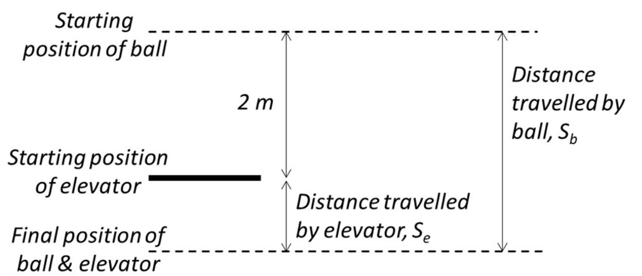
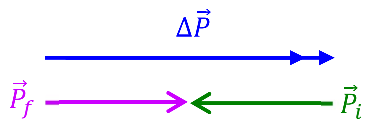
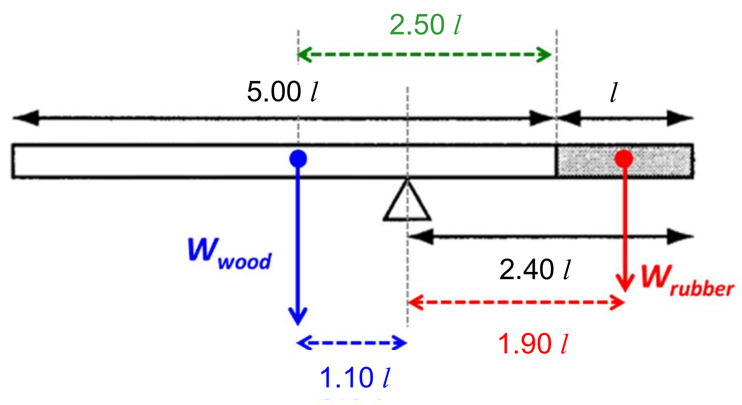
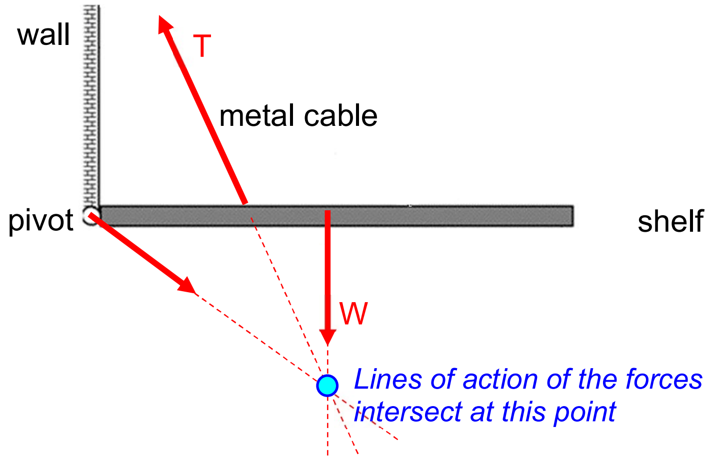
Solutions to Paper 1

1	**D**	Temperature difference = $\theta_f - \theta_i$ = 80 – 20 = 60 °C Absolute uncertainty, = $\Delta\theta_f + \Delta\theta_i$ = 0.5 + 0.5 = 1 °C Percentage uncertainty = $\frac{1\,°C}{60\,°C} \times 100\%$ = 1.7%
2	**B**	The object starts from rest and moves along a straight line. Area under the acceleration-time graph represents <u>change</u> in velocity. The triangle below the time axis shows that the change in velocity is in the negative direction. Since the <u>initial velocity is zero</u>, that triangle represents the increasing velocity (in – ve direction). This happens up to the time at A. Beyond A, the acceleration changes direction (from – ve to + ve dir). However, the velocity still points in the – ve direction after A i.e. object continues to travel in the same direction (still getting further away from the starting point), except that since the acceleration and velocity point in opposite directions, the object is slowing down. At point B the object comes to a momentary stop and it is also the furthest from the starting point. Between B and C, the object changes its velocity direction and starts to speed up back towards the starting point. At C, the object possesses maximum speed as it moves towards the starting point. Beyond C, the object slows down but it is still moving towards the starting point. At D, the object is back at the starting point.
3	**D**	 $S_b - S_e = 2$ $2.0 = [ut + (0.5)(9.81)\,t^2] - [ut + (0.5)(5.8)\,t^2]$ t = 1.00 s Or recognise that the effective acceleration = 9.81 – 5.8 = 4.01 m s^{-2}. Using $s = ut + \frac{1}{2}at^2$, $2.0 = \frac{1}{2}(4.01)t^2$, giving t = 1.00 s.
4	**A**	The question asks for the HORIZONTAL forces only. The horizontal force the propels the man forward is the frictional force of pool's floor on his feet. The horizontal resistive force on his motion comes from the drag due to water. Using Newton's second law along the horizontal direction: Net force on man = (mass of man)(acceleration of man) i.e. $f - f_D = ma$

5	**A**	Magnitude of the change in momentum ΔP = area under graph = $\frac{1}{2}(150)(40 \times 10^{-3})$ = $3\,Ns$. This change in momentum takes place in the direction of the force, i.e. opposite to the initial momentum. In the vector diagram below, the ball is approaching the racket from right to left.  $\vec{P}_f - \vec{P}_i = \Delta\vec{P}$ $P_f + P_i = \Delta P$ $(0.060)(30) + P_i = 3$ $P_i = 1.2\,Ns$
6	**C**	The thrust must provide an upward force to propel the rocket upward. This force must be least at equal to its weight. Thrust $= v\left(\frac{dm}{dt}\right)$ $v\left(\frac{dm}{dt}\right) = Mg$ $\frac{dm}{dt} = \frac{Mg}{v} = \frac{(500)(9.81)}{1000} = 4.9\,kg\,s^{-1}$
7	**C**	 Taking moments about the CG (pivot) and letting *A* be the x-sectional area, W_{wood} (distance of center-of-mass of wood from pivot) = W_{rubber} (distance of center-of-mass of rubber from pivot) $A(5.00\,l)\rho_{wood}\,g(1.10\,l) = A(l)\rho_{rubber}\,g(1.90\,l)$ $5.00\,\rho_{wood}(1.10) = \rho_{rubber}(1.90)$ $\frac{\rho_{rubber}}{\rho_{wood}} = \frac{5.50}{1.90} = 2.89$

<table>
<tr>
<td>8</td>
<td>D</td>
<td>


Lines of action of the three co-planar non-parallel forces intersecting at a point is necessary if the object is in <u>rotational equilibrium</u>.

Vector sum of all forces add to zero is necessary if the object is in translational equilibrium. Hence the answer cannot be A.
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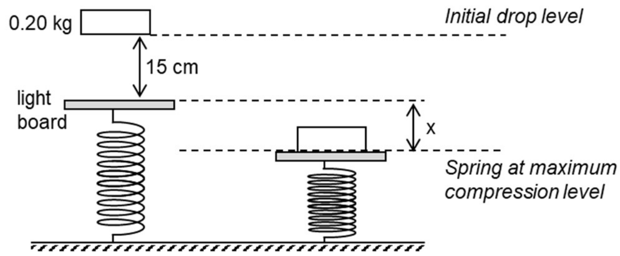
<tr>
<td>9</td>
<td>D</td>
<td>
No kinetic energy at the initial drop level as well at at the final maximum compression of spring.
Comparing the total energy at the initial and final positions,
gain in elastic potential energy = total loss in gravitational potential energy

$$\frac{1}{2}kx^2 = mg(0.15 + x)$$

$$\frac{1}{2}(85)x^2 = (0.20 \times 9.81)(0.15 + x)$$

$$42.5x^2 - 1.962x - 0.2943 = 0$$

$$x = 0.109 \text{ m}$$



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<tr>
<td>10</td>
<td>C</td>
<td>
At maximum speed, engine force = drag force of kv.

Power of boat, P = (engine force) v = kv^2

Hence, $$\frac{P_{\text{one engine}}}{P_{\text{two engines}}} = \left(\frac{v_{\text{one engine}}}{v_{\text{two engines}}}\right)^2$$

$$\frac{32}{64} = \left(\frac{v_{\text{one engine}}}{14}\right)^2$$

$$v_{\text{one engine}} = 9.9 \text{ m s}^{-1}$$
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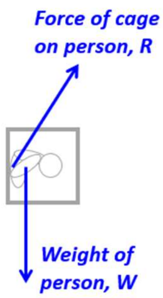
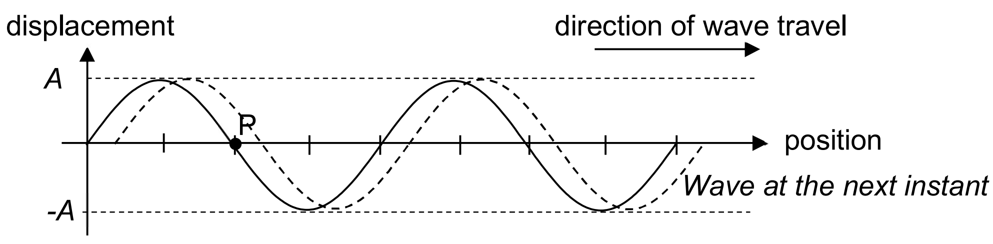
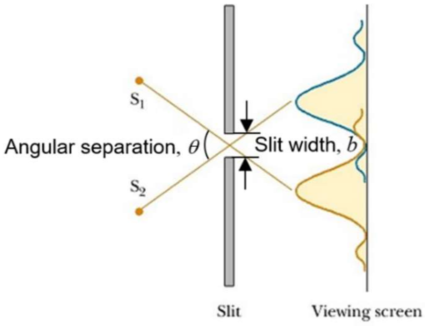
11	**A**	There are only two forces acting on the person, force of cage on him, ***R*** and his weight, ***W***. Since the man is in uniform (i.e. constant speed) circular motion, the net force on him is directed toward the centre of the circle, i.e. toward the right. The vector sum of ***R*** and ***W*** must point toward the right. Vertical component of ***R*** must balance the weight. Horizontal component of ***R*** provides the centripetal force (which is also the net force). 
12	**C**	Option A: The variable x is denoted as the distance *above the surface of the earth.* It is not defined from the centre of the Earth. Option B: $F_g = -\frac{dE_p}{dx}$. The force is the gradient of the $E_p - x$ graph, not ratio of E to x. [whereas the resistance is the ratio V to I, and not the gradient as given by dV/dI.] Option C: $F_g = -\frac{dE_p}{dx}$. Take note, for small distances above the Planet's surface, the gravitational field strength is approximately constant. Hence, the gradient of the graph is the same. Option D: The equation does not adhere to $F_g = -\frac{dE_p}{dx}$.
13	**D**	Frictional force by P on Q is the restoring force for Q. Without friction, Q will not move as P slides underneath it. Net force on Q is provided for by the frictional force by P on Q. friction = $ma = m\omega^2 x$ $5.0 = 0.2\,\{(2\pi)(1.5)\}^2 A$ A = 0.28 m
14	**B**	The components of the particle's motion in the horizontal x-direction is simple harmonic. Hence $a \propto -x$. This holds true for the motion in the y-axis as well.
15	**C**	 When the wave profile is drawn in the next instant (dotted line), one can tell that Particle P will be moving upwards in the positive direction, hence option A is incorrect. As the particle P is undergoing a simple harmonic oscillation, at this instance it is at the equilibrium position, it should have the maximum velocity, zero acceleration. So, options B and D are incorrect. As the displacement-position graph does not show a decreasing amplitude, all particles along the wave (including Particle P) have an amplitude of A. This is one of the distinguishing features between a progressive wave and a stationary wave. For the latter, the amplitude varies from maximum at the antinode and zero at the node.

16 **B**

Resolution or Rayleigh questions necessarily involve small angles.

$$\theta_{min} = \frac{\lambda}{b}$$



If angle of θ subtended at the opening by the two sources is greater than θ_{min}, the two images will be resolved (distinguished on the screen). This means that in order to make the separation of the images clearer, we can either increase θ or reduce θ_{min}.

Options A and C actually increases θ_{min} while keeping θ constant. This would make the images less resolved.

Option D does not affect either θ_{min} or θ so it should have no effect on the resolution of the images.

For option B, by reducing *D*. the angular separation θ increases for the same θ_{min}, thus the images are better resolved.

17 **A**

Using $d \sin\theta = n\lambda$,

Where there is an overlap between a lower order - longer wavelength and higher order-shorter wavelength, θ is the same. Since the same diffraction grating is used, *d* is the same.
Hence, $n\,\lambda_{longer} = (n + 1)\,\lambda_{shorter}$

Systematically working out,
When n = 1 and λ_{longer} = 700 nm, (n+1) = 2 and $\lambda_{shorter}$ = 350 nm. Since 350 nm is outside the range of 400 to 700 nm, there is no overlap between the first order's 700 nm and the second order's 400 nm.

