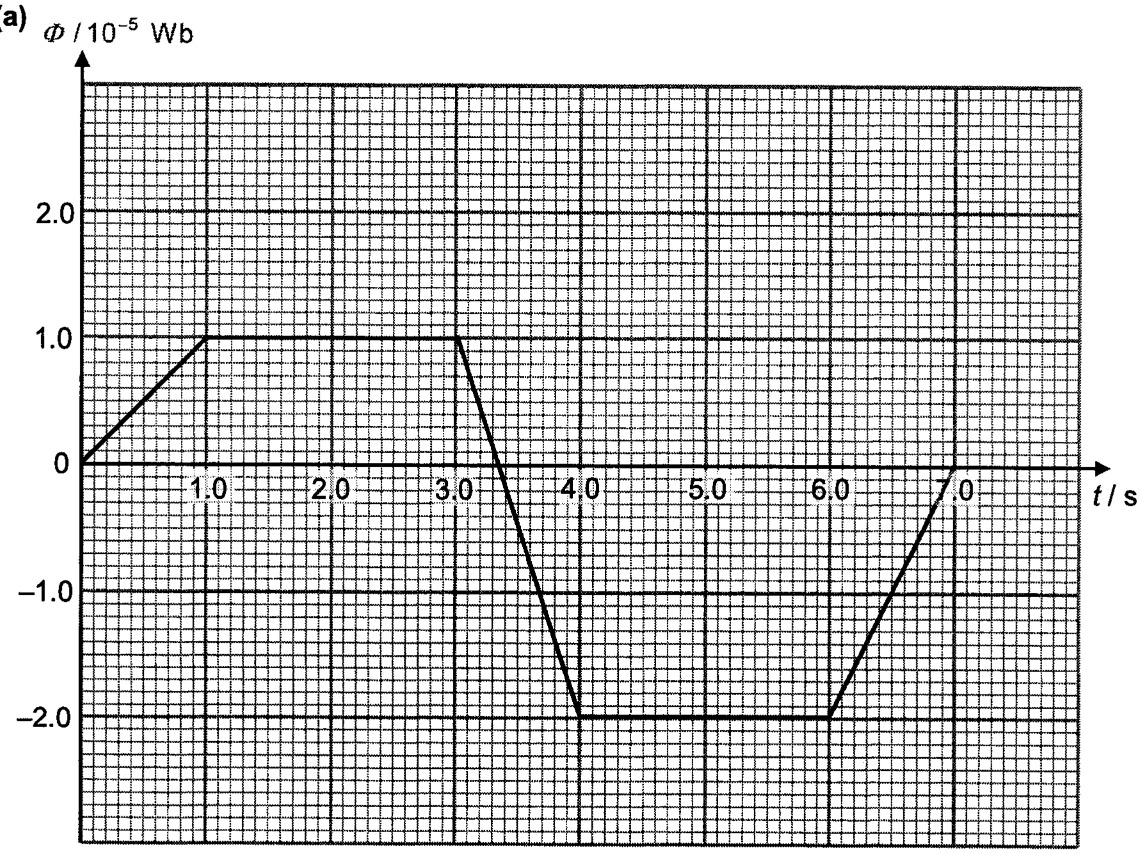
5 **(a)**



(b) By Faraday's Law, an e.m.f. is induced in the coil when there are changes in the magnetic flux linkage of the coil as it moves through the fields.

By Lenz's Law, the induced e.m.f. causes a current to flow around the coil such that it induces a magnetic force that acts on the coil in the direction opposite to the direction of the coil's velocity. This magnetic force causes the coil to decelerate.

Hence, in order to maintain constant velocity, an external force of the same magnitude as the magnetic force needs to be applied in the direction of the coil's displacement, which results in work done on the coil.

(c) The maximum e.m.f. is induced when there is a maximum rate of change of magnetic flux i.e. when it is transitioning from P to Q, where the gradient of the flux-time graph is the steepest.

By Faraday's Law,

$$|E_{max}| = \left|-\frac{d\Phi}{dt}\right|$$

$$= \left|-\frac{(-2.0\times10^{-5})-(1.0\times10^{-5})}{4.0-3.0}\right|$$

$$= 3.0\times10^{-5}\ \text{V}$$

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6 (a) The photoelectric effect is only observed when the frequency of the electromagnetic radiation incident on a particular metal is at least a minimum frequency. It does not depend on the intensity of the radiation. This is the threshold frequency and each metal has its own threshold frequency.

This can only be explained if electromagnetic radiation is made up of discrete quanta of energy known as photons.

The energy of each photon is hf, where h is the Planck constant and f is the frequency of the radiation.

An electron in the metal requires a minimum energy to leave the surface of the metal in the photoelectric effect. This minimum energy is the work function Φ of the metal.

The electron absorbs energy only from one photon in the particulate theory. Hence for photoemission to occur, the energy of each photon $hf \geq \Phi$. The minimum frequency $f = \Phi/h$ is the threshold frequency.

(b) (i) Solution 1

horizontal-intercept gives the threshold wavelength $\lambda_0 = 4.4 \times 10^{-7}$ m as $E_{max} = 0$

$$\Phi = \frac{hc}{\lambda_0}$$
$$= \frac{(6.63 \times 10^{-34})(3.00 \times 10^8)}{4.4 \times 10^{-7}}$$
$$= 4.5205 \times 10^{-19} = 4.52 \times 10^{-19} \text{ J}$$

Solution 2

$$\frac{hc}{\lambda} = \Phi + E_{max}$$
$$E_{max}\lambda = (-\Phi)\lambda + hc$$

for the graph of $E_{max}\lambda$ against λ, gradient $= -\Phi$, vertical-intercept $= hc$

$$\text{gradient} = \frac{(1.10 - 0.10) \times 10^{-25}}{(2.0 - 4.2) \times 10^{-7}} = -4.5455 \times 10^{-19}$$
$$\Phi = -\text{gradient} = 4.5455 \times 10^{-19} = 4.55 \times 10^{-19} \text{ J}$$

