HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	**23S**
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS **9749/01**

Paper 1 Multiple Choice **17 September 2024**

1 hour

Additional Materials: Optical Mark Sheet

INSTRUCTIONS TO CANDIDATES

Write in soft pencil.

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

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

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

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

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

Any rough working should be done in this booklet.

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

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

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

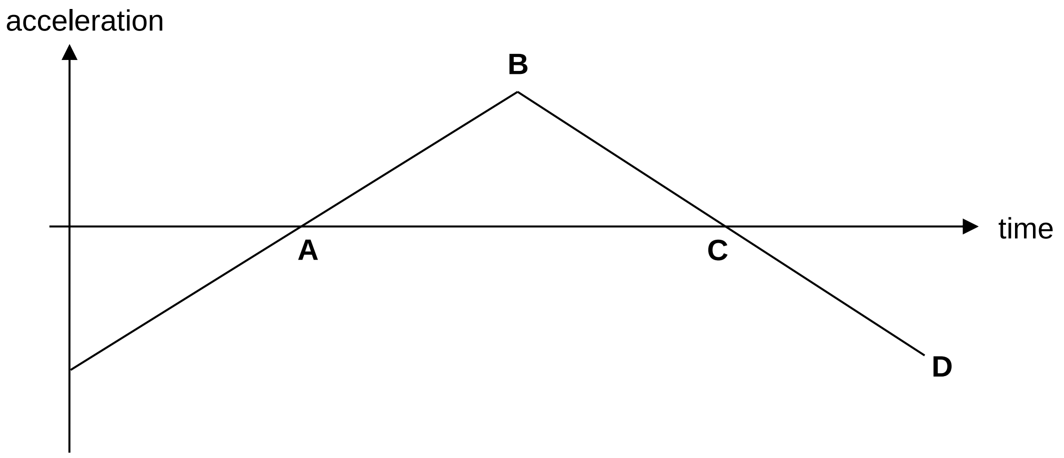
1 A thermometer can be read to an accuracy of ± 0.5 °C. This thermometer is used to measure a temperature rise from 20 °C to 80 °C.

What is the percentage uncertainty in the measurement of the temperature rise?

A 0.5 % **B** 0.8 % **C** 1.3 % **D** 1.7%

2 The acceleration−time graph of an object moving along a straight line is shown below. The object was initially at rest.

At which point on the graph is the object farthest from the starting point?



3 An elevator is moving downwards with a downward acceleration of 5.8 m s^{-2}. A ball, held 2.0 m above the floor of the elevator and at rest with respect to the elevator, is released.

How long does it take for the ball to reach the floor of the elevator?

A 0.51 s **B** 0.64 s **C** 0.83 s **D** 1.0 s

4 A man walking inside a shallow swimming pool managed to accelerate himself forward with a constant horizontal acceleration, a. Given the following information, which equation describes the horizontal motion of the man?

Mass of man: m

Upthrust: U

Drag force of water: f_D

Frictional force from the floor of the pool: f

Acceleration due to gravity: g

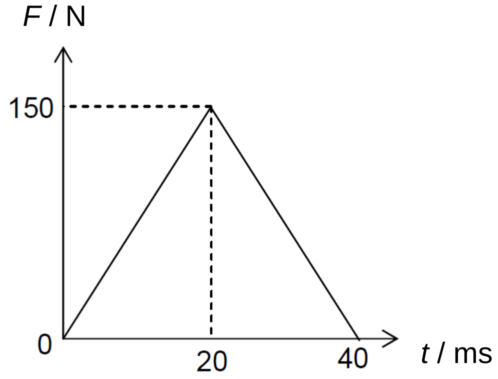
A $f - f_D = ma$

B $mg - U = ma$

C $f_D - f + mg - U = ma$

D $f - f_D + U = ma$

5 The graph shows the force delivered to an incoming ball by a tennis player. After the impact, the 60 g ball leaves the racket with a speed of 30 m s^{-1}.



What was the magnitude of the momentum, in N s, of the tennis ball before the player hit it?

A 1.2

B 1.8

C 4.8

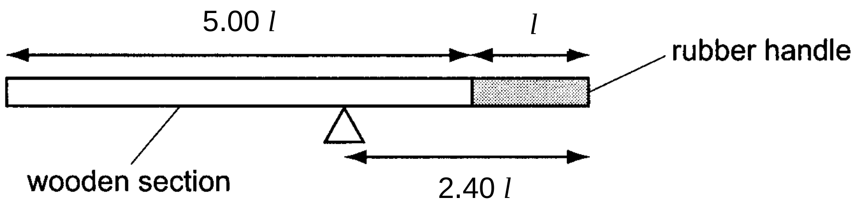
D 20

6 A thruster is used to launch a 500 kg rocket vertically upward from rest. This thruster ejects exhaust at a speed of 1000 m s^{-1}.

What should be the minimum rate, in kg s^{-1}, at which the exhaust leaves the thruster at the instant of launch?

A 0.5 **B** 2.0 **C** 4.9 **D** 20

7 A uniform rod has a wooden section and a solid rubber handle, as shown.

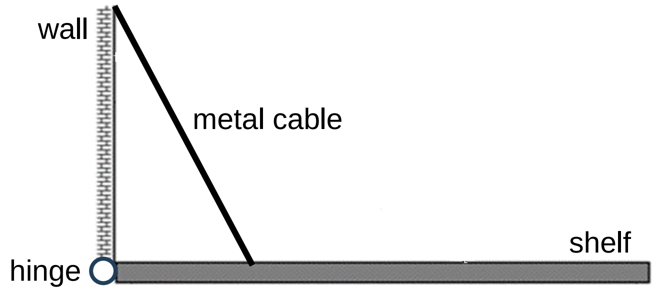


The length of the handle is l and the length of the wooden section is 5.00 l. The rod balances a distance 2.40 l from the rubber end.