When n = 2 and λ_{longer} = 700 nm, (n+1) = 3 and $\lambda_{shorter}$ = 467 nm. Since 467 nm is within the range of 400 to 700 nm, there is an overlap between the second and third orders.

The highest order of diffraction where there is no overlap is n = 1, the 1st order.

<u>Alternatively</u>

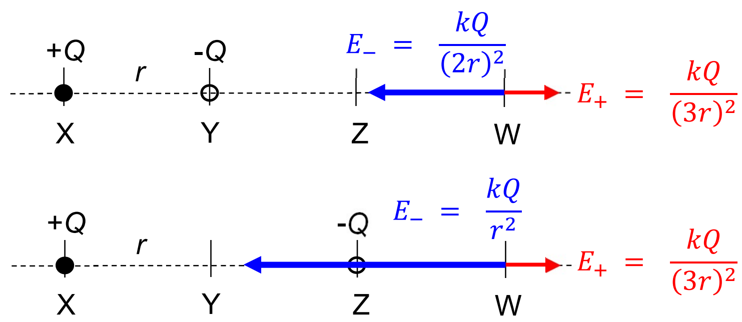
Using $d \sin\theta = n\lambda$, work out the angle of deviation θ for 400 nm light and 700 nm for each order *n*.

Order, n	θ for 400 nm	θ for 700 nm
1	6.9°	12.1°
2	13.9°	24.8°
3	21.1° (inside 2nd order)	

18 **C**

Statements A, B, D are correct assumptions while statement C is incorrect. The molecules are assumed to undergo elastic collisions with the walls of the container i.e. after the collisions the molecules move off in the opposite direction while having the same speed. Hence the change in momentum of the molecules Δp as shown below is not negligible.

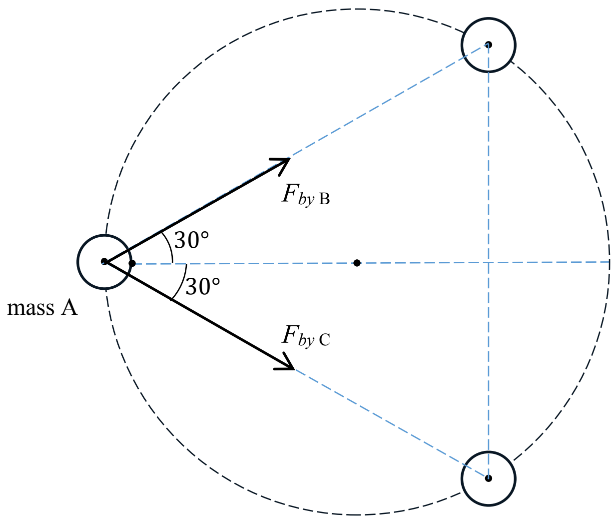
$$\Delta p = mv - m(-v) = 2mv$$

19	**A**	From the ideal gas equation: $pV = NkT$ ………(1) and total internal energy of the gas molecules in the box, $U = \frac{3}{2}NkT$ Introducing additional N molecules of the same gas into the box $\Rightarrow$ $p'V = (2N)kT'$ ………(2) and total internal energy of the gas molecules, $U' = \frac{3}{2}(2N)kT'$, where p' & T' are the new pressure and temperature, and U' is the new internal energy of the gas in the box. $U = U'$ $\rightarrow$ $\frac{3}{2}NkT = \frac{3}{2}(2N)kT'$, resulting in $T' = \frac{1}{2}T$ (2) $\div$ (1) $\rightarrow p' = p$
20	**C**	A: $U = k\frac{Q_1Q_2}{r_{12}}$. When r increases, U becomes less negative, i.e. the potential energy increases. B:  C: $V_W = k\frac{Q_1}{r_{1W}} + k\frac{Q_2}{r_{2W}}$. When -$Q$ is moved to Z, which is closer to W, V_W becomes more negative, i.e. the potential at W decreases. D: +Q and -Q are at the same distance from Y. Based on the formula above, the potential at Y is zero.
21	**D**	Volume V is constant, express cross-sectional area A in terms of V and L: $AL = V \Rightarrow A = V/L$ Hence, the resistance variation with L is given by : $R = \frac{\rho L}{A} = \frac{\rho L^2}{V} \propto L^2$
22	**B**	Resistance of each of the lamp : $R = \frac{V^2{}_{rating}}{P_{rating}}$ since, both of them have the same voltage rating: $\frac{R_A}{R_B} = \frac{P_{rating,B}}{P_{rating,A}} = \frac{40}{10} = \frac{4}{1}$ Since, both lamps are connected in series, the same current passes both lamps and power emitted by each lamp : $P_{emitted} = I^2R$. $\frac{P_{emitted,A}}{P_{emitted,B}} = \frac{R_A}{R_B} = \frac{4}{1} \Rightarrow P_A = 4P_B$

23	**A**	Consider the secondary circuit: when temperature is low the resistance of the thermistor is high. This means that the terminal p.d. across the secondary cell is larger. (note that if the secondary cell has no internal resistance it would not matter what the resistance of the thermistor was, as the terminal p.d. would always simply be the secondary cell's e.m.f.) Consider the driver circuit: when it is dark the resistance of the LDR increases. This means that less of the driver cell e.m.f. drops across wire PQ. With a smaller p.d. per unit length of PQ, a longer balance length is needed.
24	**B**	The force per unit length acting on Z by X, $\frac{F_{XZ}}{l_Z} = B_X l_Z = \frac{\mu_o\, l^2}{2\pi\,(2d)} = F$ The force per unit length acting on Z by Y, $\frac{F_{YZ}}{l_Z} = B_Y l_Y = \frac{3\mu_o\, l^2}{2\pi\, d} = 6F$ Currents in Y and Z are in the same direction: Y attracts Z. Currents in X and Z are in opposite direction: X repels Z. Hence, the net force of 5*F* towards Y.
25	**C**	The copper disc "sees" the magnet rotating. The portion of the disc either "sees" an approaching pole or a pole moving away. By Lenz's law, in order to "oppose" the change (which again, is the rotation of the magnet), the disc will tend to rotate in the same direction as the magnet so that the magnet will appear "stationary" from the disc's perspective.
26	**B**	Using the potential divider principle, potential difference across the secondary coil = $80 \times \left(\frac{1500}{1000}\right) = 120V$ Current passing through the secondary coil = $I = \frac{V}{R} = \frac{80}{1000} = 0.080A$ Power dissipated by secondary coil = $IV = 0.080 \times 120 = 9.60W$ Potential difference across the primary coil = $120 \times \frac{200}{500} = 48.0V$ Power dissipated by primary coil = $V_p I_p = 9.60 \rightarrow I_p = \frac{9.60}{48.0} = 0.20A$
27	**C**	
28	**B**	Energy of photon = $\frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{(435 \times 10^{-9})} = 4.57 \times 10^{-19} J = 2.86\ eV$ Transition B, the difference in energy level = $(-0.54) - (-3.40) = 2.86\ eV$
29	**B**	Energy released = BE of helium – BE on reactants 3.26 = 2.54 × 4 – 4 × BE/nucleon of deuterium BE/nucleon of deuterium = 1.725 MeV
30	**B**	Let the background count-rate be C_B. $\frac{1}{4}(600 - C_B) = 180 - C_B$ $0.75C_B = 30$ C_B = 40 counts min^{-1}

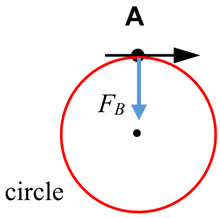
2024 HCI Preliminary Examination Paper 2 Suggested Solutions

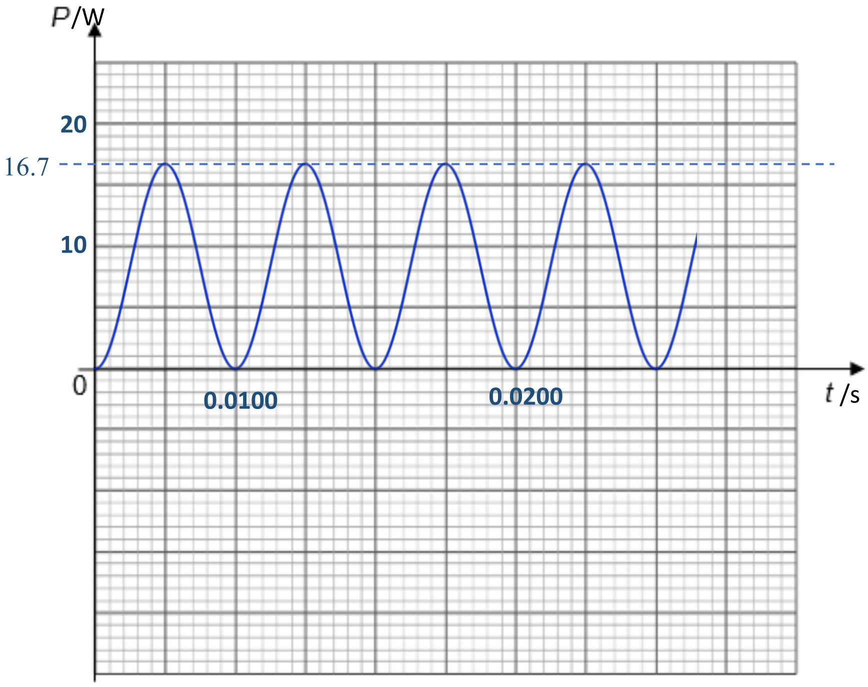
Q1		
(a)	During the collision, there are <u>no external forces acting on the photon and electron or system</u>, hence linear momentum is conserved.	**B1**
(b)(i)	**1.** $\sum p_x = 7.30\times10^{-22}\ \text{kg m s}^{-1}$	**B1**
	2. $\sum p_Y = 0\ \text{kg m s}^{-1}$	**B1**
(b)(ii)	By principle of conservation of linear momentum, $(\rightarrow)\ 7.3\times10^{-22} = (p_p)(\cos 60^o) + (p_e)(\cos 25^o) \quad \ldots(1)$ $(\uparrow)\ (p_e)(\sin 25^o) = (p_p)(\sin 60^o) \quad \ldots(2)$ Solving (1) and (2) gives, $\dfrac{(p_p)(\sin 60°)}{(p_p)(\cos 60°)} = \tan 60° = \dfrac{(p_e)(\sin 25°)}{(7.3\times10^{-22}) - (p_e)(\cos 25°)}$ $\Rightarrow p_e = 6.35\times10^{-22}\ \text{kg m s}^{-1}$ M1, M1 – 2 equations showing application of COLM A1 – final answer after solving two equations.	**M1** **M1** **A1**

Q2		
(a)	Every **point mass attracts** every other **point mass** with a **force** that is directly **proportional to the product of their masses** and **inversely proportional to the square of the distance between them**.	B1 B1
(b)(i)	 The vertical components of the two forces due to B and C cancel each other, hence, Resultant force in the y-direction = 0 Hence, Resultant force F = Resultant force in the x-direction $= 2\times\frac{GM^2}{d^2}\times\cos 30° = 2\times\left(\frac{6.67\times10^{-11}(6.20\ x\ 10^{24})^2}{(1.32\times10^{9}\ )^2}\right)\times\cos 30° = 2.5487\times10^{21}$ N $=2.55\times10^{21}$ N Alternative methods accepted.	 B1 M1
(b)(ii)	The resultant gravitational force **provides** for the centripetal force required for the rotation of planet A.	B1
	$F = m\omega^2 R$ $\omega = \sqrt{\frac{F}{mR}} = \sqrt{\frac{2.5487\times10^{21}}{6.20\times10^{24}\times7.60\times10^{8}}} = 7.3546\times10^{-7}$ rad s^{-1} $T = \frac{2\pi}{\omega} = \frac{2\pi}{7.3546\times10^{-7}} = 8.54\times10^{6}$ s	 M1 A1
(b)(iii)	The gravitational **potential is set to be <u>zero at infinity</u>**. Gravitational force is **<u>attractive</u>** in nature and **<u>the force exerted on a test mass by the external agent will be in opposite direction to the displacement of the mass</u>**. Thus negative work is done by the external force (to bring a test mass from infinity to the point and hence potential is negative). <u>OR</u> The gravitation potential is set to be **<u>zero at infinity</u>**.	B1 B1 **OR** B1