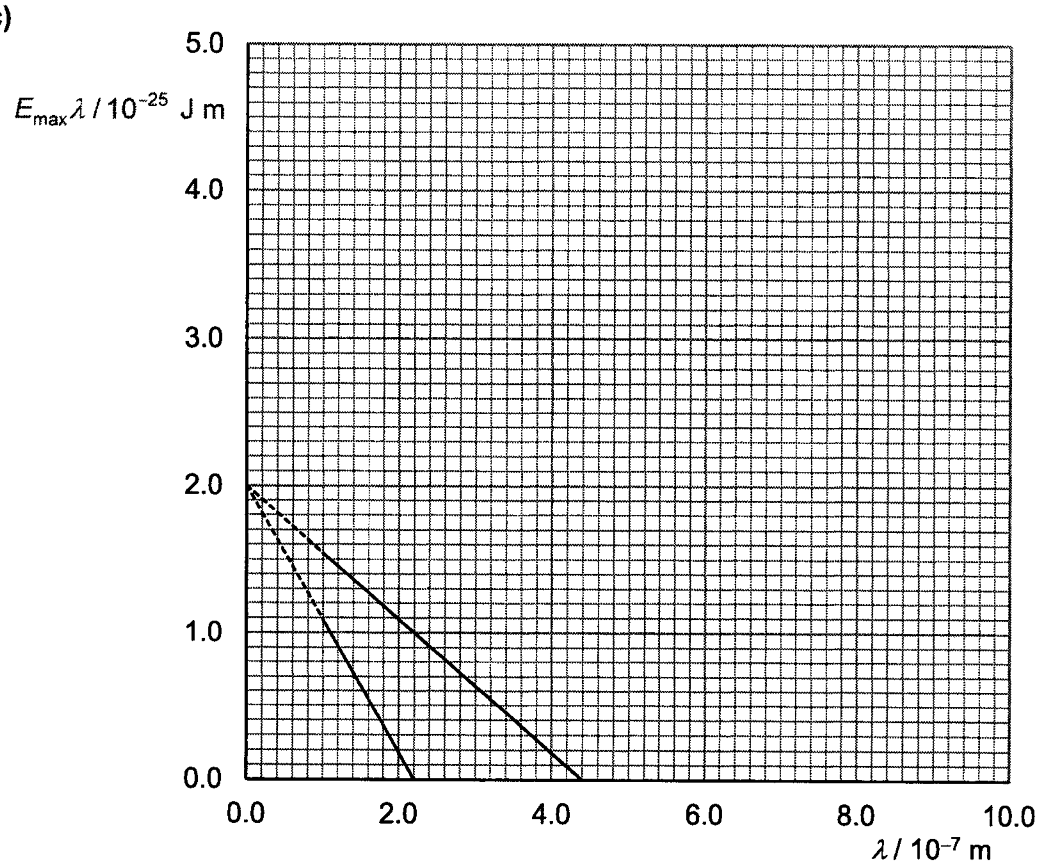
(ii) 1. for $\lambda = 2.0 \times 10^{-7}$ m, $E_{max}\lambda = 1.10 \times 10^{-25}$ J m

$$E_{max} = \frac{1.10 \times 10^{-25}}{2.0 \times 10^{-7}} = 5.5 \times 10^{-19} \text{ J}$$
$$eV_S = E_{max}$$
$$V_S = \frac{1.10 \times 10^{-25}}{(2.0 \times 10^{-7})(1.60 \times 10^{-19})}$$
$$= 3.4375 = 3.44 \text{ V}$$

2.
$$E = \frac{1}{2}mv^2 = \frac{1}{2}\frac{(mv)^2}{m} = \frac{p^2}{2m}$$
$$p = \sqrt{2mE}$$

$$\lambda = \frac{h}{p}$$
$$= \frac{h}{\sqrt{2mE_{max}}}$$
$$= \frac{6.63\times10^{-34}}{\sqrt{2(9.11\times10^{-31})(5.5\times10^{-19})}}$$
$$= 6.6230\times10^{-10} = 6.62\times10^{-10}\ \text{m}$$

(c)



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Paper 3 – Section B

7 (a) (i) For a fixed tension (or load) in the string, the speed of the transverse progressive wave on the string is constant.

For stationary wave to be seen, the length of the string must be integer multiples of half-wavelength of the wave.

Since the length of the string is fixed, this means that only certain wavelengths and hence frequencies will produce observable stationary waves.

(ii) Since length of string L must be integer multiples of half-wavelength,

$$L = n \times \tfrac{1}{2}\lambda_n = n \times \tfrac{1}{2} \cdot \frac{v}{f_n} \qquad (v = f\lambda)$$

where n, the number of segments, is an integer.
Rearranging,

$$f_n = n\frac{v}{2L} \text{ (shown)}$$

(iii) $n = 4$ for a stationary wave with 5 nodes

$$v = \frac{2Lf_n}{n} = \frac{2 \times 0.600 \times 40.0}{4} = 12.0 \text{ m s}^{-1}$$

(iv) $f_n \propto v \propto T^{1/2}$

Solution 1

$$\frac{f_n'}{f_n} = \sqrt{\frac{T'}{T}} = \sqrt{0.98}$$

$$f_n' = \sqrt{0.98} f_n = \sqrt{0.98} \times 40.0 = 39.598 = 39.6 \text{ Hz}$$

Solution 2
Since $f_n \propto v \propto T^{1/2}$,

$$\frac{\Delta f_n}{f_n} = \frac{1}{2}\frac{\Delta T}{T} = \frac{1}{2} \times (-0.02) = -0.01$$

$$\Delta f_n = -0.01 f_n = -0.01 \times 40.0 = -0.4 \text{ Hz}$$

New frequency

$$f_n' = f_n + \Delta f_n = 40.0 + (-0.4) = 39.6 \text{ Hz}$$

(b) (i) **1.** Using $b \sin\theta_m = m\lambda$ where $m = 1$

$$\theta_1 = \sin^{-1}\left(\frac{\lambda}{b}\right) = \sin^{-1}\left(\frac{600 \times 10^{-9}}{0.30 \times 10^{-3}}\right) = 2.0 \times 10^{-3} \text{ rad (shown)}$$

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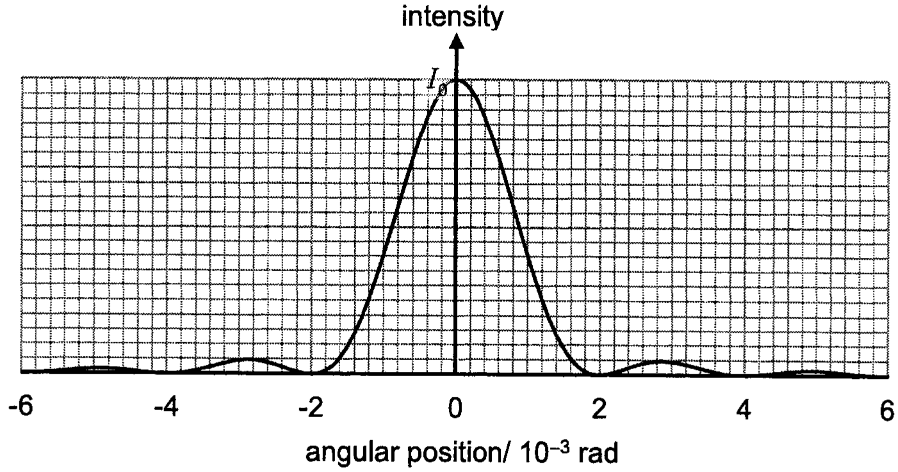
2.



3. For the two point sources to be just resolved,

$$\theta_1 = \theta_{min} = 2.0 \times 10^{-3}$$

$$\frac{0.50}{D} = 2.0 \times 10^{-3}$$

$$D = \frac{0.50}{2.0 \times 10^{-3}} = 250 \text{ m}$$

The distance of the sources from the slit is 250 m.

(ii) 1. Separation between 2 slits

$$a = 0.30 - 0.10 = 0.20 \text{ mm}$$

2. first minimum of single slit diffraction envelop:

$$\theta_1 = \sin^{-1}\left(\frac{\lambda}{b}\right) = \sin^{-1}\left(\frac{600 \times 10^{-9}}{0.10 \times 10^{-3}}\right) = 6.0 \times 10^{-3} \text{ rad}$$

single slit minima: $b \sin\theta_m = m\lambda$ --- (1)
double slit maxima: $a \sin\theta_n = n\lambda$ --- (2)
for $\theta_m = \theta_n$, $\frac{(1)}{(2)}$: $\frac{b}{a} = \frac{m}{n}$

missing orders of maxima of double slit interference pattern
$n = m\frac{a}{b} = m\frac{0.20}{0.10} = 2m$

An interference pattern is observed with maxima occurring at intervals of 3.0×10^{-3} rad.