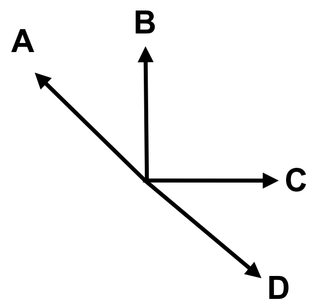
What is the ratio $\dfrac{\text{density of rubber}}{\text{density of wood}}$?

A 5.42 **B** 5.00 **C** 2.89 **D** 0.345

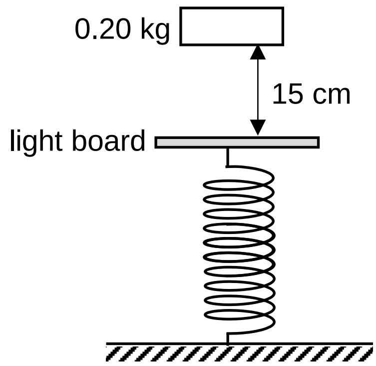
8 A shelf made of uniform material is held horizontally against a wall by a metal cable. The forces acting on the shelf are its weight, the force exerted by the metal cable, and the force exerted by the hinge.



Which arrow could represent the direction of the force the hinge exerts on the shelf?



9 A block of mass 0.20 kg is dropped from a height of 15 cm above a light spring of spring constant 85 N m^{-1}, as shown below. The block lands on a light board and compresses the spring.



Determine the maximum compression of the spring.

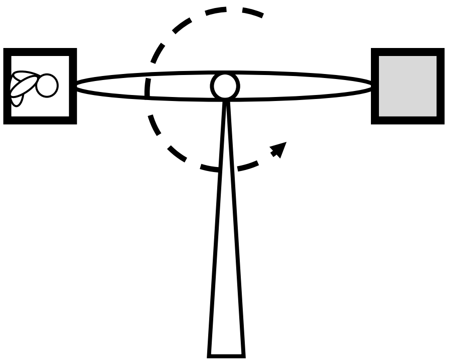
A 2.3 cm **B** 4.6 cm **C** 8.3 cm **D** 11 cm

10 A speed boat with two engines, each of power 32 kW, can travel at a maximum speed of 14 m s^{-1}. The total drag force on the boat is directly proportional to the speed of the boat.

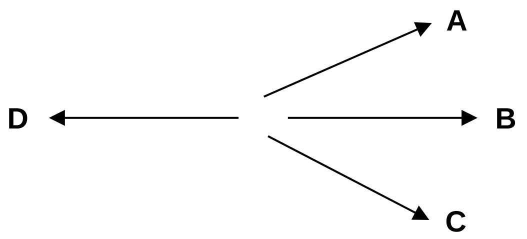
What is the maximum speed of the boat when only one engine is working?

A 3.5 m s^{-1} **B** 7.0 m s^{-1} **C** 9.9 m s^{-1} **D** 11 m s^{-1}

11 In an amusement park ride, a person sits in a cage which moves in a vertical circle at a constant speed. The person stays stationary with respect to the cage.

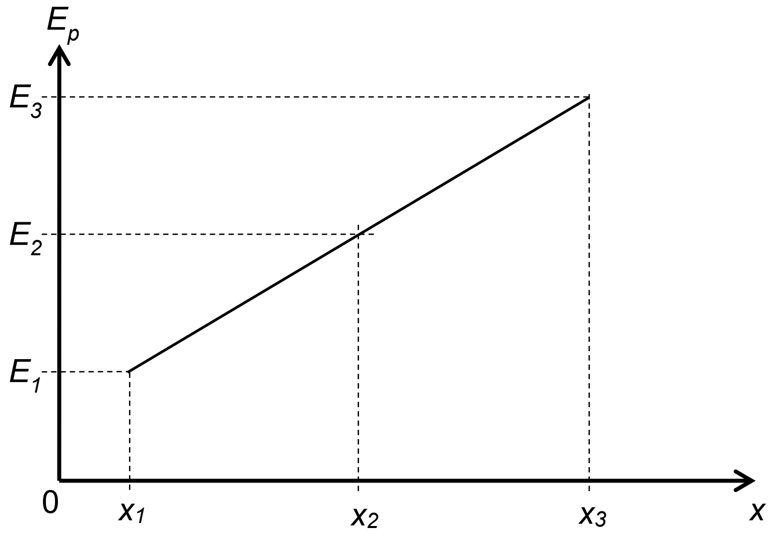


At the instant shown, what is the direction of the force exerted by the cage on the person?



12 An object of mass m is moving radially away from Earth of mass M.

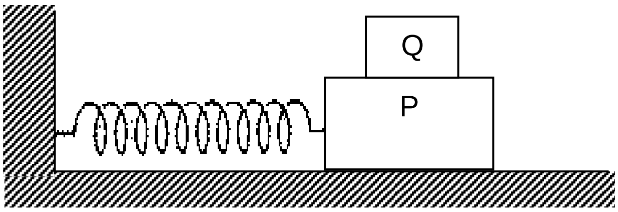
For a small distance x above the surface of the Earth, the variation with x of the stone's gravitational potential energy E_p is shown. At a point a distance x_2 from the surface of the Earth, the potential energy of the stone is E_2.



What is the magnitude of the force acting on the stone?

A $\dfrac{GMm}{(x_2)^2}$ **B** $\dfrac{E_2}{x_2}$ **C** $\dfrac{E_3 - E_1}{x_3 - x_1}$ **D** $\dfrac{(x_1 + x_2)\times(E_2 + E_1)}{4}$

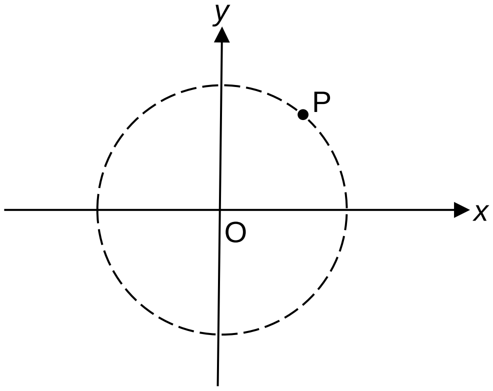
13 A system consisting of a large block P with a smaller block Q resting on it, oscillates on a frictionless surface with a frequency of 1.5 Hz. The maximum static friction *between* the two blocks is 5.0 N.