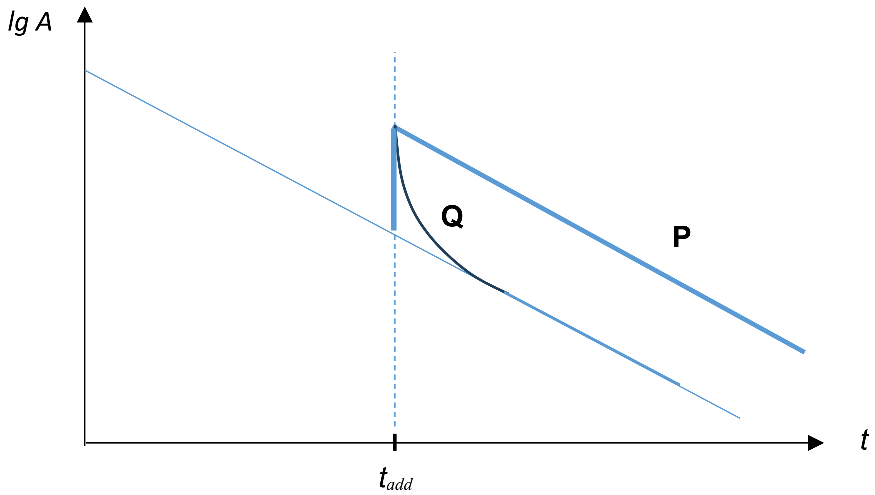
	Since gravitational force is **attractive** in nature, (positive) **work is done by an external agent to bring a (test) mass from the point** (in the field if these 3 planets) **to infinity**, hence the (initial) potential is therefore (lower than at infinity and hence) negative.	**B1**
(b)(iv)	$U = U_{AB} + U_{AC} + U_{BC}$ $= -\frac{Gm^2}{d} + \left(-\frac{Gm^2}{d}\right) + \left(-\frac{Gm^2}{d}\right)$ $= 3 \times \left(-\frac{6.67 \times 10^{-11}\left(6.20\ x\ 10^{24}\right)^2}{1.32 \times 10^9}\right)$ $= -5.83 \times 10^{30}$ J	 **M1** **A1**

Q3		
(a)	A polarised wave is one in which the vibrations/oscillations of the wave are restricted to only one direction in the plane normal/perpendicular to the direction of energy transfer.	**B1** **B1**
(b)(i)	As long as polarising filter B is perpendicular to either polarising filter A or filter C, the emergent light from filter C will be zero. Hence, the other angle that occurs will be when polarising axis of B is 90° of C, i.e. $\theta = 135°$	 **A1**
(b)(ii)	Using Malus' Law, Intensity of light emergent from polarising filter B = $I \cos^2(60°)$ Intensity of light emergent from polarising filter C = $I \cos^2(60°) \cos^2(60° - 45°)$ $= 0.233\, I$	 **M1** **A1**

Q4		
(a)(i)	 (Use FLHR to get the direction of force – the force will provide for centripetal acceleration for circular motion as it is always perpendicular to the velocity and hence points towards centre of circle. The center of circle should be below point A) Complete circle with centre of circle vertically below point A and the arrow tangential to the circle.	B1
(a)(ii)	The magnetic force provides for the centripetal force required for circular motion,	B1
	$Bqv = \frac{mv^2}{R} \quad \Rightarrow R = \frac{mv}{Bq} = \frac{(9.11\times10^{-31}\text{ kg})(2.8\times10^{7}\text{ m s}^{-1})}{(1.2\times10^{-3}\text{ T})(1.60\times10^{-19}\text{ C})} = 0.133\text{ m}$ = 13 cm (shown)	M1
(b)(i)1	Direction of electric field is downward in the plane of the paper.	A1
(b)(i) 2	For the electron to be undeflected, the net force on it must be zero. $qvB = qE$ $\Rightarrow E = vB = (2.8\times10^{7})(1.2\times10^{-3})$ $= 3.36\times10^{4}\text{ N C}^{-1}$	 M1 A1
(b)(ii)	Helix (out of the plane of the paper) with an increasing pitch *Remarks :* • Spiral not accepted as answer. Spiral is not helix – a spiral has a changing radius. • "Increasing pitch" can be marked from the diagram if it is included. But at least four turns needs to be drawn for any credit.	B1 B1

Q5		
(a)(i)	$\omega = \frac{2\pi}{T} = 628 \Rightarrow T = 1.00 \times 10^{-2}$ s	A1
(a)(ii)	$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{15}{\sqrt{2}} = 10.6$ V = 11 V	A1
(a)(iii)	$\frac{1}{R_{eff}} = \frac{1}{12.0} + \frac{1}{3.0+6.0} = \frac{7}{36} \Rightarrow R_{eff} = 5.1429\ \Omega$	M1
	$I_0 = \frac{V_0}{R} = \frac{15}{5.1429} = 2.92$ A = 2.9 A	A1
(a)(iv)	V_{rms} across 6.0 Ω resistor = $\frac{V_0}{\sqrt{2}} = \frac{(15 \times \frac{6.0}{9.0})}{\sqrt{2}} = \frac{10.0\text{ V}}{\sqrt{2}} = 7.071$ V	M1
	Mean power = $\frac{V^2}{R} = \frac{7.071^2}{6.0} = 8.33$ W = 8.3 W	A1
(b)	 $P_0 = 8.33 \times 2 = 16.7\ W$	
	B1 : Correct shape (sin² graph) *B1: at least 2 cycles shown with period labelled correctly ($t \geq 2T$ i.e. 4 maximum power in graph)* *B1: correct peak value labelled on graph.*	B3

Q6		
(a)(i)	Gain in kinetic energy of electron = Loss in EPE of system $\frac{1}{2}mv^2 - 0 = eV$ $v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2(1.6 \times 10^{-19})(100)}{9.11 \times 10^{-31}}} = 5.93 \times 10^{6}$ m s^{-1}	**M1** **A1**
(a)(ii)	$\lambda = \frac{h}{p} = \frac{(6.63 \times 10^{-34})}{(9.11 \times 10^{-31})(5.93 \times 10^{6})}$ $= 1.23 \times 10^{-10}$ m	**M1** **A1**
(b)(i)	$2d \sin \theta$	**B1**
(b)(ii)1.	The electrons emerge with a larger speed/kinetic energy and hence momentum.	**B1**
	By de Broglie relationship ($\lambda = \frac{h}{p}$), the wavelength of the electrons decreases.	**B1**
(b)(ii)	The path difference of the electron waves (from the different atomic planes) arriving at the detector remains constant, however the wavelength of the electrons decreases continually.	**B1**
	When the path difference is integer multiple of the de Broglie wavelength of the electrons (0, λ, 2λ, …..), constructive interference occurs/ the electron waves meet in phase,	**B1**
	the likelihood/chance/probability of the electrons arriving at the detect is large and a maximum value of I is detected.	**B1**
	B1 - path difference is constant *B1 - CI /maxima occurs when path difference is integer multiple of the wavelength of the electrons.* *B1 – maxima corresponds to high chance probability of electron arriving there*	

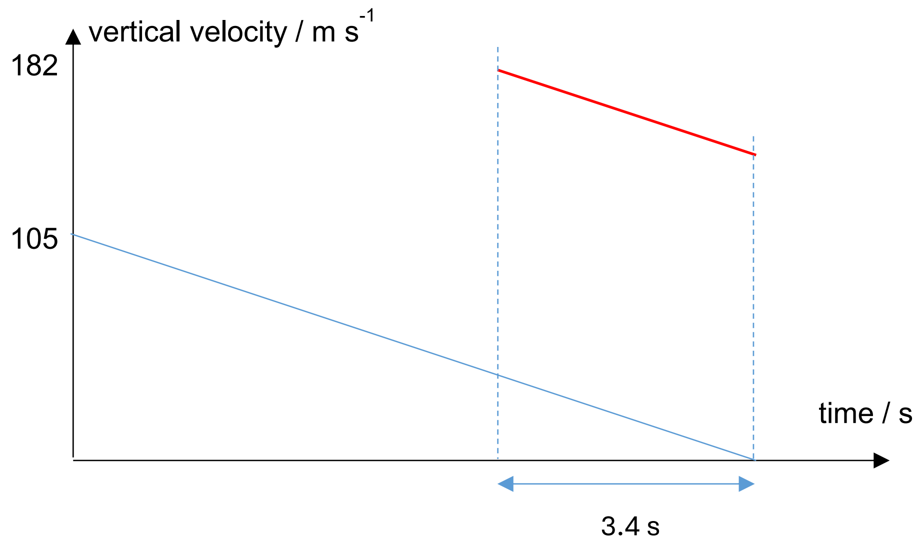
Q7		
(a)	The half-life of a radioactive nuclide is the <u>average time</u> taken for half of the original <u>number</u> of nuclei in a sample of the radioactive nuclide to decay. Or the activity of a sample of the radioactive nuclide to halve.	B1
(b)	Activity is the number of disintegrations per unit time.	B1
(c)(i)	Half-life = 12.5 h = 12.5 × 60 × 60 = 45000 s Decay constant $= \dfrac{\ln 2}{\text{half-life}} = \dfrac{\ln 2}{45000}$ $= 1.54 \times 10^{-5}\ \text{s}^{-1}$	B1 M1 A1
(c)(ii)	$A = \lambda N = \dfrac{\ln 2}{T_{1/2}}(0.22N_0) = \dfrac{\ln 2}{(12.5 \times 60 \times 60)}(0.22N_0)$ $= 3.39 \times 10^{-6} N_0$ Bq	M1 A1
(d)(i) and (ii)	 For P, the gradient is the negative of the decay constant. Same nuclide same decay constant and hence same gradient. For Q with a very much shorter half-life compared to K-42, it will approach the original graph quite quickly. ($A = A_{10}e^{-\lambda_1 t} + A_{20}e^{-\lambda_2 t}$. Cannot linearise to give a straight line.)	 B1 B1

Q8		
(a)(i)	From graph, when v = 25 m s^{-1}, P = 500 W	B1
(a)(ii)	$P = Fv$ $F = \frac{P}{v} = \frac{500}{25} = 20$ N	M1 A1
(a)(iii)	At constant velocity, the net force on the rider is zero. Furthermore, F_{slope} = 0 since the ground is level. Hence, the propulsive force = the drag force F_{air} ρ = 1.0 x 10^{-3} g cm^{-3} = $\frac{1.0\times10^{-3}\times10^{-3}}{10^{-6}}\frac{\text{kg}}{\text{m}^3} = 1.0$ kg m^{-3} $F_{air} = \frac{1}{2}\rho C_D A v^2$ $20 = \frac{1}{2}(1.0)(C_D A)(25^2)$ Effective drag area, $C_D A = 0.064\text{m}^2$ C1 – appreciate that F_{air} = F allow mark as long as 20 N is substituted for M1 – for correct conversion of density to kg m^{-3} A1 – correct calculation of drag area.	C1 M1 A1
(b)(i)	$\tan(\alpha) = \frac{37}{100} \Rightarrow \quad \alpha = 20.304°$	M1
	$F_{slope} = mg\sin\alpha$ $= (85)(9.81)(\sin 20.304°)$ $= 290$ N	M1 A1
(b)(ii)1.	work done against gravity = (mg sin α)(x) = (289)(6.4) = 1850 J	M1 A1
(b)(ii)2.	Since the cyclist and bicycle is moving up the slope at constant speed, $F'_{prop} = F_{air} + F_{slope}$	C1
	From (a), F_{air} = 20 N	
	Hence, P' = F'_{prop} v = (20 N + 289 N) (25 m s^{-1}) = 7 725 W = 7700 W	M1 A1
(c)(i)	By Newton's 2nd Law, $\Sigma\vec{F} = m\vec{a}$ (↑) $N_1 + N_2 = W = mg$ ....(1) (→) $\mu N_1 + \mu N_2 = ma$ ......(2) Hence, $\mu(N_1 + N_2) = \mu mg = ma$	M1 M1

	Solving, $a = \mu g = (0.37)(9.81) = 3.63$ m s^{-2}	A1
(c)(ii)	Taking moments about the CG, by principle of moments Sum of anticlockwise moments = Sum of clockwise moments $(43)N_2 \quad + \quad (114)\mu N_1 \quad + \quad (114)\mu N_2 \quad = \quad (107-43)N_1$ $\Rightarrow \; 43N_2 + 42.18W = 64N_1$ ......(1) Since, $N_1 + N_2 = W$ ……(2) Substituting (2) into (1) and solving, $43\,(W - N_1) + 42.18\,W = 64N_1 \;\Rightarrow N_1 = 0.7960\,W = 0.80\,W$ (Shown)	M1 M1
(c)(iii)	Comparing the normal contact force at the front wheel to that at the back wheel, the ratio = 4.	B1
(c)(iv)	If the centre of mass moves forward, the (clockwise) torque produced by N_1 decreases and (anticlockwise) N_2 increases. Hence, there is now a net anticlockwise torque on the bicycle causing the bicycle to flip forward.	B1 B1