The pattern is modulated by a diffraction envelop with minima occurring at intervals of 6.0×10^{-3} rad.

Even orders of interference maxima are missing.

3. Before applying the film, assume that the amplitude of the light at the central maximum is A_0, then $I_0 = kA_0^2$.

Amplitude at the central maximum due to each slit is now $A_0/3$.
(1/3 the number of original waves arrive at the central maximum)

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Amplitude at central maximum due to both slits is $2A_0/3$.
(superposition of waves from each slit)

intensity of central maximum

$$I = k\left(\frac{2A_0}{3}\right)^2 = \frac{4}{9}\cdot kA_0^2 = \frac{4}{9}\cdot I_0$$

8 **(a)** The number *238* refers to the <u>number of nucleons in the nucleus</u> or <u>number of protons and neutrons in the nucleus</u>.

(b) $^{238}_{\boxed{92}}U \rightarrow \, ^{\boxed{234}}_{90}Th + \, ^{4}_{\boxed{2}}He$

(c) **(i)** kinetic energy $= 40.0\times(5.90\times10^{3})(2.70\times10^{-18})$

$= 6.372\times10^{-13}$

$= 6.37\times10^{-13}$ J (shown)

(ii) kinetic energy, $E_k = \frac{1}{2}mv^2 = \frac{1}{2}\frac{(mv)^2}{m} = \frac{p^2}{2m}$

Since uranium nucleus was initially at rest, by the principle of conservation of momentum,

$p_{Th} + p_\alpha = 0$

$p_{Th} = -p_\alpha$

$= -\sqrt{2m_\alpha E_\alpha}$

$= -\sqrt{2\times(4\times1.66\times10^{-27})(6.37\times10^{-13})}$

$= -9.1975\times10^{-20} = -9.20\times10^{-20}$ Ns

(iii) $E_{k,Th} = \frac{p_{Th}{}^2}{2m_{Th}} = \frac{(9.20\times10^{-20})^2}{2(234\times1.66\times10^{-27})} = 1.0895\times10^{-14} = 1.09\times10^{-14}$ J

$E_{k,\text{Total}} = E_{k,Th} + E_{k,\alpha}$

$= (1.09\times10^{-14}) + (6.37\times10^{-13})$

$= 6.479\times10^{-13}$ J

$= \frac{6.479\times10^{-13}}{(10^6)(1.60\times10^{-19})}$ MeV

$= 4.0494 = 4.05$ MeV

(iv) No other particles or photons were emitted during the decay.

(d) **(i)** Nuclear binding energy is the energy equivalent of the mass defect of a nucleus. It is the energy required to separate to infinity all the nucleons of a nucleus.

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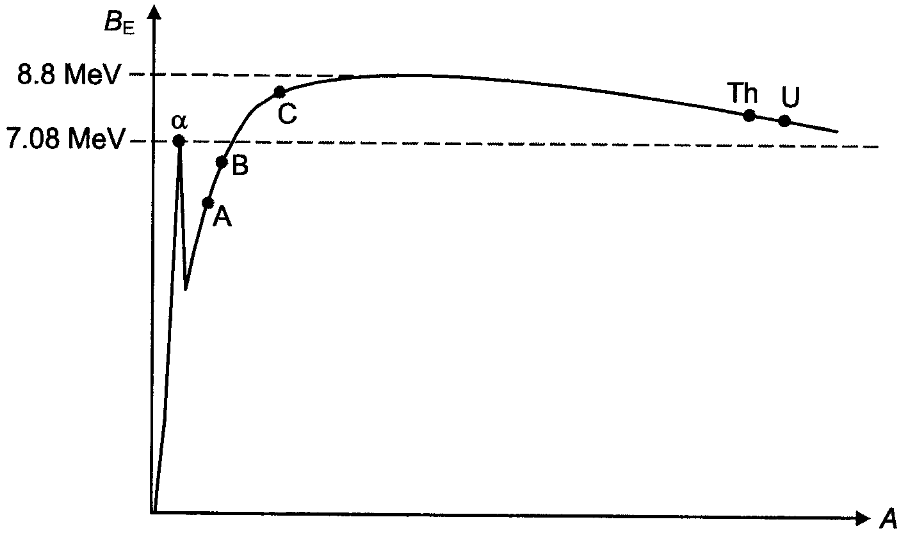
(ii) Possible nuclides: iron-56 (^{56}Fe), iron-58 (^{58}Fe), nickel-62 (^{62}Ni)
$B_E = 8.8$ MeV

(iii)
$$\Delta E = E_{k,\text{Total}} = BE_{Th} + BE_{\alpha} - BE_{U}$$
$$4.05 = BE_{Th} + (4 \times 7.08) - (238 \times 7.57)$$
$$BE_{Th} = 1777.39 \text{ MeV}$$
$$\frac{BE_{Th}}{A_{Th}} = \frac{1777.39}{234}$$
$$= 7.5957 = 7.60 \text{ MeV}$$

(iv)



On the left part of curve, He or α-particle on the sharp peak.

On the right part of curve, U (7.57 MeV) above α (7.08 MeV), and Th (7.60 MeV) just above U and just to its left.

(v) **1.** Nuclear fusion occurs when two light nuclei combine to form a nucleus of greater mass.

2. All A, B and C on the left of the highest B_E point.
Nuclei A and B lighter than or on the left of C, but B_E of C is higher than both nuclei A and B.

Centre Number	Class Index Number	Name	Class
S3016		SOLUTION (JC)	

RAFFLES INSTITUTION

2022 Preliminary Examination

PHYSICS **Higher 2** Paper 4 Practical	**9749/04** **15 August 2022** **2 hours 30 minutes**

READ THESE INSTRUCTIONS FIRST

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

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Candidates answer on the Question Paper.

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

Write your answers in the spaces provided on the question paper.

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

You may lose marks if you do not show your working or if you do not use appropriate units.

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

At the end of the examination, fasten all your work securely together.

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

Shift
Laboratory

For Examiner's Use	
1	/ 10
2	/ 12
3	/ 21
4	/ 12
Total	/ 55

This document consists of **20** printed pages and **1** blank page.

1 In this experiment, you will investigate the effect of friction on a simple pulley system.

(a) You are provided with a spring of unstretched length L_0, as shown in Fig. 1.1.

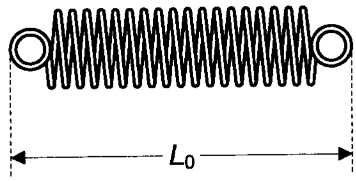


Fig. 1.1

Measure and record L_0.

L_0 = 4.1 cm .... [1]

(b) Set up the apparatus as shown in Fig. 1.2.