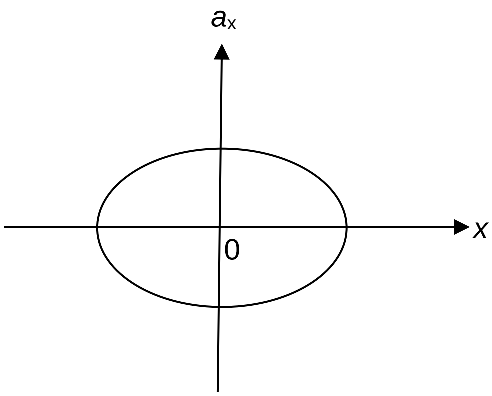
If the mass of P is 2.0 kg and the mass of Q is 0.20 kg, what is the maximum amplitude of oscillation of the system in order that block Q does not slip?

A 0.026 m **B** 0.028 m **C** 0.056 m **D** 0.28 m

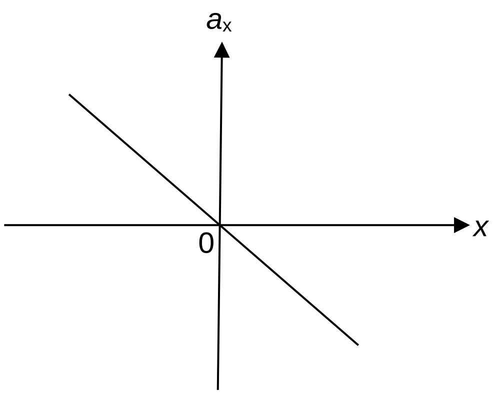
14 A particle P performs uniform circular motion about the origin O in the x-y plane as shown below.



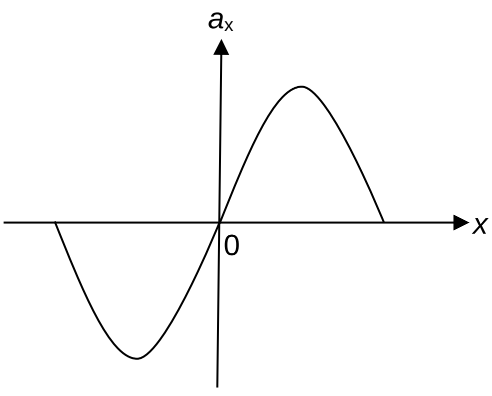
Which of the following graphs shows the relationship between the x-component of the acceleration a_x and the displacement in the x-direction?



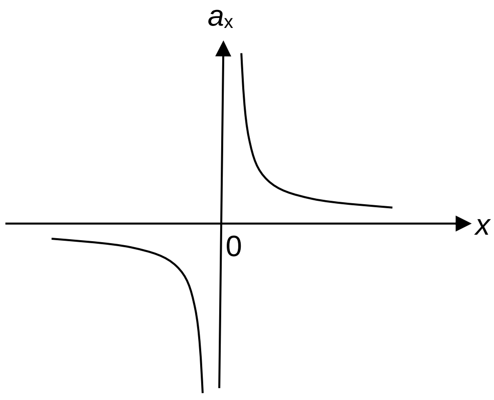
A



B

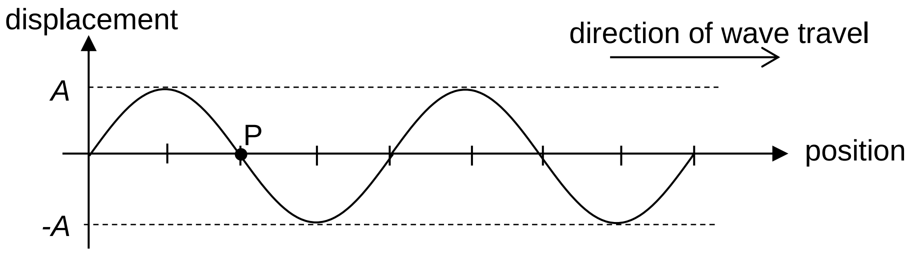


C



D

15 The displacement-position graph of a progressive wave is shown below. Particle P is a point along the wave.



Which of the following statements is **true** about particle P at the instant shown in the graph?

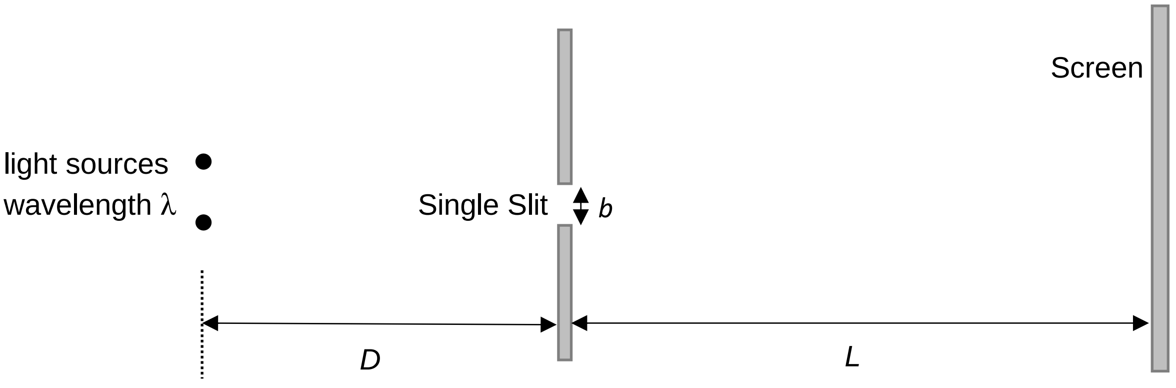
A It is moving towards the negative direction.

B It has zero velocity.

C It has an amplitude of *A*.

D It is experiencing the largest acceleration.