2024 HCI Preliminary Examination Paper 3 Suggested Solutions

Q1		
(a)	Random errors are deviations of the measured value from the mean value, with varying signs and magnitudes. Systematic errors are deviations of the mean value from the true value, with same sign and similar magnitude.	**B1** **B1**
(b)	The units of P are $\frac{(\text{kg m s}^{-2})(\text{m})}{\text{s}}$= kg m^2 s^{-3} The units of $k\rho A^p v^q$ are (1) $(\frac{\text{kg}}{\text{m}^3})(\text{m}^2)^p(\text{m s}^{-1})^q = \text{kg m}^{-3+2p+q}\text{s}^{-q}$ For the equation to be homogeneous, the units of P must be equal to the units of $k\rho A^p v^q$. Comparing power: seconds: $-q = -3 \Rightarrow q = 3$ metres: $-3 + 2p + q = 2 \Rightarrow p = 1$	**M1** **M1** **A1**

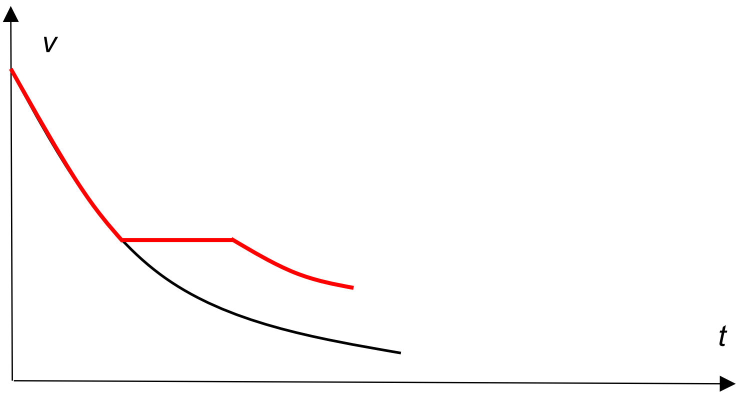
Q2		
(a)	The **acceleration** of an object is its **rate of change of velocity** with respect to time.	**A1**
(b)(i)	Taking upward to be positive and using $v_y{}^2 = u_y{}^2 + 2a_y s_y$, where v_y is the vertical component of the final velocity, u_y is the vertical component of the initial velocity, a_y is the vertical component of the acceleration and s_y is the vertical component of the displacement. At the highest point, the vertical component of the velocity is zero. Furthermore, ignoring air resistance, the vertical component of the acceleration is $a_y = -g = -9.81$ m s^{-2}. Hence, $0 = (210 \sin (30^o))^2 + 2(-9.81)\, h$ $h = 561.9$ m $= 560$ m (1, 2 or 3 s.f.)	**M1** **A1**
(b)(ii)	Taking upwards as positive and using $v_y = u_y + a_y t$ $0 = (210 \sin (30^o)) + (-9.81)\, t$ $t = 10.703$ s $= 11$ s (1, 2 or 3 s.f.)	**M1** **A1**
(b)(iii)	From (b)(i), we know that the highest point for P is 561.9 m. Using $s_y = u_y t + \frac{1}{2} a_y t^2$, $561.9 = (210 \sin (60^o))t_Q + (0.5)(-9.81)\, t_Q{}^2$ $t = 3.4$ s or $t = 33.7$ s Since t must be less than 10.7 [from part (b)(ii)], $t = 33.7$ s should be rejected. $t = 3.4$ s (shown)	**B1** **A0**
(b)(ii)	 B1 – **parallel to** and **above** original line. (P starts at $210 \sin 30° = 105$ m s^{-1} while Q starts at $210 \sin 60° = 182$ m s^{-1}. Values not needed in sketch) B1 – **starts after mid-point** of original line and **ends at the same time** (3.4 s not needed in sketch)	

Q3		
(a)(i)	Fluid **pressure increases with depth**.	B1
	The **upward forces** due to the fluid pressure acting on the lower surface of the material are larger than the **downward forces** due to the fluid pressure acting on the upper surface of the material, resulting in a **net upward force** called the upthrust.	B1
(a)(ii)	Upthrust on cup = weight of water displaced = $V \rho_{water} g$ = $(6.8 \times 10^{-5}) \times (1000) \times (9.81) = 0.66708$ N	M1
	Weight of cup = $V \rho_{cup} g$ = $(6.8 \times 10^{-5}) \times (2200) \times (9.81)$ = 1.4676 N	M1
	Since the weight of the cup is larger than the upthrust acting on the cup, an *upwards* external force *F* is required to keep the cup stationary. Since the cup is held in equilibrium, the net force acting on the cup is zero. Hence, $F + U = W_{cup}$ $F = W_{cup} - U$ = 1.4676 – 0.66708 = 0.800496 = 0.80 N	A0
(a)(iii)	Since the cup was already fully submerged, there is **no difference in the volume** and hence weight **of fluid displaced**, the upthrust stays constant.	B1
	or	
	The **difference in pressure between the upper and lower surface remains the same** and therefore the upthrust stays constant.	B1
(b)	Pressure of compressed air = pressure at depth *d* = (atmospheric pressure) + (hydrostatic pressure) = $p_{atm} + \rho g d$ = $(1.0 \times 10^5) + (1000) \times (9.81) \times (0.30)$ = 1.02943×10^5 Pa	B1
	Applying $p V$ = constant, since temperature is unchanged, $(1.0 \times 10^5)(5.50 \times 10^{-4}) = (1.02943 \times 10^5) V$	M1
	$V = 5.3429 \times 10^{-4}$ m^3 $= 5.3 \times 10^{-4}$ m^3	A1

Q4		
(a)	An oscillatory motion where the acceleration is directly proportional to displacement from equilibrium, and where acceleration is always opposite to displacement / acceleration is always directed toward equilibrium.	**B1** **B1**
(b)	Since $a \propto -y$ By comparing with $a = -\omega^2 x$, $\omega^2 = \dfrac{\rho A g}{M}$ $T = \dfrac{2\pi}{\omega}$ $= 2\pi\sqrt{\dfrac{M}{\rho A g}}$ $= 2\pi\sqrt{\dfrac{0.012 + 0.025}{1000 \times 6.0 \times 10^{-4} \times 9.81}}$ $= 0.498$ s $= 0.50$ s	 **B1** **B1**
(c)(i)	Energy of oscillation is the (maximum) kinetic energy the test-tube possesses, which decreases with time due to damping. Energy of oscillation = $\dfrac{1}{2}mv_0^{\ 2} = \dfrac{1}{2}m(\omega A)^2 = \dfrac{1}{2}m\omega^2 A^2$. A reduction of 75 % would mean that the energy of oscillation remaining is 25 % of its original. $\dfrac{E'}{E} = \dfrac{A'^2}{1.0^2}$ $\dfrac{1}{4} = \dfrac{A'^2}{1.0^2}$ $A' = 0.50$ cm From the graph, this happens at 1.0 s.	 **M1** **A1**
(c)(ii)	Natural frequency of the system is 2.0 Hz (since period is 0.5 s). However, the driving frequency is only 1.0 Hz. Energy transfer from the (external forcing agent) water waves to the test-tube is not optimal / does not result in resonance.	**B1** **B1**

Q5		
(a)(i)	Q = mass x specific latent heat of vaporisation $= 0.37 \times 2.3 \times 10^6$ $= 8.5 \times 10^5$ J	**A1**
(a)(ii)	$pV = nRT$ $T = (100 + 273) = 373$ K Number of moles, $n = 0.37 \times 1000$ g / 18 g $V = \dfrac{(0.37 \times 1000) \times 8.31 \times 373}{18 \times (1.0 \times 10^5)}$ $= 0.63714$ $= 0.64$ m^3	 **B1** **B1** **B1**
(a)(iii)	Work done *by* the water = (atmospheric pressure)(increase in volume) $= (1.0 \times 10^5)(0.64)$ $= 6.4 \times 10^4$ J	**A1**
(a)(iv)	Work done on water is negative. From the first law of thermodynamics, increase in internal energy = heat supplied + work done *on* water $= (8.5 - 0.64) \times 10^5$ $= 7.9 \times 10^5$ J	 **M1** **A1**
(b)	Kinetic energy of the molecules remains unchanged because there is no temperature change. Potential energy of the molecules increases, because molecular bonds are broken and the molecules are further apart. Hence, the internal energy of the system increases.	**B1** **B1** **A0**

Q6		
(a)(i)	The resistance is infinite.	**B1**
(a)(ii)	The resistance decreases as *V* increases.	**B1**
(b)(i)	Method 1: When the galvanometer reads zero, $V_{XZ} = V_{LDR} = \frac{R_{LDR}}{R_{LDR} + R}E = \frac{1600}{1600 + 1200}(9.0) = 5.143$ V For the wire, $\frac{V_{XZ}}{V_{XY}} = \frac{L_{XZ}}{L_{YZ}} \quad \Rightarrow L_{XZ} = \frac{V_{XZ}}{V_{XY}}L_{YZ} = \frac{5.143}{9.0}(1.2) = 0.6857$ $= 0.69$ m Method 2: $\frac{V_{XZ}}{V_{ZY}} = \frac{V_R}{V_{LDR}} \Rightarrow \frac{kL_{XZ}}{kL_{ZY}} = \frac{I \times 1600}{I \times 1200} = \frac{4}{3}$ $L_{XZ} = \frac{4}{7} \times 1.2$ $= 0.69$ m	**M1** **A1** **M1** **A1**
(b)(ii)1	As intensity of light is increased, the resistance of the LDR decreases and there is a smaller potential difference across the LDR. The length of XZ decreases.	**M1** **A1**
(b)(ii)2	The total resistance of the circuit decreases and more current is drawn from the battery. Hence power produced by the battery increased. OR The total resistance of the circuit decreases. Since power produced by battery = V^2/R_{total}, power produced by battery increased.	**M1** **A1** **M1** **A1**

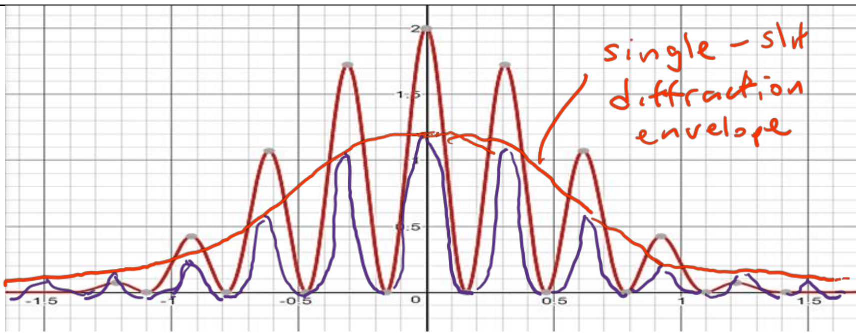
Q7		
(a)	The magnetic flux (linkage) is given by $\Phi = NBA = B(wx)$ where x is the distance AB has moved past P. Hence the induced emf is given using **Faraday's Law** by $E = \dfrac{d\Phi}{dt} = Bw\dfrac{dx}{dt}$ $Bw\dfrac{dx}{dt} = Bwv$	**B2**
(b)(i)	As AB moves from P towards Q, **magnetic flux linkage** over the area ABCD enclosed by the frame **increases** resulting in an **induced e.m.f.** generated in the frame **by Faraday's Law**. **By Lenz's Law**, an **induced current** will flow **such that it opposes the increase in magnetic flux linkage**. (current flows in anticlockwise direction) Consequently, a **magnetic force acts on AB towards the left**, causing it to slow. (Using Fleming's Left Hand Rule) <u>Alternative</u>: AB **cuts the magnetic flux** as it moves through PQ, resulting in an induced e.m.f. generated in the frame **by Faraday's Law**. There is **induced current** in the full circuit **in the anticlockwise direction**. (or electrons in the clockwise direction) Consequently, a **magnetic force acts on AB towards the left**, causing it to slow. B1 – why there is an induced emf B1 – how is the direction of induced current determined B1 – effect on AB/frame	**B1** **B1** **B1** **B1** **B1** **B1**
(b)(ii)	 B1 – same slope where the speed is the same as the original graph B1 – plateau B1 – shorter time to pass through the field, higher speed as it leaves the field	**B3**