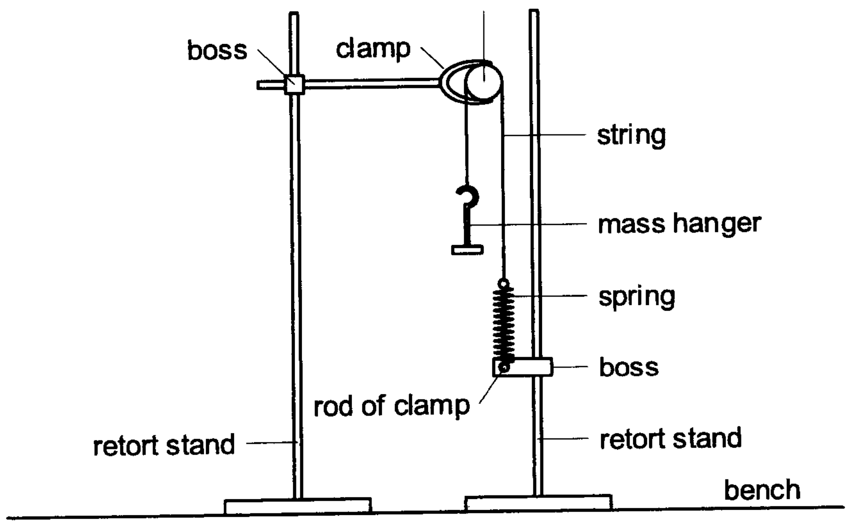


Fig. 1.2

Ensure that the pipe remains horizontal at all times, and that the strings on each side of the pipe are vertical and parallel with each other.

The spring should only stretch minimally at this instant.

(i) Place a 50 g slotted mass onto the mass hanger and **slowly** lower the mass hanger, allowing the spring to extend to a new equilibrium length L_1,

Measure and record L_1.

L_1 = 6.1 cm .... [1]

(ii) Calculate the extension x_1 of the spring from its unstretched length, where

$$x_1 = L_1 - L_0$$

$x_1 = L_1 - L_0 = 6.1 - 4.1 = 2.0$ cm

x_1 = 2.0 cm .... [1]

(iii) Pull the mass hanger downwards by about 10 cm, causing the spring to extend further. Hold the hanger while allowing it to **slowly** rise upwards until the spring retracts to another equilibrium length L_2, where L_2 is larger than L_1.

Measure and record L_2.

L_2 = 11.3 cm ....

(iv) Calculate the new extension x_2 of the spring from its unstretched length, where

$$x_2 = L_2 - L_0$$

$x_2 = L_2 - L_0 = 11.3 - 4.1 = 7.2$ cm

x_2 = 7.2 cm .... [1]

(c) Theory suggests that x_1 and x_2 are related by the expression

$$\ln\frac{x_2}{x_1} = 2\beta\theta$$

where β is a constant and θ is the angle of contact (expressed in radians) between the string and the pipe, as shown in Fig. 1.3.

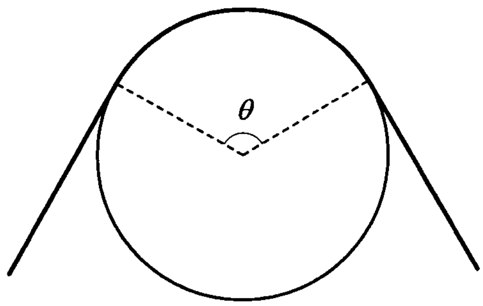


Fig. 1.3

(i) State the value of θ for the set-up in Fig. 1.2.

θ = π rad [1]

(ii) Determine a value for β.

$$\beta = \frac{\ln(x_2/x_1)}{2\theta} = \frac{\ln(7.2/2.0)}{2\pi} = 0.204 \text{ rad}^{-1}$$

Accept both 2 s.f. or 3 s.f.

β = 0.204 rad^{-1} [1]

(iii) The experiment is repeated with different numbers of slotted masses to obtain more values of x_1 and x_2.

State how a straight line graph can be plotted and used to determine the value of β, assuming the theory is correct.

$$\ln\frac{x_2}{x_1} = 2\beta\pi \Rightarrow \frac{x_2}{x_1} = e^{2\beta\pi} \Rightarrow x_2 = \left(e^{2\beta\pi}\right)x_1$$

Plot a graph of x_2 against x_1 where the gradient is $e^{2\beta\pi}$ and the vertical intercept is zero.

Hence, $\beta = \frac{1}{2\pi}\ln(\text{gradient})$.

or

$$\ln\frac{x_2}{x_1} = 2\beta\pi \Rightarrow \ln x_2 - \ln x_1 = 2\beta\pi \Rightarrow \ln x_2 = \ln x_1 + 2\beta\pi$$

Plot a graph of $\ln x_2$ against $\ln x_1$ where the gradient is 1 and the vertical intercept is

$2\beta\pi$. Hence, $\beta = \frac{1}{2\pi}(\text{vertical intercept})$. [2]

(iv) State the value of β if the pipe is frictionless. Explain your answer.

If the pipe is frictionless, $x_1 = x_2$, as the spring will retract back to an extension of x_1 after being stretched further. Hence, $\ln(x_2/x_1) = \ln(1) = 0$ and this implies $\beta = 0$. [2]

Note:
β is the coefficient of friction between the string and the pipe. Hence, $\beta = 0$ when the pipe is frictionless.

[Total: 10]

2 In this experiment, you will investigate an electrical circuit.

(a) Component Z in the circuit shown in Fig. 2.1 is a combination of three resistors: X, X and Y.

The values of the resistance of X and Y are 2.2 Ω and 3.3 Ω respectively.

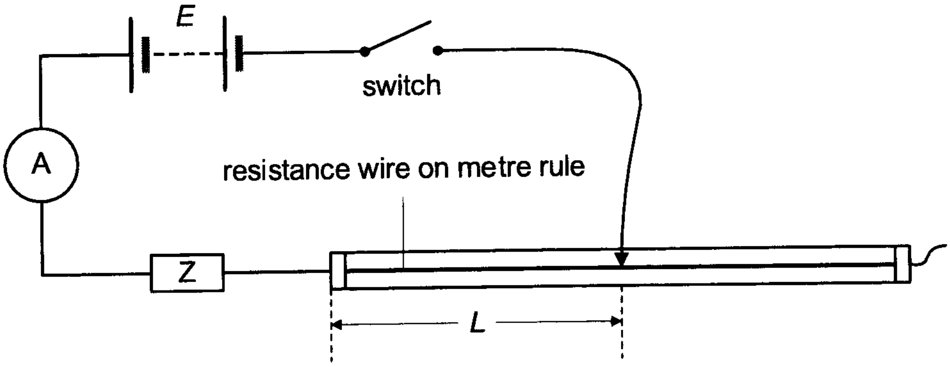
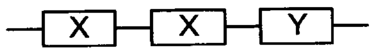


Fig. 2.1

Set up the circuit in Fig. 2.1 such that Z is a combination of X, X and Y connected in series.

Draw this series combination.

Calculate the effective resistance R_Z of Z.



$R_Z = 2.2 + 2.2 + 3.3 = 7.7\ \Omega$

R_Z = 7.7 Ω .... [1]

Close the switch.

Adjust length L to obtain an ammeter reading I of approximately 0.10 A.

Measure and record I and L.