16 Two monochromatic light sources of wavelength λ are separated by a fixed distance. Light from the sources pass through a single slit of width *b* at a distance of *D*. The image of the light sources is projected on a screen at a distance *L* from the single slit.



One is just able to distinguish that there are two light sources from the image captured on the screen.

For the image captured on screen, which of the following changes will make it easier to distinguish that there are two light sources?

A λ is increased.

B *D* is reduced.

C *b* is decreased.

D *L* is increased.

17 White light (400 - 700 nm) is directed perpendicularly towards a diffraction grating. The diffraction grating has 300 lines per mm and the resulting image is projected on a screen.

What is the highest order of diffraction whereby a complete spectrum (red to violet) which does not overlap with the next order is clearly visible?

A 1^{st} order **B** 2^{nd} order **C** 3^{rd} order **D** 4^{th} order

18 In deriving the equation $p = \frac{1}{3}\rho\langle c^2 \rangle$ using the kinetic theory of gases, which of the following is **not** a valid assumption?

A The volume of the molecules is negligible compared with the volume of the gas.

B The duration of a collision is negligible compared with the time between collisions.

C The molecules experience negligible change of momentum on collision with the walls of the container.

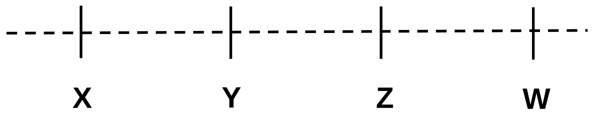
D Collisions with the walls of the container and with other molecules cause no change in the average kinetic energy of the molecules.

19 *N* molecules of a monatomic ideal gas are contained in a rigid box at pressure *p* and temperature *T*. An additional *N* molecules of the same gas are added to the box in such a way that the internal energy is kept constant at its original value.

Which of the following indicates the values of the temperature and pressure of the gas after the addition?

	temperature	pressure
A	$\frac{1}{2}T$	p
B	$\frac{1}{2}T$	$\frac{1}{2}p$
C	T	$2p$
D	T	p

20 X, Y, Z and W are four points on a straight line as shown below. The points are equally spaced apart.



A point charge +Q is fixed at X. When another point charge -Q is moved from Y to Z, which of the following statements is **false**?

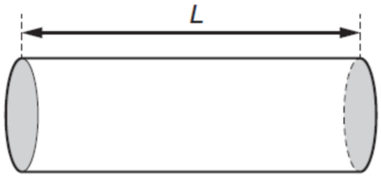
A The electric potential energy of the system of charges will increase.

B The magnitude of the electric field strength at point W will increase.

C The electric potential at point W will increase.

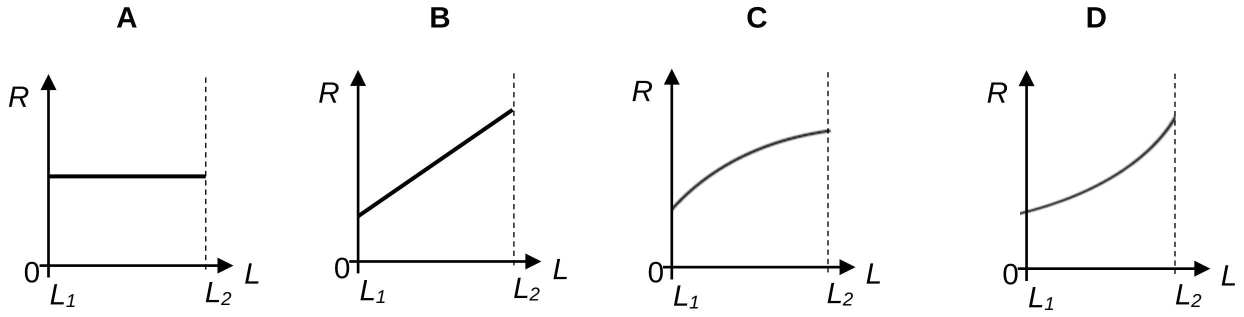
D The electric potential at point Y will become zero.

21 A piece of conducting modelling clay of constant resistivity is formed into a cylindrical shape. The resistance R between its flat ends (shaded) is measured.

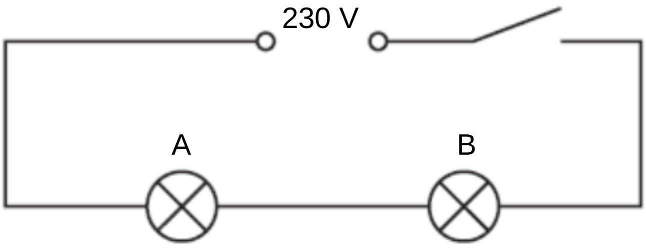


The same volume of modelling clay is re-formed into cylinders of different lengths L in the range of L_1 to L_2 and the resistance R between the flat ends is measured for each value of L.

Which graph best shows the variation of R with L?



22 In the circuit shown, lamp A is rated 230 V, 10 W and lamp B is rated 230 V, 40 W. The two lamps are connected in series to a 230 V power supply.



Assume that the resistance of each lamp remains constant at all temperatures.

Which statement most accurately describes what happens when the switch is closed?

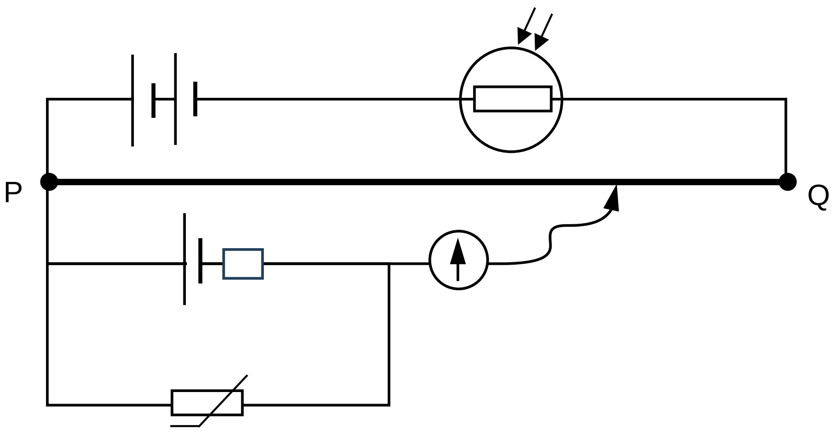
A Lamp A emits twice as much power as lamp B.