Q8		
(a)(i)	α-particles are very strong ionising radiation and hence have very weak penetrating power and would be stopped by a few cm of air. **OR** Alpha particles could be deflected by air molecules (obscuring the results).	**B1**
(a)(ii)1	Majority of α-particles passed through with little or no angular deflection. (This suggests that the gold nucleus is made up mostly of empty space, hence the nucleus must be very tiny. Students who stated something to the effect of 'few of the alpha particles underwent deflection or large deflection' would not get the credit. The reason being that the reverse of the statement need not be 'most of the alpha particles were undeflected', it could be that 'most of the alpha particles were absorbed.' This could still imply that the gold nucleus is large in dimensions.)	**B1**
(a)(ii)2	<u>One of the following:</u> A few α-particles were scattered by large angles. **OR** A few α-particles backscattered. (The deflections suggest that the gold nucleus is charged (as the alpha-particle is charged, and the back scattering – deflections that are larger than 90° imply that the nucleus is massive)	**B1**
(b)(i)	$E = \Delta m\, c^2$ $= [(18.00696 - 18.00568) \times 1.66 \times 10^{-27}] \times (3.0 \times 10^8)^2$ $= 1.91232 \times 10^{-13}$ J $= 1.9 \times 10^{-13}$ J	**B1**
(b)(ii)	The helium nuclei possessed kinetic energy that can be used for the reaction.	**B1**
(b)(iii)	The products must also have non-zero kinetic energy after the reaction since the reactants had non-zero total momentum to begin with.	**B1**

Q9		
(a)	When two or more waves overlap/meet at the point (at a particular instance), the **resultant displacement** at that point is the **vector sum of the displacements** which would be caused by each wave at the point (at that instance).	**B1** **B1**
(b)(i)	From graph, Period of waves = 40.0×10^{-9} s Frequency = $1/40.0 \times 10^{-9} = 25.0 \times 10^{6}$ Hz = 25.0 MHz	 **B1** **A0**
(b)(ii)	At M, the waves arrive in phase / path difference is zero, hence constructive interference occurs Resultant wave amplitude = 2A (where A is the amplitude due to an individual wave), A = 0.5 units When only one source is on, the amplitude is 0.5 units. Diagram of waveform with same period, phase and amplitude = 0.5 units drawn. B1 – explain why constructive interference B1 – either indicating that resultant wave amplitude is twice or that the amplitude of each wave (from A or B) is half that observed at M. B1 – correct graph drawn	**B1** **B1** **B1**
(b)(iii)	Distance from M to N = distance between an antinode to a node = ¼ λ = ¼ (c/f) = ¼ (3.00×10^{8} / 25.0×10^{6}) = 3.00 m M1 – relating MN to λ/4 M1 – for finding λ using c=f λ Alternative: Let the distance moved be *x* so that the path difference increased by half a wavelength. (AN – BN) = ½ λ (6.00 + *x*) – (6.00 – *x*) = (0.5) (3.00×10^{8} / 25.0×10^{6}) where *x* is distance from M to N. *x* = 3.00 m	 **M1** **M1** **A0**

(b)(iv)	Point M is 6.00 m from A and B respectively. Point N is 9.00 m from A and 3.00 m from B As A and B are point sources, intensity of wave from each source, $I = \frac{\text{Power from source}}{4\pi r^2}$ (As power from sources are equal and constant), Hence $I \propto \frac{1}{r^2}$ $\frac{I_A}{I} = (\frac{6.00}{9.00})^2$ $I_A = 0.4444I$ $= 0.444$ I (shown) $\frac{I_B}{I} = (\frac{6.00}{3.00})^2$ I_B = 4.00 I (shown)	**B1** **B1** **B1**
(b)(v)	Using $I \propto A^2$ At point N, A_A is amplitude of wave due to source A and A_B is amplitude of wave due to source B. At point M, I is the intensity of wave from a single source (either A or B) and the amplitude of a wave from either source is 0.5 units. $\frac{0.444I}{I} = (\frac{A_A}{0.5})^2$ A_A = 0.333 units $\frac{4I}{I} = (\frac{A_B}{0.5})^2$ A_B = 1.00 units At N, waves source A and B arrive in antiphase, resultant amplitude = 1.000 – 0.333 = 0.666 units.	**M1** **M1** **A1**
(c)(i)	1. *D* must be much larger than *a*. (so that the two paths are parallel, resulting in $a\sin\theta = n\lambda$, where θ is the angle of each order. Clearly from the equation, the orders are not equally spaced). 2. *a* must be much larger than λ. (so that the angle is small and small-angle approximations can be made and fringe separation is then constant).	**A1** **A1**
(c)(ii)	$x = \frac{\lambda D}{a}$ (students must use the symbols defined in the question)	**A1**
(c)(iii)	As the slits have a finite width, the 1st order minima (due to single-slit diffraction) coincides where the 5th order maxima (due to double-slit interference) occurs.	**A1**

(c)(iv)



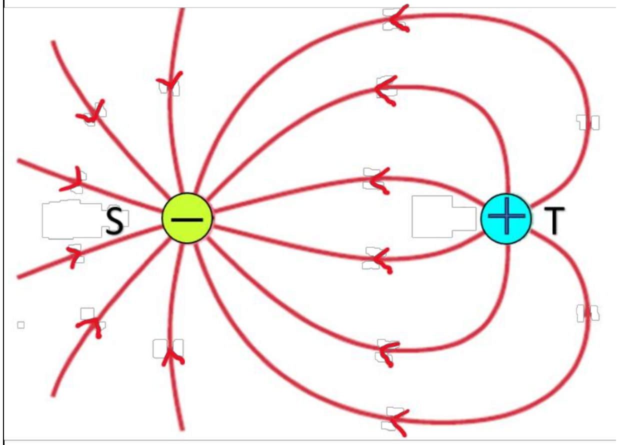
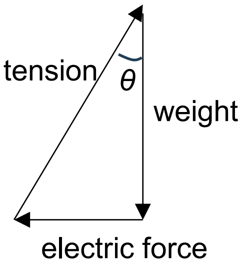
Marking points:

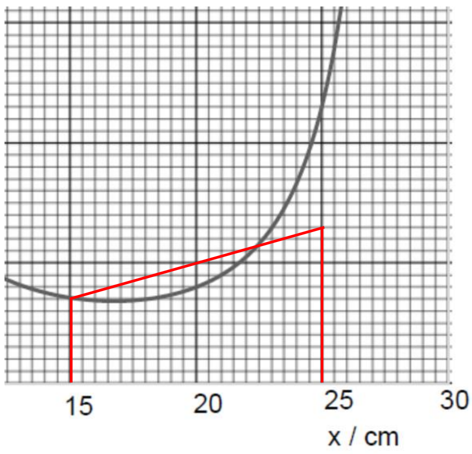
- All **fringes** should be clearly shown to **occur at the same position as original** diagram. (As fringe separation x does not change.) **(This mark must be awarded for the next mark to be awarded)** **A1**
- **5th order maxima** should be **visible** **A1**

  (Using $\sin\theta = \dfrac{\lambda}{b}$ (single-slit diffraction), when b decreases, the angle of diffraction (of 1st or minima) gets wider thus the 5th order maxima of the double-slit interference pattern should be visible.

Additional points (not assessed)

- The fringes should not exceed the single-slit diffraction envelope. (Also there should be symmetry of intensity about the zero order maximum.
- As b decreases, amount of energy that passes through slits decreases, thus the intensity of light at the zero order maximum (for the double-slit interference pattern) should be reduced. For example, if the width is halved, the amplitude at the central maximum would be halved, resulting in intensity that is ¼ of the original.

Q10		
(a)	Electric field strength at a point is the **electric force per unit positive charge** on a small test charge placed at the point.	**B1**
(b)(i)	 Correct direction. Correct ratio of lines (2:1). Correct asymmetry.	**B1** **B1** **B1**
(b)(ii)1	Consider the force-diagram of sphere T. The electric force must act horizontally to the left since S and T are align horizontally. The weight must act vertically down. Since T is in equilibrium under the effect of 3 forces, these three forces must force a closed right angle triangle as shown.  Electric force $= \dfrac{1}{4\pi\varepsilon_0}\dfrac{(2.4\times10^{-6})(1.2\times10^{-6})}{0.30^2}$ $= 0.287738$ N $\theta = \tan^{-1}\left(\dfrac{\text{electric force}}{\text{weight}}\right) = \tan^{-1}\left[\dfrac{0.287738}{0.036(9.81)}\right]$ $= 39°$	**M1** **M1** **A1**
(b)(ii)2	Once the string is cut, the net force on sphere T will be the vector sum of the weight and electric force. $\Sigma F = ma$ $\sqrt{[(0.036)(9.81)]^2 + 0.287738^2} = (0.036)a$ $a = 13$ m s^{-2}	**B1** **M1** **A1**

(b)(iii)	Area under the graph is **change** in potential. $\Delta V = \frac{1}{2}(0.10)\left[(0.14+0.26)\times 10^{7}\right]$ $= 2.0\times 10^{5}$ V (accept +/- 10%) From 25 cm to 15 cm, the positive helium nucleus loses potential energy and gains kinetic energy.  Gain in KE = $q\Delta V = 2(1.60\times 10^{-19})(2.0\times 10^{5}) = 6.4\times 10^{-14}$ J	**B1** **M1** **M1** **A1**
(c)(i)	Weight of lithium ion = $mg = 6.941\times 1.66\times 10^{-27}\times 9.81 = 1.13\times 10^{-25}$ N Electric force on ion = $qE = 1.60\times 10^{-19}\times\left(\frac{150}{0.020}\right) = 1.2\times 10^{-15}$ N The electric force is about 10^{10} times larger or 10 orders of magnitude larger than the gravitational force or weight.	**M1** **M1** **A1**
(c)(ii)	Time taken to travel through plates = $\frac{0.090}{3.0\times 10^{5}} = 3.0\times 10^{-7}$ s Applying $s = ut + \frac{1}{2}at^{2}$ in the vertical direction, $y = \frac{1}{2}\left(\frac{1.2\times 10^{-15}}{6.941\times 1.66\times 10^{-27}}\right)(3.0\times 10^{-7})^{2}$ y = 4.7 mm	**M1** **M1** **A1**

HWA CHONG INSTITUTION
C2 Preliminary Examination
Higher 2

A

CANDIDATE NAME	Suggested Solutions	**CT GROUP**	23S
TUTOR NAME			

PHYSICS

9749/04

Paper 4 Practical

22 August 2024

2 hours 30 mins

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your name, CT group and tutor's name in the boxes 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.

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, submit sets A, B and C separately.
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**

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1 In this experiment, you will investigate the period of torsional oscillations of a suspended disc with loaded mass.

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

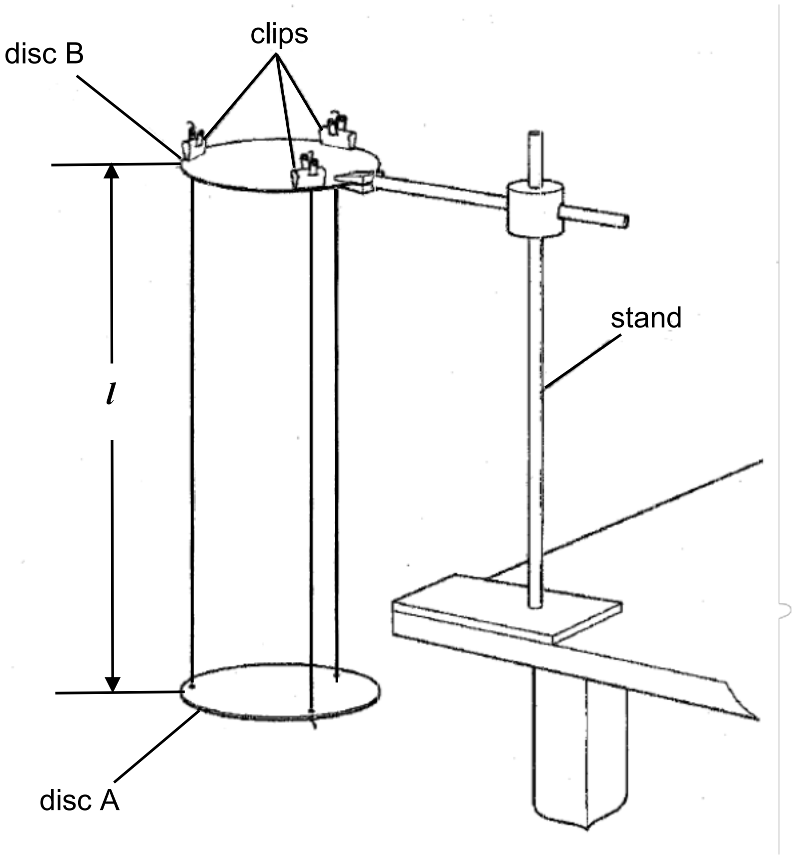


Fig. 1.1

Disc A and disc B have three small holes spaced at regular intervals near the edge. Pieces of string have been threaded through the holes.