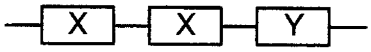
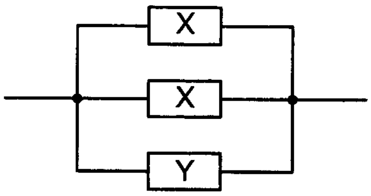
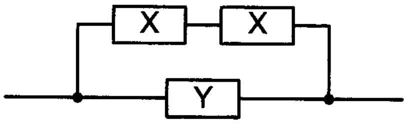
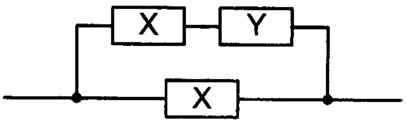
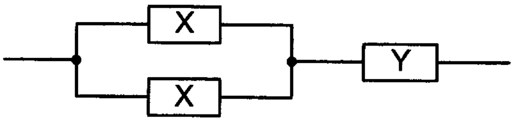
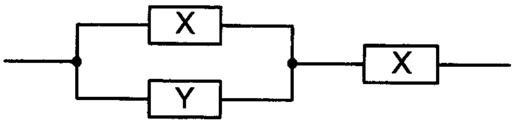
I = 0.1002 A ....

L = 0.472 m .... [1]

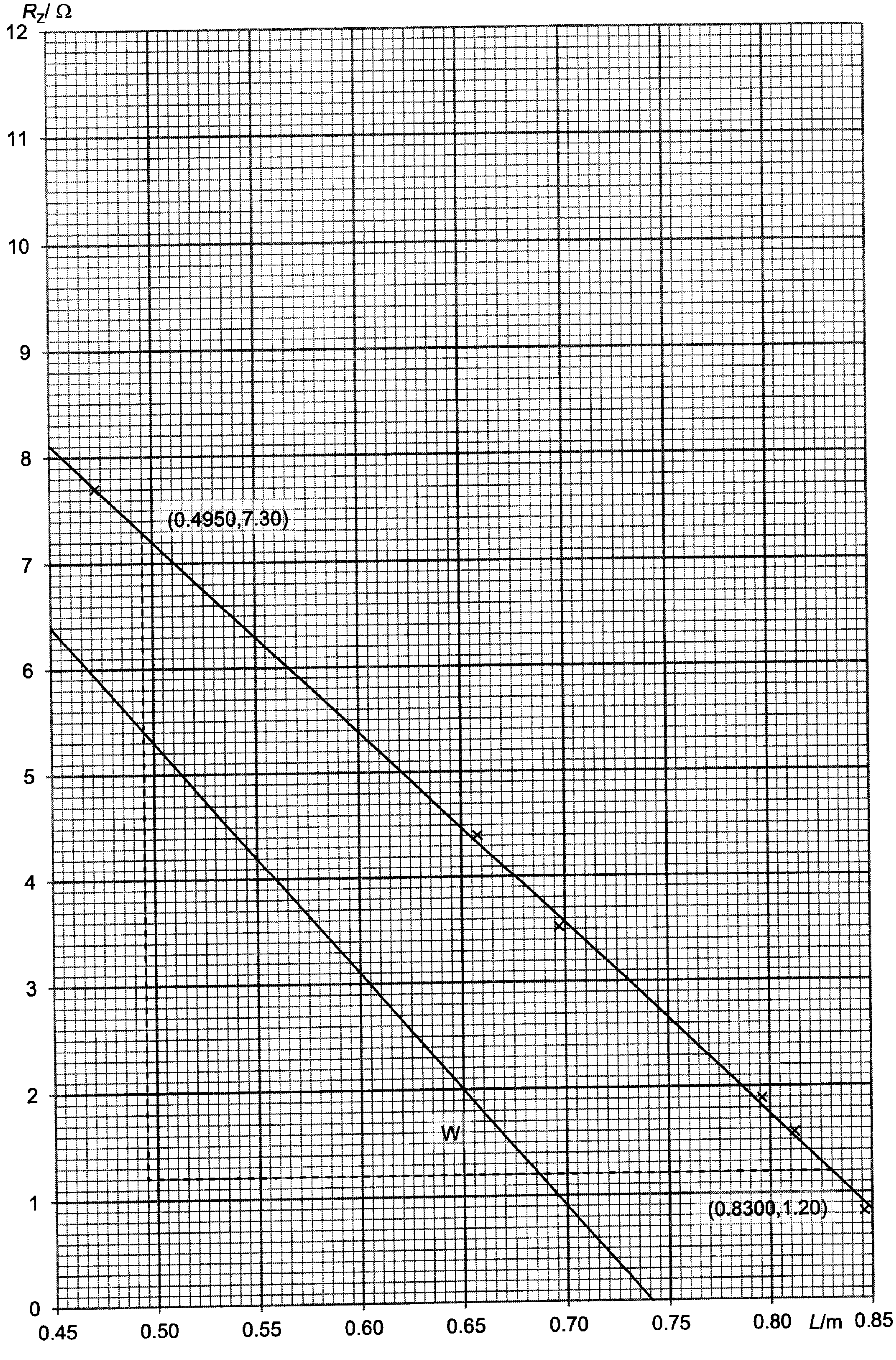
Open the switch.

(b) Vary R_Z using different combinations of **ALL** the resistors X, X and Y and repeat **(a)**, keeping I constant throughout.

Present your results clearly. Include drawings of the different combinations of X, X and Y.

Connections of X, X and Y	R_Z / Ω	L / m
	7.70	0.472
	0.825	0.846
	1.89	0.796
	1.57	0.812
	4.40	0.658
	3.52	0.697

[3]


R_Z/ Ω
12
11
10
9
8
7
6
5
4
3
2
1
0
(0.4950,7.30)
W
(0.8300,1.20)
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
L/m
0.85

(c) R_Z and L are related by the expression

$$E = IR_Z + kIL$$

where E is the electromotive force of the cell and k is a constant.

Plot a suitable graph to determine a value for k.

$$R_Z = \frac{E}{I} - kL$$

Plot a graph of R_Z against L where the gradient is $-k$ and the vertical intercept is $\frac{E}{I}$.

Using the points (0.4950,7.30) and (0.8300,1.20),

$$\text{gradient} = \frac{7.30 - 1.20}{0.4950 - 0.8300} = \frac{6.10}{-0.3350} = -18.2$$

Resistance per unit length

$$k = -\text{gradient} = 18.2\ \Omega\ \text{m}^{-1}$$

> **Note:**
> Measured resistance per unit length of wire is $18.35\ \Omega\ \text{m}^{-1}$
> Measured $\frac{E}{I} = \frac{1.60}{0.1002} = 16.0\ \Omega$, vertical intercept from graph $= 16.3\ \Omega$

k = $18.2\ \Omega\ \text{m}^{-1}$ [5]

(d) It is given that

$$k = \frac{\rho}{A}$$

where ρ and A are the resistivity and the cross-sectional area of the resistance wire respectively.

By making appropriate measurements, determine the value of ρ.

Use micrometer screw gauge to measure the diameter of the resistance wire.

zero error = 0.00 mm

$d_1 = 0.19$ mm, $d_2 = 0.19$ mm

$\langle d \rangle = 0.19$ mm

Resistivity

$$\rho = kA = 18.2 \times \pi \left(0.095 \times 10^{-3}\right)^2 = 5.16 \times 10^{-7}\ \Omega\ \text{m}$$

> **Note:** Resistivity of wire is $4.9 \times 10^{-7}\ \Omega\ \text{m}$ at 20 °C.