B Lamp A emits four times as much power as lamp B.

C Lamp B emits twice as much power as lamp A.

D Lamp B emits four times as much power as lamp A.

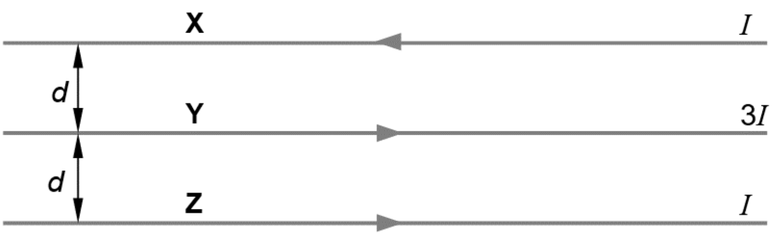
23 A NTC thermistor and a light-dependent resistor are connected in a potentiometer circuit. PQ is a resistance wire.



Which combination of temperature and lighting condition maximises the balance length?

	temperature	lighting
A	low	dark
B	low	bright
C	high	dark
D	high	bright

24 The diagram below shows three long, parallel, straight wires X, Y and Z placed in the same plane in a vacuum. Wires X and Z each carries a current of I, and wire Y carries a current of $3I$. Wire Y is halfway between wire X and wire Z.

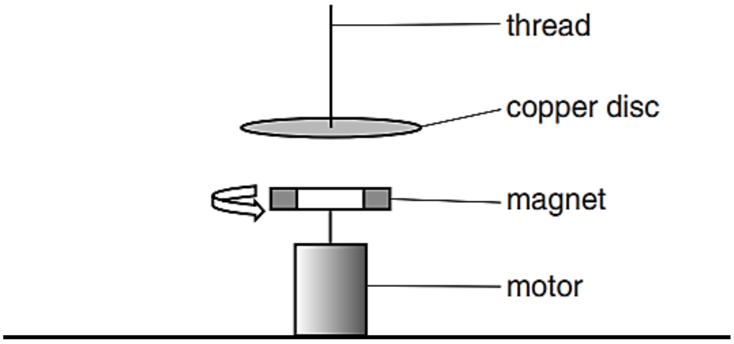


The magnitude of the force per unit length acting between X and Z is F.

What is the direction and magnitude of the net force per unit length acting on Z?

	Direction	Magnitude
A	Towards Y	F
B	Towards Y	$5F$
C	Away from Y	$5F$
D	Away from Y	$7F$

25 A magnet is attached to a motor and rotates below a freely-suspended copper disc as shown below.



Which of the following statements is correct?

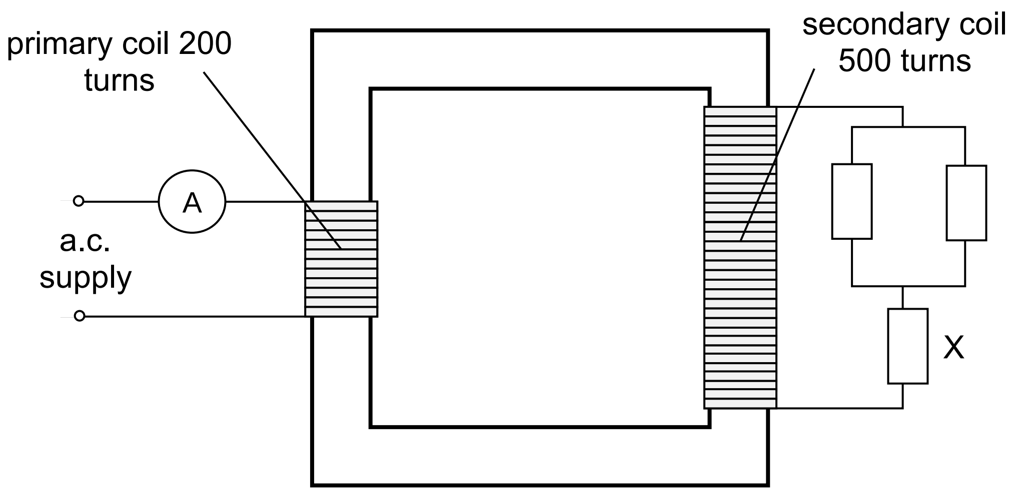
A The disc remains stationary as copper is not magnetic.

B The disc rotates in the same direction as the magnet as copper is magnetic.

C The disc rotates in the same direction as the magnet as eddy currents are induced in the disc.

D The disc rotates in the opposite direction as the magnet as eddy currents are induced in the disc.

26 A 100% efficient transformer is connected to a sinusoidal a.c. supply as shown below. The secondary coil is connected to 3 identical resistors, each of resistance 1000 Ω. The potential difference across resistor X is 80 V.



What is the reading on the ammeter?

A 0.080 A **B** 0.20 A **C** 0.40 A **D** 2.3 A

27 Which of the following statements is **true** when the photoelectric effect occurs?

A The maximum speed of emitted electron is proportional to the intensity of the incident light.

B The maximum energy of the emitted electrons increases with the wavelength of the incident light.

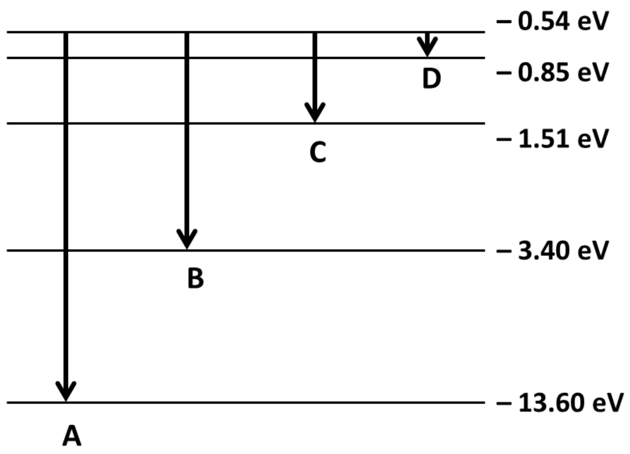
C The number of electrons emitted per unit time is proportional to the intensity of the incident light.