Clamp disc B horizontally using two small blocks of wood. Use the clips on disc B to adjust the length l of each string until l is about 100 cm.

Place a 50 g mass in the centre of disc A.

(b) **(i)** Gently rotate disc A through a small angular displacement and release it so that the disc performs torsional oscillations of period *T* in a horizontal plane as shown in Fig. 1.2.

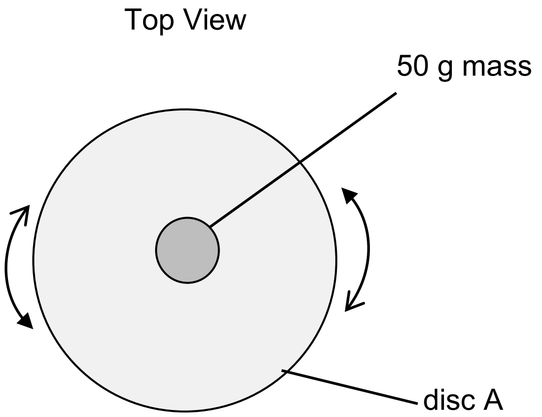


Fig. 1.2

Determine and record *T*.

- Repeated readings of timings t shown
- Calculate T with working

For n = 20 oscillations,
t_1 = 20.0 s
t_2 = 20.2 s

$T = \frac{t_1+t_2}{2n} = \frac{20.0+20.2}{40} = 1.01$ s (3 s.f.)

T = ... [2]

(ii) Repeat **(b)(i)** for different values of mass *m*, by stacking the slotted masses on top of each other, until you have five sets of readings of *T* and *m*.

Present your results clearly.

m / g	No. of oscillations n	Timing for n oscillations		T / s	lg (m / g)	lg (T / s)
		t_1 / s	t_2 / s			
50	20	20.0	20.2	1.01	1.70	0.002
100	30	24.7	24.9	0.827	2.000	-0.083
150	30	21.5	21.4	0.715	2.176	-0.146
200	30	20.0	20.0	0.667	2.301	-0.176
250	35	21.8	22.1	0.627	2.398	-0.234

[4]

- 5 sets of readings
- Timing $t \geq 20$ s
- Column headings: Each column heading must contain a quantity, a unit and a separating mark where appropriate. The presentation of quantity and unit must conform to accepted scientific convention
- Correct precision for raw data and s.f for calculated data

(c) It is suggested that T and m are related by the expression:

$$T = km^n$$

where k and n are constants.

Plot a suitable graph to determine the values of k and n.

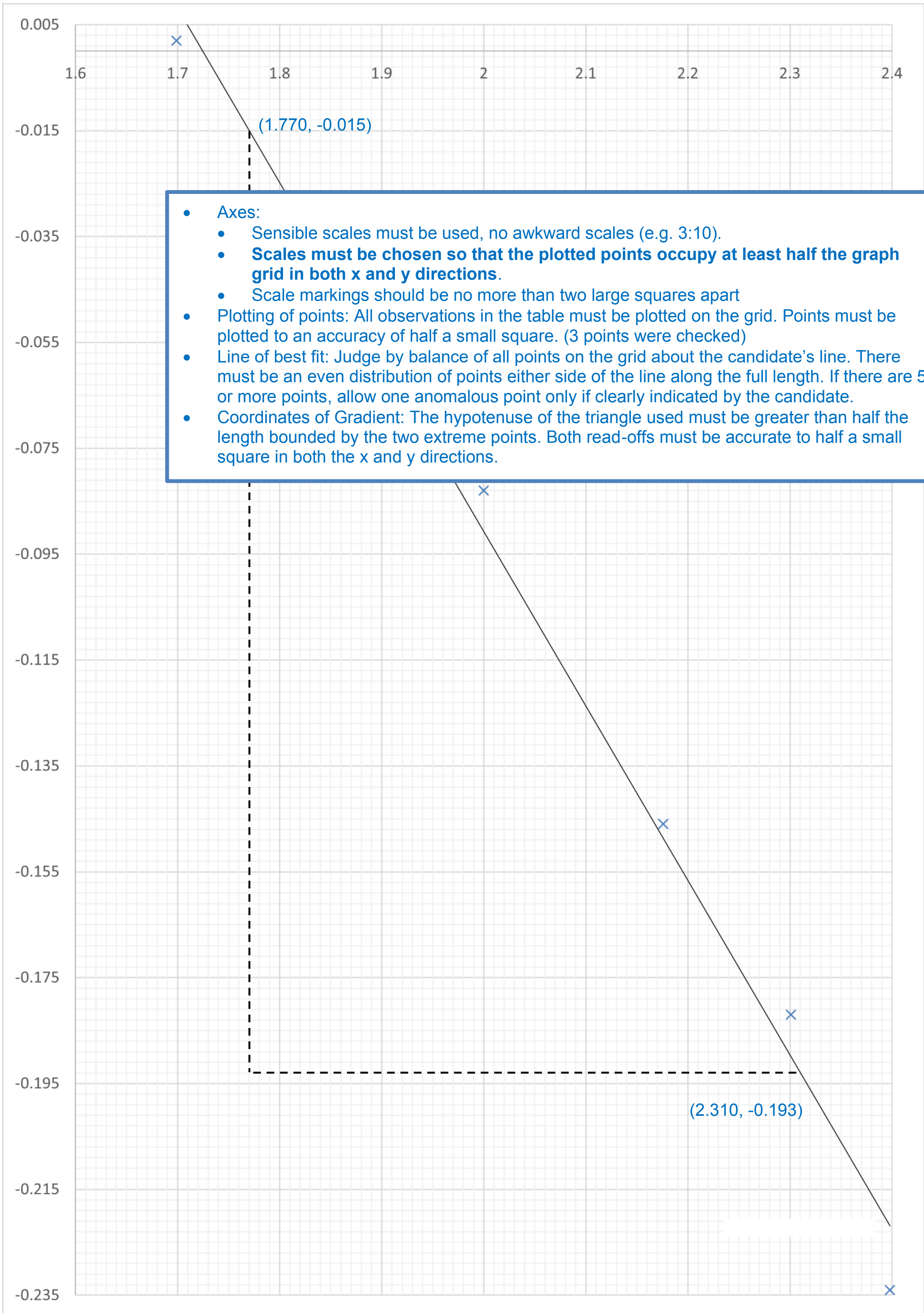
Since lg T = n lg m + lg k
By plotting a graph of lg T vs lg m, a straight line graph should be obtained with gradient = n and y-intercept = lg k

From graph plotted,

Gradient of graph = $\frac{-0.015-(-0.193)}{1.770-2.310}$ = -3.3296 = -3.30 (3 s.f)
(-0.015) = -3.3296 (1.770) + y-intercept
y-intercept = 0.5684

Hence
n = -3.30
lg k = 0.5684
k = 3.70 s g^{-n}
= 3.70 s $g^{3.30}$

[6]



- Axes:
  - Sensible scales must be used, no awkward scales (e.g. 3:10).
  - **Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions**.
  - Scale markings should be no more than two large squares apart
- Plotting of points: All observations in the table must be plotted on the grid. Points must be plotted to an accuracy of half a small square. (3 points were checked)
- Line of best fit: Judge by balance of all points on the grid about the candidate's line. There must be an even distribution of points either side of the line along the full length. If there are 5 or more points, allow one anomalous point only if clearly indicated by the candidate.
- Coordinates of Gradient: The hypotenuse of the triangle used must be greater than half the length bounded by the two extreme points. Both read-offs must be accurate to half a small square in both the x and y directions.

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.

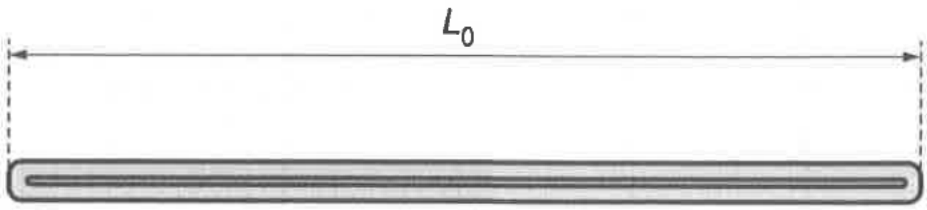


Fig. 2.1

Measure and record L_0 for your rubber band.

- Value of L_0 in the range 7.0 cm to 8.0 cm & (to nearest 0.1 cm or 0.001 m)

L_0 = ...7.5 cm........ [1]

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

w = 1.5 mm , h = 1.5 mm

$V = (2 \times 7.5 \times 10^{-2} \times 1.5 \times 10^{-3} \times 1.5 \times 10^{-3})$

- Correct calculation of volume V (e.g. $2 \times L_0 \times w \times h$) (Where w is the width and h is the height of rubber band.)

V = ...3.4×10^{-7} m^3 / 0.34 cm^3........ [1]

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

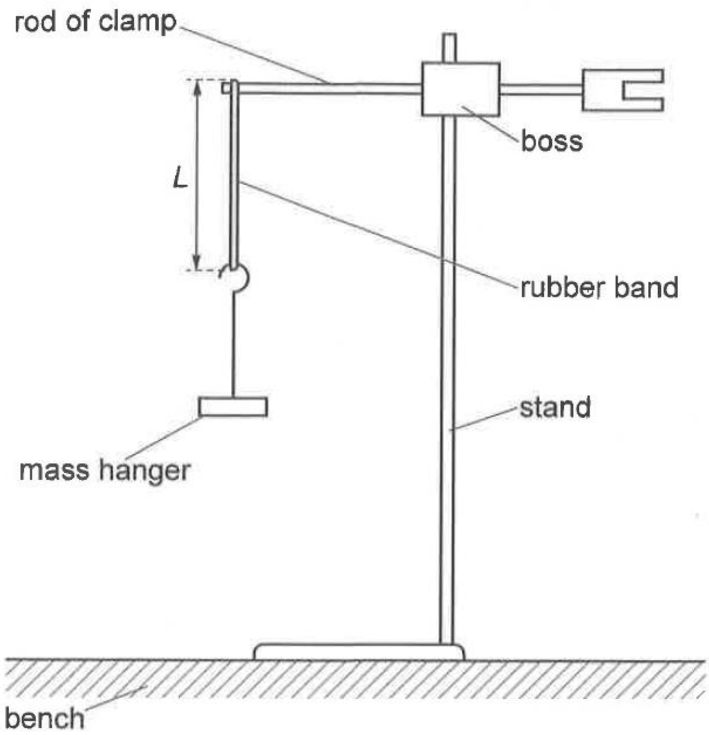


Fig. 2.2

The extended length of the rubber band is L.

Calculate the extension e of the rubber band where:

$$e = L - L_0.$$

e = 8.5 – 7.6 = 0.9 cm
= 0.009 m

Record your answer in metres.

e = ...0.009............ 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 N kg^{-1}.

Calculate and record F.