ρ = $5.16 \times 10^{-7}\ \Omega\ \text{m}$ [1]

(e) The experiment is repeated using a resistance wire of the same material but with a smaller diameter.

Sketch a line on your graph grid on Page 8 to show the expected result.

Label this line W. [1]

Smaller diameter $d \Rightarrow A$ decreases while ρ, E and I remains constant.

The gradient ($-k$) of W will be more negative while its vertical intercept remains the same.

Draw W with a negative gradient, steeper and below the previous straight line, passing through the same vertical intercept.

[Total: 12]

3 In this experiment, you will investigate the behaviour of an oscillating system.

You have been provided with a set of acrylic discs A and B and three long strings.

(a) **(i)** Fig. 3.1 shows disc B of diameter D. On the disc are three small holes at equal distance r from the centre of the disc.

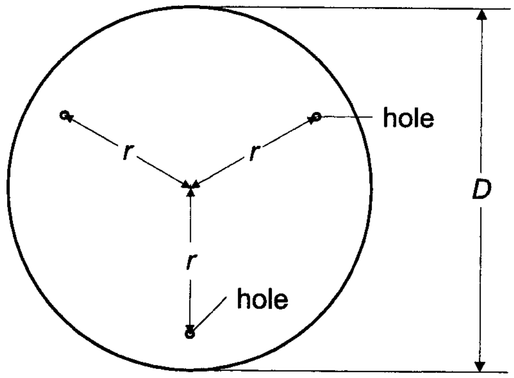


Fig. 3.1

Measure the diameter D of disc B using a pair of vernier callipers.

zero error = 0.01 cm

$D_1 = 15.02$ cm, $D_2 = 15.02$ cm

$\langle D \rangle = \frac{1}{2}(D_1 + D_2) = 15.02$ cm

D = 15.02 cm [1]

(ii) Measure the distance r of the holes from the centre of the acrylic disc.

Explain how r is measured.

$x_1 = 0.48$ cm, $x_2 = 0.29$ cm, $x_3 = 0.42$ cm

$\langle x \rangle = \frac{1}{3}(x_1 + x_2 + x_3) = 0.40$ cm

$r = \frac{1}{2}D - x = \frac{1}{2} \times 15.02 - 0.40 = 7.11$ cm

r = 7.11 cm [1]

Measure distance x of one hole from its nearest edge of the disc with vernier callipers.

Distance $r = \frac{1}{2}D - x$. Repeat for the other holes and take average. [1]

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

$$\text{percentage uncertainty} = \frac{\Delta r}{r} \times 100\% \approx \frac{\Delta x}{r} \times 100\% = \frac{\frac{1}{2}(0.48 - 0.29)}{7.11} \times 100\% = 1.3\%$$

percentage uncertainty in r = 1.3%

(b) Set up the apparatus as shown in Fig. 3.2.

Clamp the top disc between two wooden blocks.

Thread the strings through the holes on both discs and secure the strings to the discs with adhesive tape only.

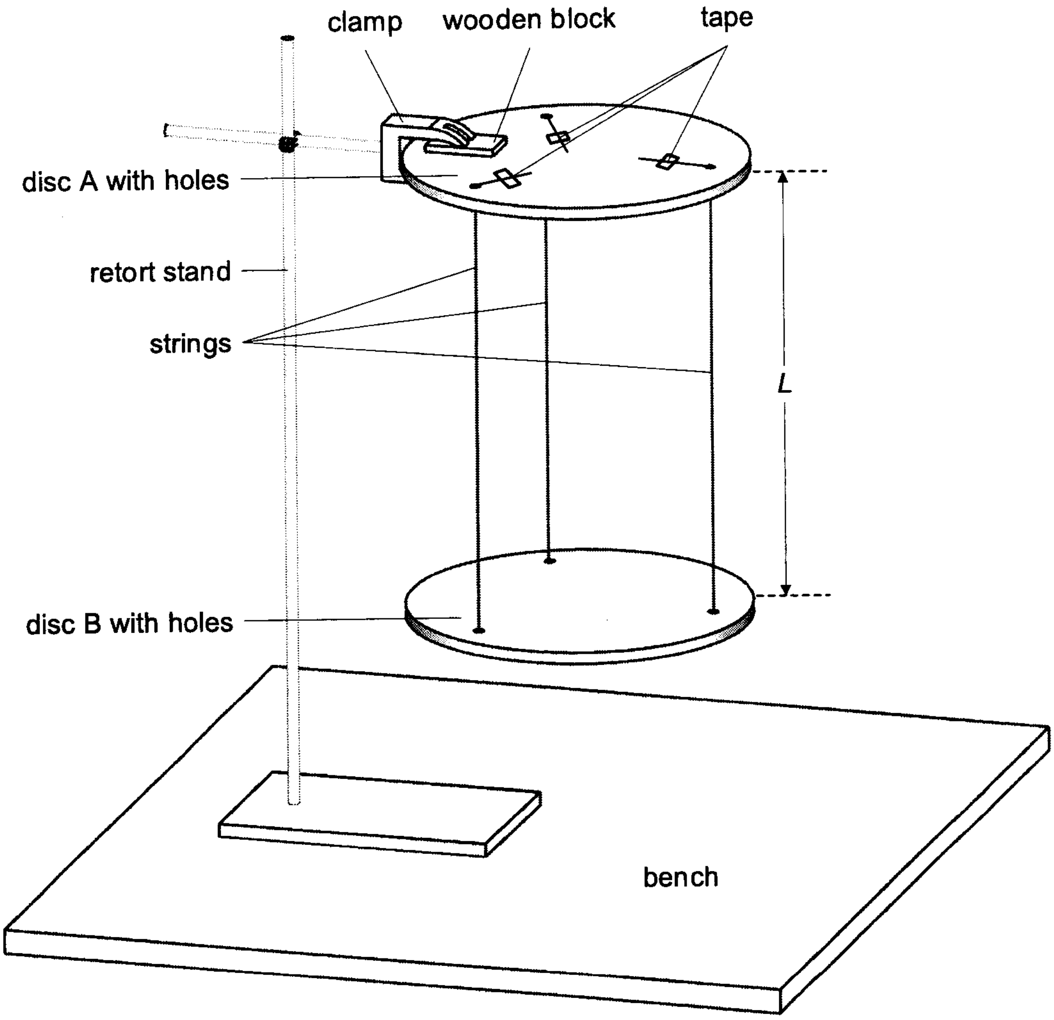


Fig. 3.2

The distance between the bottom face of disc A and the top face of disc B is L.

Adjust the lengths of the strings until L is approximately 30 cm.

Both discs should be horizontal.

Measure and record L.

$L_1 = 29.9$ cm, $L_2 = 29.9$ cm, $L_3 = 29.7$ cm

$\langle L \rangle = \frac{1}{3}(L_1 + L_2 + L_3) = 29.8$ cm

L = 29.8 cm .... [1]

(i) Rotate disc B so that it oscillates about a vertical axis through its centre. Determine the period T_R of these oscillations.