D The wavelength of the incident light must be greater than a certain threshold value.

28 The energy level diagram represents the five lowest energy levels of hydrogen.

A spectral line of wavelength 435 nm corresponds to one of the lines in the spectrum of hydrogen.

Which of the transitions gives this particular spectral line?



29 Two deuterium nuclei undergo a fusion reaction to form a helium nucleus as represented by

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + \text{energy}$$

The binding energy per nucleon of helium is 2.54 MeV.
The minimum amount of energy released in this reaction is 3.26 MeV.

What is the binding energy per nucleon of deuterium?

A 1.45 MeV **B** 1.73 MeV **C** 3.36 MeV **D** 3.45 MeV

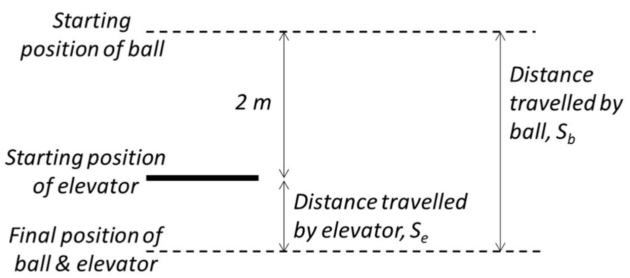
30 A detector detects an average count-rate of 600 counts min^{-1}. Two half-lives later, the count-rate drops to 180 counts min^{-1}.

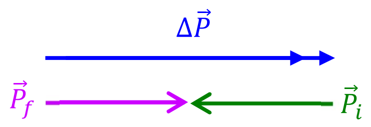
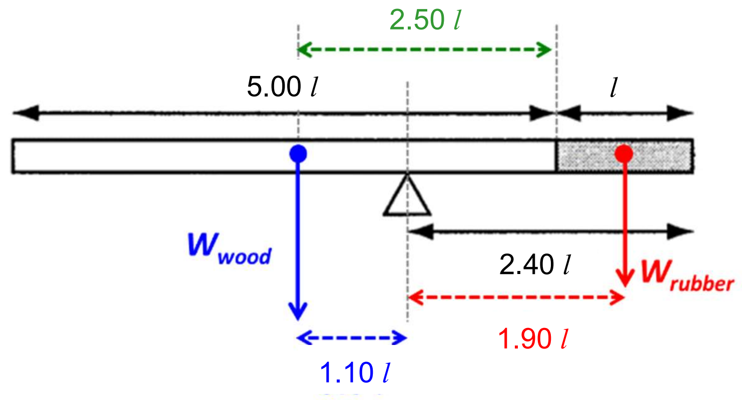
Determine the average background count-rate, in counts min^{-1}.

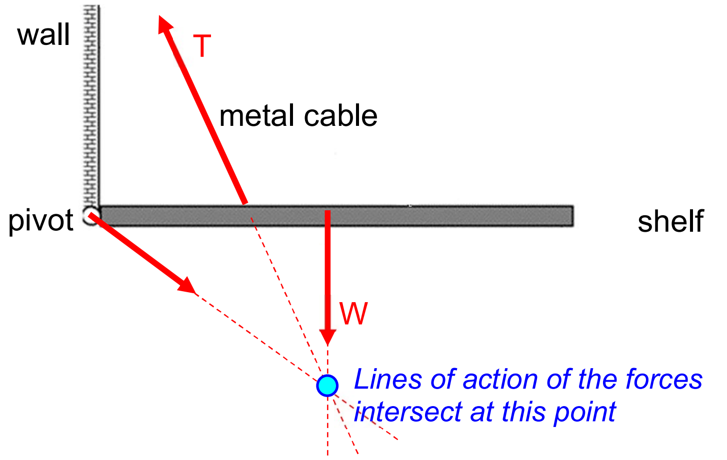
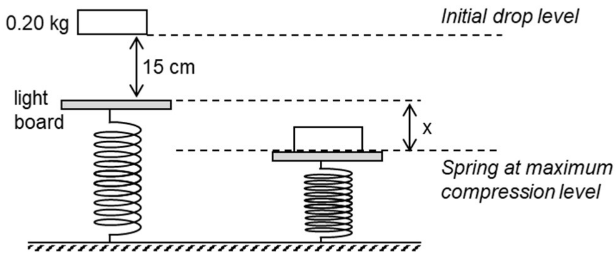
A 15 **B** 40 **C** 60 **D** 120

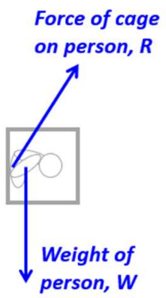
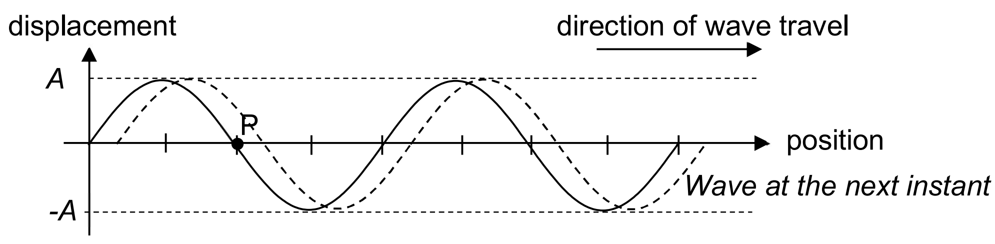
END OF PAPER

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) $A(5.00\,l)\rho_{wood}\,g(1.10\,l) = A(l)\rho_{rubber}\,g(1.90\,l)$ $5.00\,\rho_{wood}(1.10) = \rho_{rubber}(1.90)$ $\frac{\rho_{rubber}}{\rho_{wood}} = \frac{5.50}{1.90} = 2.89$