Both e is calculated correctly and correct precision (0.001 m) and *F* is calculated to correct value and correct s.f. (accept 2 or 3 s.f. as *m* may be read to 2 or 3 s.f)

F = ...F = 0.100 x 9.81 = 0.981 N............ N
[1]

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

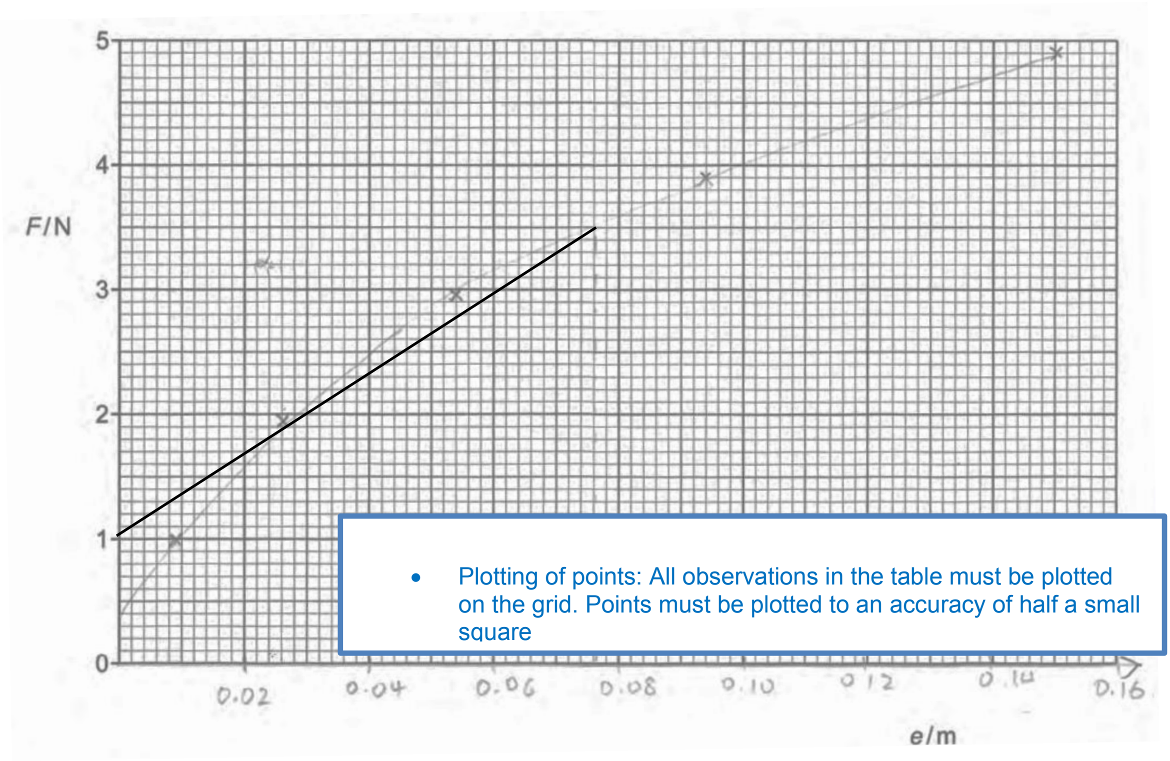
Present your results clearly.

m / g	*L* / m	*e* / m	*F* / N
100	0.085	0.009	0.981
200	0.102	0.026	1.96
300	0.130	0.054	2.94
400	0.170	0.094	3.92
500	0.226	0.150	4.91

[3]

- 5 sets of readings (using 100 g mass intervals not 50 g)
- Column headings: Each column heading (*m, L, e and F*) must contain a quantity, a unit and a separating mark where appropriate. The presentation of quantity and unit must conform to accepted scientific convention
- Correct precision for raw data and s.f for calculated data

(iii) Plot your results on the grid below.



- Plotting of points: All observations in the table must be plotted on the grid. Points must be plotted to an accuracy of half a small square

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

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

- Estimate correctly the area under graph up till $e = L_0$

  Show working
  Acceptable range (0.08 to 0.20 J)
  Common mistake is thinking that the $e = 2L_0$

Estimated area = Area under black line

= ½ x (3.5 – 1.0) x 0.076
= 0.095 J

energy stored = ... J [1]

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

- Correct calculation of energy stored per unit volume in J m^{-3}. In particular taking note of the correct units.

Energy stored per unit volume = Energy stored / volume
= 0.095 / 3.4 x 10^{-7}
= 2.8 x 10^{5} J m^{-3}

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

[Total: 9]

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HWA CHONG INSTITUTION
C2 Preliminary Examination
Higher 2

B

CANDIDATE NAME		**CT GROUP**	**23S**
TUTOR NAME		**SCORE**	

PHYSICS

Paper 4 Practical

Candidates answer on the Question Paper.

No Additional Materials are required.

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.

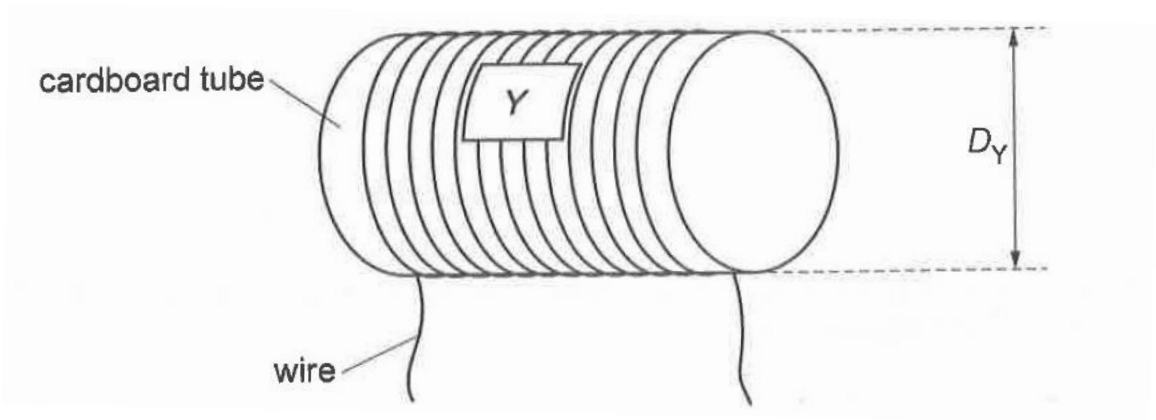


Fig. 3.1

Measure and record D_Y and d_Y.

Average $D_Y = \dfrac{4.4 + 4.5}{2} = 4.5$ cm

- repeated measurement of D_Y
- value of D_Y recorded to nearest 0.1 cm
- 4.0 cm $\leq D_Y \leq$ 4.6 cm

Average $d_Y = \dfrac{0.29 + 0.28}{2} = 0.29$ mm

- repeated measurement of d_Y
- value of d_Y recorded to nearest 0.01 mm
- 0.26 mm $\leq d_Y \leq$ 0.30 mm

D_Y = ... 4.5 .... cm

d_Y = ... 0.29 .... mm
[2]

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

Estimate and record your value for L_Y.

Show your working.

Number of turns of wire round the tube = 14
Circumference of 1 turn = $(\pi)(D_Y)$

$L_Y = 14 \times (\pi)(D_Y)$
$= 14 \times (\pi)(4.5)$
$= 195.72$

- formula to estimate L_Y
- substitution of number into formula
- value of L_Y calculated correctly
- $180\text{ cm} \leq L_Y \leq 220\text{ cm}$
- L_Y express to the nearest cm or tens of cm.

L_Y = ...196.............. cm [2]

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

$L_Y = 14 \times (\pi)(D_Y)$

$$\frac{\Delta L_Y}{L_Y} = \frac{\Delta D_Y}{D_Y} = \frac{0.2}{4.5} \times 100\% = 4.44\%$$

- $1\% < (\Delta Ly/Ly) \times 100\% \leq 10\%$
- If ΔLy is quoted, it should be to the order of cm and to **1 s.f.**
- Final percentage uncertainty expressed to 1 or 2 s.f.

percentage uncertainty in L_Y = ...4.4 %.............. [1]

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

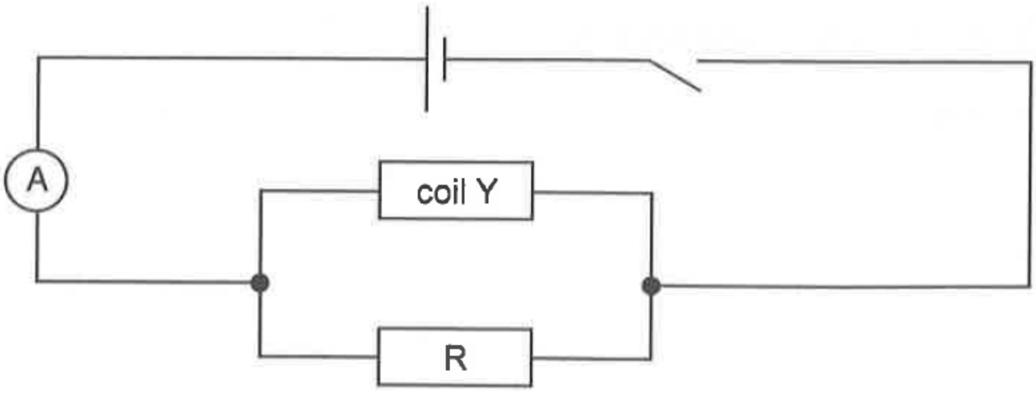


Fig. 3.2

Close the switch.

Note and record R and the ammeter reading I.

- value of R recorded, measurement via DMM is not required.
- value of I recorded to the correct decimal place in A (in this case 4, e.g. 0.1340 A)

R = ………………15……………….. Ω

I = ……136.6 x 10^{-3} or 0.1366……….. A

[1]

Open the switch.

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

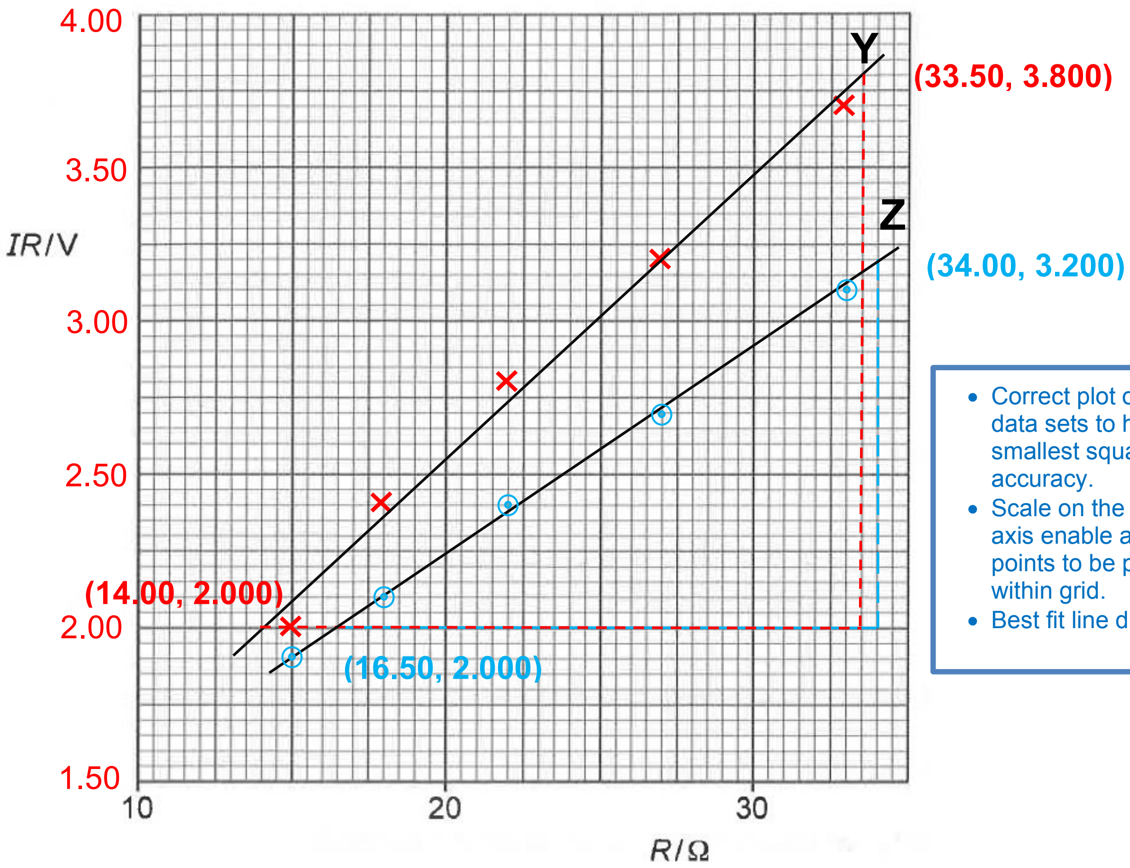
(d) Present your results clearly.

R / Ω	I / A	IR / V
15	0.1366	2.0
18	0.1349	2.4
22	0.1258	2.8
27	0.1186	3.2
33	0.1130	3.7

- a table with correct column headings & units for 5 sets of readings
- no split tables!
- display correct trend (R increases, I decreases)
- value of IR calculated correctly and expressed to correct s.f. (In this case the lesser of the two s.f.'s between R and I is 2.)

[3]

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



- Correct plot of all data sets to half the smallest square accuracy.
- Scale on the vertical axis enable all data points to be plotted within grid.
- Best fit line drawn.

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.

$$G = \text{gradient} = \frac{3.800 - 2.000}{33.50 - 14.00} = 0.09231$$

- Coordinates of points used for calculating to be read correctly to half the smallest square accuracy
- Correctly calculate Gradient = G,

To find H, substitute (14.00, 2.000) and G into the given expression:

$2.000 = (0.09231)(14.00) + H$

$H = 2.000 - 1.292 = 0.708$

- Correctly deduce y-intercept = H
- Correctly calculate $X_Y = H/G$

$$\therefore X_Y = \frac{0.708}{0.09231} = 7.67\ \Omega$$

$X_Y =$ 7.67 Ω

[3]

(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.

- Value of D_Z within (and include) 2 mm of Dy
- Value of d_Z to nearest 0.01 mm.
- 0.17 mm $\leq$ d_Z $\leq$ 0.23 mm.
- Value of L_Z calculated correctly.