Timing for 25 oscillations

$t_1 = 20.93$ s , $t_2 = 20.85$ s

$\langle t \rangle = \frac{1}{2}(t_1 + t_2) = 20.89$ s

Period

$$T_R = \frac{\langle t \rangle}{25} = 0.8356 \text{ s}$$

T_R = 0.8356 s [1]

(ii) Displace disc B to the left and release such that it oscillates in a vertical plane. Determine the period T_S of these oscillations.

Timing for 20 oscillations

$t_1 = 22.04$ s , $t_2 = 21.92$ s

$\langle t \rangle = \frac{1}{2}(t_1 + t_2) = 21.98$ s

Period

$$T_S = \frac{\langle t \rangle}{20} = 1.099 \text{ s}$$

T_S = 1.099 s [1]

(c) Increase L to approximately 50 cm. Repeat **(b)(i)** and **(b)(ii)**.

$L_1 = 50.0$ cm , $L_2 = 50.0$ cm , $L_3 = 50.0$ cm

$\langle L \rangle = \frac{1}{3}(L_1 + L_2 + L_3) = 50.0$ cm

Timing for 20 oscillations in **(b)(i)**

$t_1 = 21.48$ s , $t_2 = 21.54$ s

$\langle t \rangle = \frac{1}{2}(t_1 + t_2) = 21.51$ s

Period $T_R = \frac{\langle t \rangle}{20} = 1.076$ s

Timing for 20 oscillations in **(b)(ii)**

$t_1 = 28.43$ s , $t_2 = 28.34$ s

$\langle t \rangle = \frac{1}{2}(t_1 + t_2) = 28.39$ s

Period $T_S = \frac{\langle t \rangle}{20} = 1.419$ s

L = 50.0 cm

T_R = 1.076 s

T_S = 1.419 s [2]

(d) It is suggested that

$$T_R = k \cdot \frac{\sqrt{L}}{r}$$

where k is a constant.

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

Since $k = \frac{T_R r}{\sqrt{L}}$,

$$k_1 = \frac{T_{R1} r}{\sqrt{L_1}} = \frac{0.8356 \times 0.0711}{\sqrt{0.298}} = 0.109 \text{ m}^{1/2} \text{ s}$$

$$k_2 = \frac{T_{R2} r}{\sqrt{L_2}} = \frac{1.076 \times 0.0711}{\sqrt{0.500}} = 0.108 \text{ m}^{1/2} \text{ s}$$

first value of k = $0.109 \text{ m}^{1/2}$ s

second value of k = $0.108 \text{ m}^{1/2}$ s [2]

(ii) Justify the number of significant figures given in your values of k.

k is calculated from r, L and T, and the percentage uncertainty due to r, L and T are 1.3% [from **(a)(iii)**], 0.5% ($\frac{1}{2} \times \frac{0.003}{0.298} \times 100\%$) and 0.2% ($\frac{0.04}{20.89} \times 100\%$) respectively.

This gives total uncertainty of 2.0% and an absolute uncertainty of $0.002 \text{ m}^{1/2}$ s for k.

Hence, k is rounded to the nearest $0.001 \text{ m}^{1/2}$ s. [1]

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

Percentage uncertainty in $k = \frac{\frac{1}{2}(k_1 - k_2)}{\frac{1}{2}(k_1 + k_2)} \times 100\% = \frac{\frac{1}{2}(0.109 - 0.108)}{\frac{1}{2}(0.109 + 0.108)} \times 100\% = 0.46\%$.

Since this is smaller than the percentage uncertainty of 1.3% calculated in **(a)(iii)**, the results do support the relationship.

or

Since this is smaller than the percentage uncertainty of 2.0% calculated in **(d)(ii)**, the results do support the relationship. [1]

(e) The period T_S of the oscillations in a vertical plane varies linearly with $\sqrt{L}$.

Use your results in **(b)** and **(c)** to estimate a value of L where $T_R = T_S$.

Assuming that $T_S = m_S\sqrt{L} + c_S$,

$$m_S = \frac{1.419 - 1.099}{\sqrt{0.500} - \sqrt{0.298}} = \frac{0.320}{0.161} = 1.99$$

$$c_S = 1.419 - 1.99 \times \sqrt{0.500} = 0.012$$

Therefore $T_S = 1.99\sqrt{L} + 0.012$.

Similarly, $T_R = m_R\sqrt{L} + c_R$,

$$m_R = \frac{1.076 - 0.8356}{\sqrt{0.500} - \sqrt{0.298}} = \frac{0.240}{0.161} = 1.49$$

$$c_R = 1.076 - 1.49 \times \sqrt{0.500} = 0.022$$

Therefore $T_R = 1.49\sqrt{L} + 0.022$.

When $T_R = T_S$,

$$1.99\sqrt{L} + 0.012 = 1.49\sqrt{L} + 0.022$$

$$0.50\sqrt{L} = 0.010$$

$$L = 4.0 \times 10^{-4} \text{ m}$$

Accept $T_R = m_R\sqrt{L} = \frac{k}{r}\sqrt{L}$.

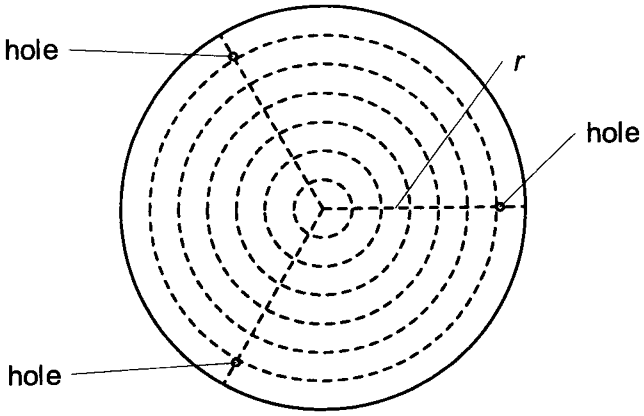
L = 4.0×10^{-4} m [4]

(f) The behaviour of the oscillating system in **(b)(i)** also depends on *r*, the distance of the strings from the centre of the disc according to the expression in **(d)**.

Explain how you would investigate this relationship.

Your account should include:

- your experimental procedure
- how the holes in both discs are accurately located
- control of variables
- how you would use your results to show that *T* is inversely proportional to *r*.



1. With a compass, draw 11 concentric circles of incremental radius of 0.5 cm up to 7.5 cm (radius of the disc). Also draw 3 radial lines at 120° interval from the centre of the circle.

2. Stack disc A and B and align the discs to the circle and secure with a clamp.

3. Drill small holes (diameter of 1 mm) at all intersection points between the lines and circles.

4. Measure *r* using the method described in (a)(ii).

4. Setup the apparatus as shown in Fig. 3.2.

5. Measure distance *L* between discs at 3 positions (near the strings) with a metre rule. Calculate the average distance *L*.

6. Rotate disc B about a vertical axis and release. Measure the time *t* for *N* number of oscillations with a stopwatch such that $t > 20$ s. Period $T = t/N$.

7. Repeat step 7 for a total of 10 sets of readings of *r* and *T* by threading the strings through different sets of holes of same *r*.

8. If $T \propto 1/r \Rightarrow T = k/r$, where *k* is a constant. Plot a graph of *T* against $1/r$. If a straight-line graph with zero vertical intercept (or close to zero) is obtained, then *T* is inversely proportional to *r*.