8	**D**	 Lines of action of the three co-planar non-parallel forces intersecting at a point is necessary if the object is in rotational equilibrium. Vector sum of all forces add to zero is necessary if the object is in translational equilibrium. Hence the answer cannot be A.
9	**D**	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  $\frac{1}{2}kx^2 = mg(0.15 + x)$ $\frac{1}{2}(85)x^2 = (0.20 \times 9.81)(0.15 + x)$ $42.5x^2 - 1.962x - 0.2943 = 0$ $x = 0.109$ m
10	**C**	At maximum speed, engine force = drag force of kv. Power of boat, P = (engine force) v = kv^2 Hence, $\frac{P_{\text{one engine}}}{P_{\text{two engines}}} = \left(\frac{v_{\text{one engine}}}{v_{\text{two engines}}}\right)^2$ $\frac{32}{64} = \left(\frac{v_{\text{one engine}}}{14}\right)^2$ $v_{\text{one engine}} = 9.9 \text{ m s}^{-1}$

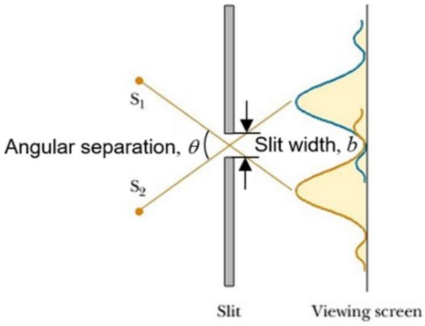
11	**A**	There are only two forces acting on the person, force of cage on him, ***R*** and his weight, ***W***. Since the man is in uniform (i.e. constant speed) circular motion, the net force on him is directed toward the centre of the circle, i.e. toward the right. The vector sum of ***R*** and ***W*** 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 $\theta_{\min}$, 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 $\theta_{\min}$.



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

Option D does not affect either $\theta_{\min}$ 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 $\theta_{\min}$, 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)	

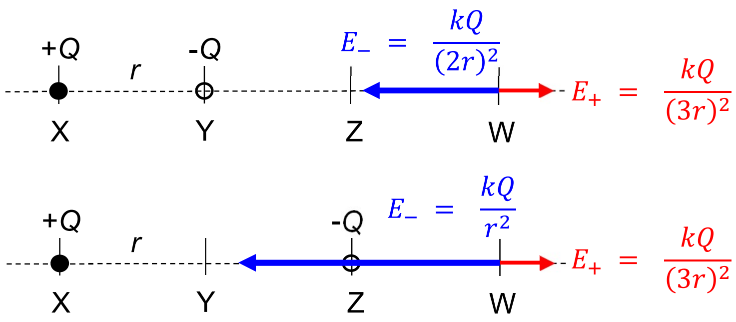
---

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.

Before *After*

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

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}

HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	23S
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS — 9749/02

Paper 2 Structured Questions

10 September 2024

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

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

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

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

For Examiner's Use		
Paper 2		
1		6
2		11
3		5
4		8
5		9
6		10
7		9
8		22
Deductions		
Total		80

Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_0	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	$= 8.85 \times 10^{-12}$ F m^{-1}
		$\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall,	g	$= 9.81$ m s^{-2}

Formulae

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

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1 Fig. 1.1 shows an incident photon of momentum 7.30 x 10^{-22} kg m s^{-1} colliding with a stationary electron.

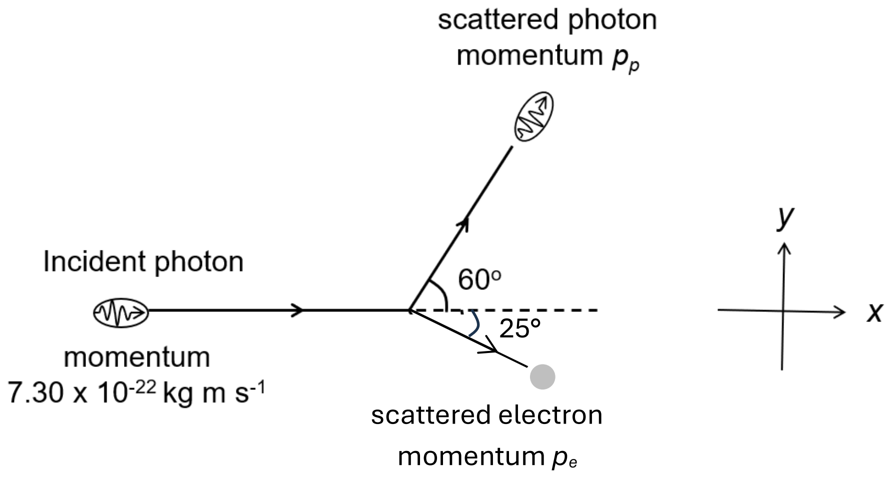

Fig. 1.1

After the collision, the photon is scattered off through an angle of 60° and has a momentum p_p. The electron gets scattered off at an angle of 52° with a momentum p_e. Their scattering angles are measured with respect to the path of the incident photon.

(a) Explain why linear momentum is conserved in this collision for the system of photon and electron.

....

.... [1]

(b) Consider the photon and electron as a system.

(i) State the total momentum of the system along the

1. *x*-direction,

momentum in *x*-direction = ... kg m s^{-1} [1]

2. *y*-direction.

momentum in *y*-direction = ... kg m s^{-1} [1]

(ii) Applying the principle of conservation of momentum in both directions, determine the momentum p_e of the electron after the collision.

momentum p_e of the electron = ... kg m s^{-1} [3]

[Total: 6]

2 **(a)** State Newton's law of gravitation.

....

....

....[2]

(b) Fig. 2.1 shows a hypothetical stable three-body system. The system comprises of three identical masses A, B and C orbiting about a common centre of rotation O.

The radius of orbit is 7.60×10^8 m.