Average $D_Y = \dfrac{4.5+4.5}{2} = 4.5$ cm

Average $d_Y = \dfrac{0.21+0.23}{2} = 0.22$ mm

D_Z = ...4.5.................... cm

d_Z = ...0.22.................... mm

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

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

$L_Z = \dfrac{3 \times 195.721}{4} = 146.79$ cm = 147 cm

Calculate L_Z.

L_Z = ...147.................... 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.

R / Ω	I / A	IR / V
15	0.1277	1.9
18	0.1175	2.1
22	0.1090	2.4
27	0.1000	2.7
33	0.0932	3.1

- A table with correct column headings & units for 5 sets of readings
- At least one of the graphs must be labelled.

G = gradient = $\dfrac{3.200-2.000}{34.00-16.50} = 0.06857$

Find H:

2.000 = (0.06857)(16.50) + H

H = 2.000 – 1.131 = 0.869

$X_Y = \dfrac{0.869}{0.06857} = 12.7\ \Omega$

Plot of line Z on Fig. 3.3
- At least 3 data points must be within the grid
- Generally below Y graph

X_Z = ...12.7.................... Ω [2]

(iii) Use a digital multimeter to measure X_Z. measured X_Z = 22.8 Ω

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

difference The measured value is larger than the calculated value by 10.13 Ω

reason Internal resistance of the cell is not accounted for / not negligible.

[1]

- Need to record the measured value of X_Z.
- Measure value should be compared to be larger than the value of X_Z found in (f)(ii)
- Additional resistance due to internal resistance of battery / heating effect or energy lost within battery.

(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.

$$k = \frac{xd^2}{L}$$

$$k_Y = \frac{7.67 \times (0.29 \times 10^{-3})^2}{196 \times 10^{-2}} = 3.3 \times 10^{-7}\ \Omega\text{m}$$

$$k_Z = \frac{12.7 \times (0.22 \times 10^{-3})^2}{147 \times 10^{-2}} = 4.2 \times 10^{-7}\ \Omega\text{m}$$

- Two values of k calculated correctly
- values of k expressed to the 2 or 3 s.f.
- correct units of k

first value of k = 3.3×10^{-7} Ωm

second value of k = 4.2×10^{-7} Ωm

[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)**.

$$\%\text{ difference in } k = \frac{(4.18\times10^{-7}-3.29\times10^{-7})}{\left(\frac{4.18\times10^{-7}+3.29\times10^{-7}}{2}\right)}\times100 = 24\%$$

Since the percentage difference in *k* is greater than the percentage uncertainty in *L* of 4.4 %, the experiment does not support the suggested relationship.

- working shown for % difference for *k* or uncertainty of *k*
- reference made to (b)(ii) in calculation of uncertainty
- correct conclusion drawn from above comparison

[1]

(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.

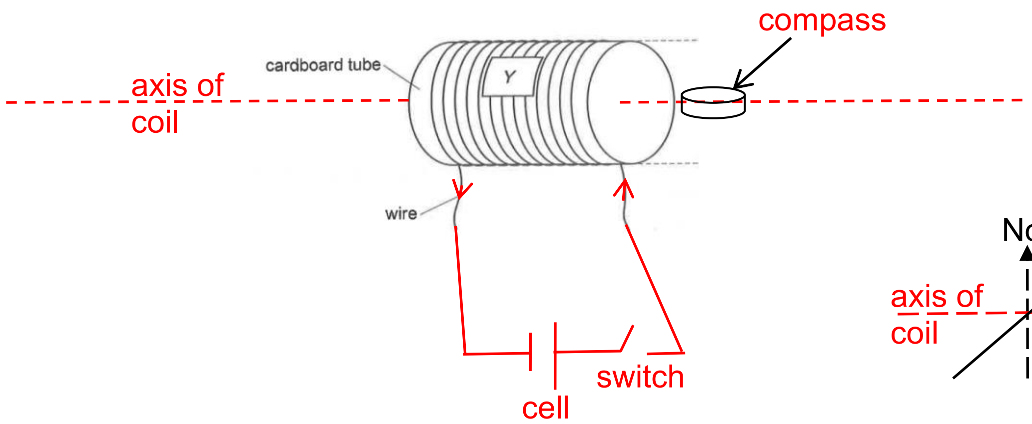
$n_Y > n_Z$, and since $X_Z > X_Y$, $I_Y > I_Z$. Hence the magnetic flux density at the end of tube Y is greater.

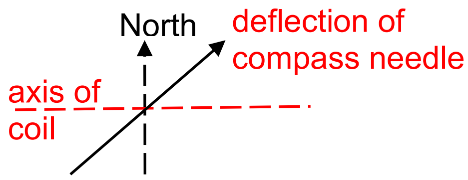
- Tube Y produces a greater magnetic flux density
- Tube Y has a greater number of coil per unit length (n)
- Tube Y has a higher current flow (I) through it

[1]

(ii)

Describe, using a diagram, how you could check your conclusion in **(h)(i)** using a small compass.





1. Connect the ends of the coil of wire on tube Y to a cell as shown in the diagram.
2. Place a small compass at the centre of the end of tube Y.
3. Ensure the compass needle points towards the North in the direction of the Earth's magnetic field.
4. Orientate tube Y so that the axis of the coil is perpendicular to the compass needle.
5. Close the switch.
6. The magnetic field generated at the end of the coil deflects the needle. Note the angle of deflection of the compass needle from the North.
7. Repeat steps 1 to 6 with the coil on tube Z.

The angle of deflection of the compass needle would be greater for the coil which exerts a stronger magnetic flux density at its end.

....

....

....[3]

[Total: 22]

- Diagram: (1) Correct placement of compass relative to coiled tube.
  (2) Appropriate circuit connected to coils.
- Consideration for Earth's magnetic field
- Repeat experiment for both coils and clear explanation on how to draw conclusion based on proposed experiment

HWA CHONG INSTITUTION
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Higher 2

C

CANDIDATE NAME		**CT GROUP**	**23S**
TUTOR NAME		**SCORE**	

PHYSICS

Paper 4 Practical

Candidates answer on the Question Paper.

No Additional Materials are required.

4 A student is investigating how the boiling point of a salt solution varies with pressure and the density of the salt solution.

It is suggested that the relationship between the Celsius temperature θ at which the water of the solution starts to boil, the air pressure P and the density σ of the salt solution is

$$\theta = k\sigma^{x}P^{y}$$

where k, x and y are constants.

Design a laboratory experiment to determine the values of x and y.

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

(a) the equipment you would use

(b) the procedure to be followed

(c) the control of variables

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

Diagram

....

....

....

....

....

Suggested solution

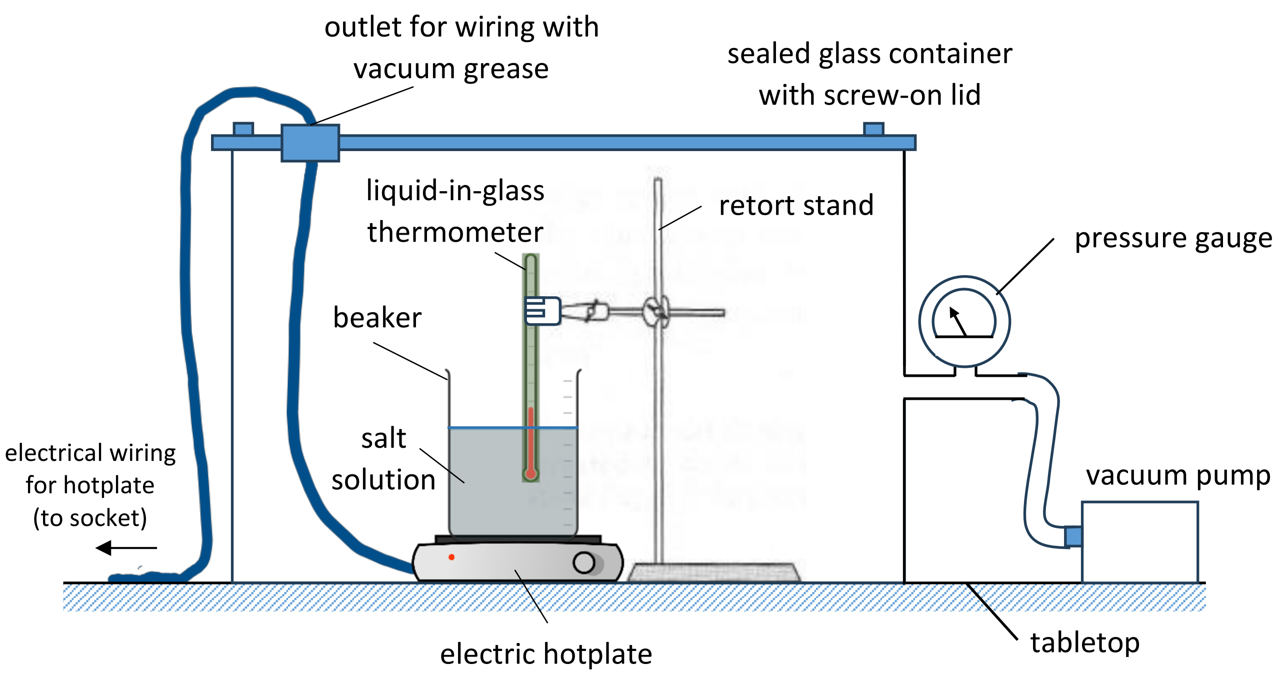

Fig. 1

Aim: The relationship between the Celsius temperature θ at which the water of the solution starts to boil, the air pressure P and the density σ of the salt solution is

$$\theta = k\sigma^x P^y$$

$$\Rightarrow \lg\theta = \lg k + x\lg\sigma + y\lg P$$

Determine x and y.

Experiment 1: Keep P constant, vary σ and determine θ

- *Plot graph of lg θ vs lg σ. If the relationship is valid, the data points will present a straight-line trend. Draw a best-fit straight line and determine gradient = x.*

Experiment 2: Keep σ constant, vary P and determine θ

- *Plot graph of lg θ vs lg P. If the relationship is valid, the data points will present a straight-line trend. Draw a best-fit straight line and determine gradient = y.*

Apparatus and Method to Measure the Various Quantities:

Dependent Variable: θ	*Measured with a liquid-in-glass thermometer.* Salt solution starts to boil when the bubbles move to the top of the solution and the temperature reaches a maximum for a few seconds.
Independent Variable: σ	*Weigh the mass M of the salt solution using the electronic balance. Measure the volume V of the salt solution using a measuring cylinder. Density σ = M/V*
Independent Variable: P	*Measured with the pressure gauge*
Additional controls:	*The type of salt used to make the solution can affect the boiling point. Hence, the salt solution should only be made with distilled water and laboratory-grade salt, e.g. NaCl; keep the same type of salt throughout the experiment.*

Experiment 1: Keep *P* constant, vary σ *to find* θ

1) *Prepare a large amount of salt solution by adding salt to water in a large container. Determine and record the density* σ *of the salt solution to be used and fill the beaker with the salt solution.*
2) *Set up the apparatus as shown in Fig. 1. Record the pressure P indicated*
3) *Switch on the electrical heater and wait for the solution to start to boil. Read off the temperature* θ*.*
4) *Repeat the experiment for Steps 1 to 3 for 10 different values of* σ *while keeping P constant.* σ *can be varied by adding additional salt to the solution in Step 1.*
5) *Plot a graph of lg* θ *vs lg* σ *and determine gradient = x.*

Experiment 2: Keep σ constant, vary *P* to find θ,**.**

6) *Setup the apparatus as shown in Fig.1.*
7) *Repeat the experiment for steps 1 to 3 by now varying P and keeping* σ *constant. The pressure P can be changed by using the vacuum pump to pump out some of the air each time. Obtain 10 sets of data of different values of P and the corresponding values of* θ*, while keeping* σ *constant.*
8) *Plot a graph of lg* θ *vs lg P and determine gradient = y.*

Additional Details

- *Conduct preliminary experiments to find a suitable range for* σ *and P that will lead to a good variation of measurable values of* θ *.*
- *The pressure P may still change (in Experiment 2) as the water heats and steam builds up, so the P value recorded should be the value when the water boils. Hence, read the value of P at the same time as when* θ *is read.*
- *There is some judgement in deciding when exactly is the point when the solution starts to boil. One way to address this is to repeat the experiment 3 times and take the average of* θ *for each* σ *(Experiment 1) or each P (Experiment 2). This checks for reproducibility of results as well.*

Safety Precautions

- *Wear protective goggles to protect the eyes from possible implosion of the container when the pressure is reduced.*
- *Handle the hot beakers and thermometers with thermal gloves to protect the hands from accidental burns.*