9. Repeat step 5 for each *r* to ensure that *L* is constant before timing.

[5]

[Total: 22]

4 When two ends of a copper rod of length L have a temperature difference of ΔT, the temperature gradient $\frac{\Delta T}{L}$ along the rod is related to the rate of heat transfer P through the rod and the cross-sectional area A of the rod by

$$\left(\frac{\Delta T}{L}\right) = kP^m A^n ,$$

where k, m and n are constants.

Design an experiment to determine the values m and n.

You are provided with an electrical heating coil, ice cubes and cylindrical copper rods of different dimensions.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to

(a) the equipment you would use

(b) the procedure to be followed

(c) how you would determine the rate of heat transfer

(d) the control of variables

(e) any precautions that should be taken to improve the accuracy of the experiment.

Problem Definition (optional to write)

Experiment 1

Independent variable:	Rate of heat transfer P through the rod
Dependent variable:	Temperature gradient $\Delta T/L$ between ends of the rod
Control variables:	Cross-sectional area A of the rod

Experiment 2

Independent variable:	Cross-sectional area A of the rod
Dependent variable:	Temperature gradient $\Delta T/L$ between ends of the rod
Control variables:	Rate of heat transfer P through the rod

Experimental Set-up

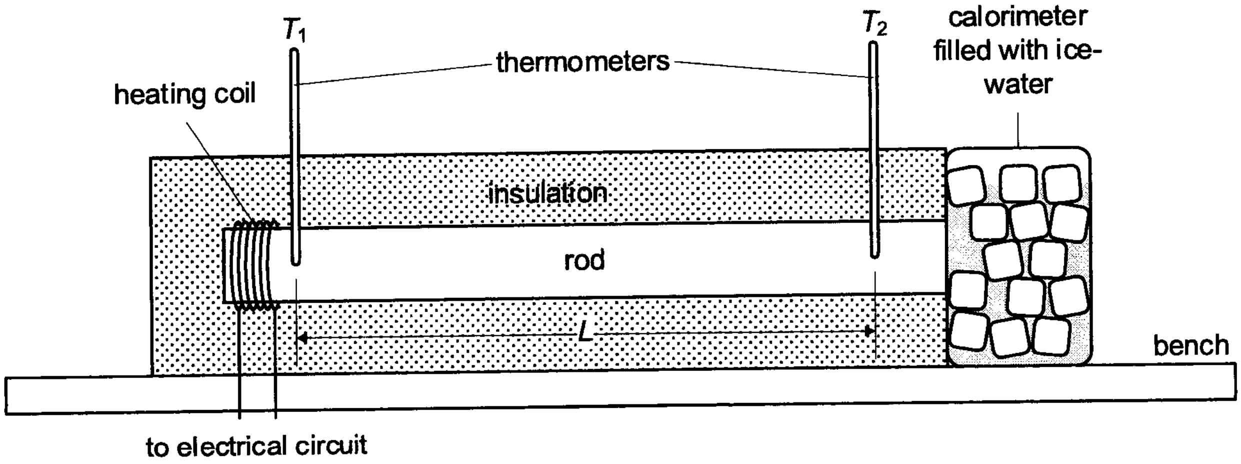


Fig. 4.1

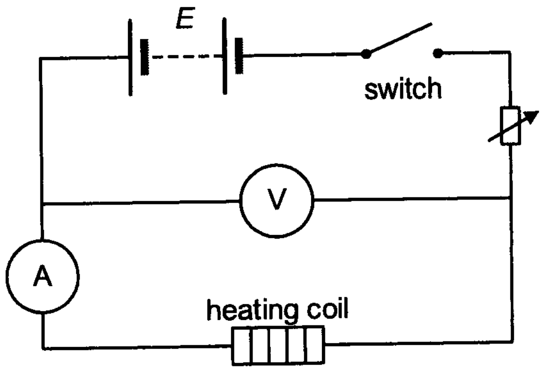


Fig. 4.2

Procedure

1. Set up the apparatus as shown in Fig. 4.1 and Fig. 4.2.
2. Drill a hole near each end of each rod and insert a thermometer into each hole.
   Measure and record the length L between the holes using a metre ruler.
3. Measure and record the diameter d of the rod using a pair of vernier callipers.
   Cross-sectional area of the rod is $A = \pi (d/2)^2$.
4. Close the switch.
5. Measure and record the current I through the coil with an ammeter and p.d. V across the coil with a voltmeter.
   If the heater and the rod are well insulated, the rate of heat transfer P through the rod is same as the power supplied to the coil $P = IV$.

   or

   Measure and record the mass m of ice melted, using an electronics balance, in time t, using a stopwatch.
   If the rod and the calorimeter is well insulated, the rate of hear transfer P through the rod is $P = ml_f/t$, where l_f is the specific latent heat of fusion of ice.
6. Measure and record the temperatures T_1 and T_2 of the thermometers when the readings are steady.
   Temperature gradient between the holes is $\frac{\Delta T}{L} = \frac{T_1 - T_2}{L}$.

Experiment 1: Variation with P of $\Delta T/L$ [heading is optional]

7. Repeat steps 4 to 6 to obtain a total of 10 sets of values of P and $\Delta T/L$ by adjusting the variable resistor to vary P.
8. Cross-sectional area A of the rod is kept constant by using the same rod.

Analysis

$$\lg\left(\frac{\Delta T}{L}\right) = m \lg P + \lg\left(kA^n\right)$$

Plot a graph of $\lg\left(\frac{\Delta T}{L}\right)$ against $\lg P$.

If the relationship is true, then a straight line will be obtained where m is the gradient and $\lg\left(kA^n\right)$ is the vertical intercept.

Experiment 2: Variation with *A* of $\Delta T/L$ [heading is optional]

9. Repeat steps 3 to 6 to obtain a total of 10 sets of values of A and $\Delta T/L$ by using rods of different diameters d.

10. Power supplied to the coil P is kept constant by maintaining the same current I and p.d. V.

Analysis

$$\lg\left(\frac{\Delta T}{L}\right) = n\lg A + \lg\left(kP^m\right)$$

Plot a graph of $\lg\left(\frac{\Delta T}{L}\right)$ against $\lg A$.

If the relationship is true, then a straight line will be obtained where n is the gradient and $\lg\left(kP^m\right)$ is the vertical intercept.

Additional Details

1. To ensure accurate temperature readings, create good thermal contacts by drilling holes into the rod to hold the thermometers and adding conducting liquid in the hole.
2. To ensure that steady state has been achieved, take temperature readings only when T_1 and T_2 are steady.
3. To prevent heat loss to the environment, insulate the rod.
4. Stir the ice-water bath constantly to ensure uniform temperature.
5. To reduce the percentage uncertainty in ΔT, either increase the power supplied to the heating coil or use longer rods so that ΔT is sufficiently large.

   or

   Adjust the rheostat to produce the appropriate power so that temperature T_1 and/or T_2 is within the range of the thermometer.
6. To reduce percentage uncertainty in d or A, measure diameter d at multiple positions and determine the average diameter.

Safety Precautions [No Marks Awarded]

1. Wear gloves when handling the heating element or rod to prevent accidental burns.