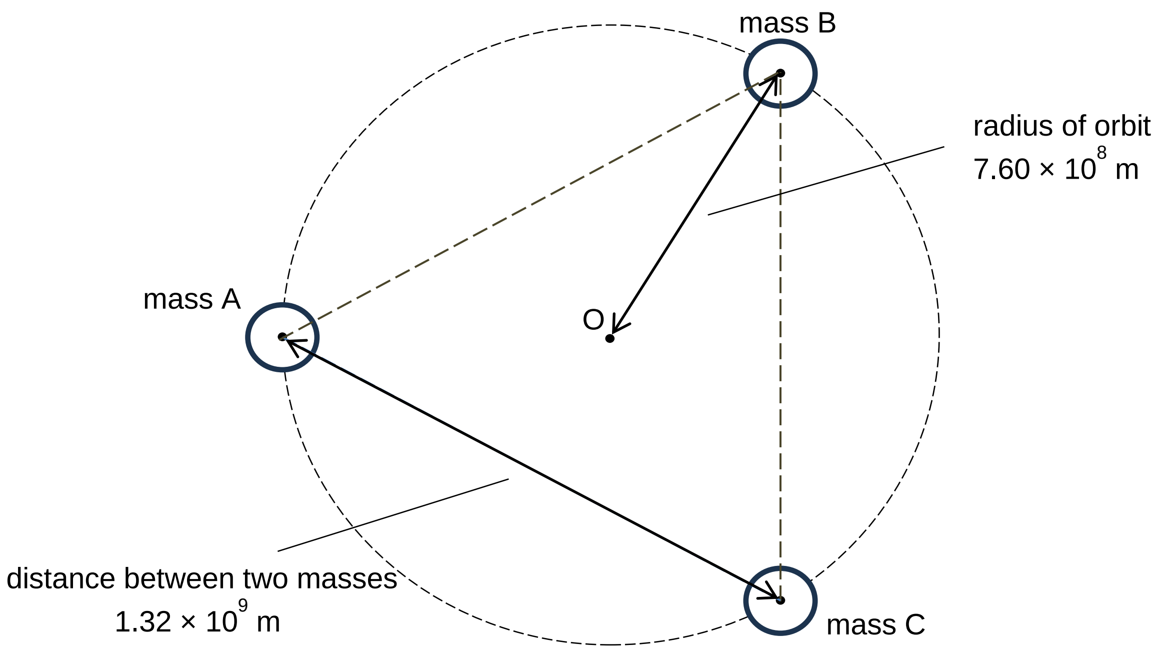

Fig 2.1

The masses are equally distributed along the circular path of orbit, such that the distance between any two masses is always the same.

The distance between the centres of any two masses is 1.32×10^9 m. Each mass is 6.20×10^{24} kg.

(i) Show that the resultant force on mass A is 2.55×10^{21} N.

[2]

(ii) Hence, calculate the period of orbit of the three masses about O. Explain your working.

period = ... s [3]

(iii) Explain why gravitational potential near this system of three masses is always negative.

....

....

....

.... [2]

(iv) Calculate the gravitational potential energy of this system of three masses.

gravitational potential energy = ... J [2]

[Total: 11]

3 **(a)** Describe what is meant by a *polarised* wave.

....

....

....

....[2]

(b) A narrow beam of light is incident on three ideal polarising filters A, B and C as illustrated in Fig. 3.1.

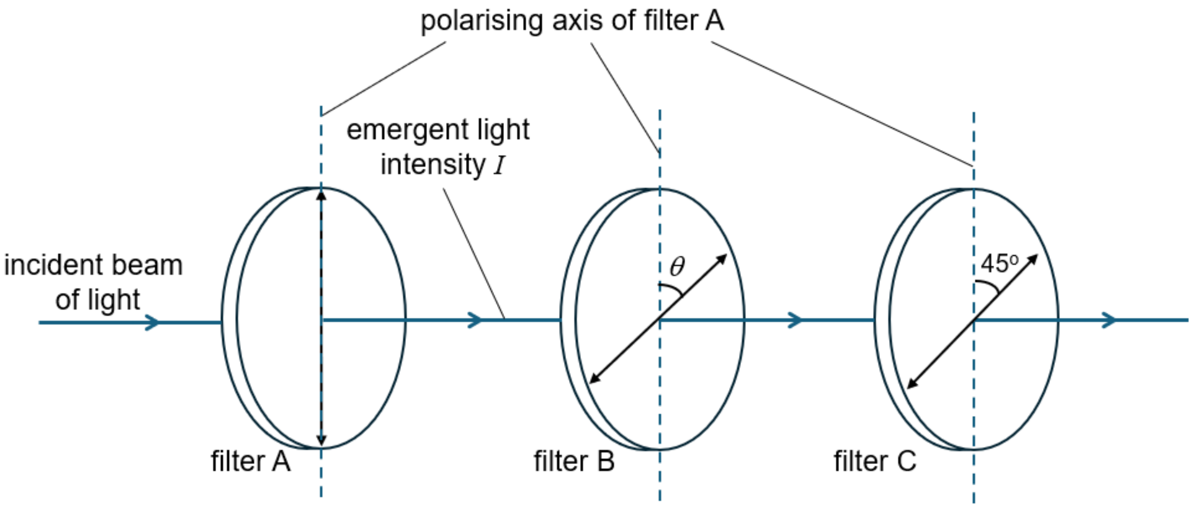

Fig. 3.1

The emergent beam after passing through filter A has an intensity of I.

Filter C is fixed in position such that its polarising axis is at an angle of 45° from the polarising axis of filter A.

Filter B is allowed to rotate. θ is the angle between the polarising axes of filter A and B.

(i) Polarising filter B is rotated from θ = 0° to θ = 180°.

Besides θ = 90°, there is another angle θ where the intensity of light emergent from filter C is zero. State the value of this angle.

θ = ... ° [1]

(ii) Filter B is adjusted such that $\theta = 60°$.

Determine the intensity of light, in terms of I, that emerges from filter C.

intensity = ... I [2]

[Total: 5]

4 An electron is travelling at right angles to a uniform magnetic field of flux density 1.2 mT, as illustrated in Fig. 4.1.

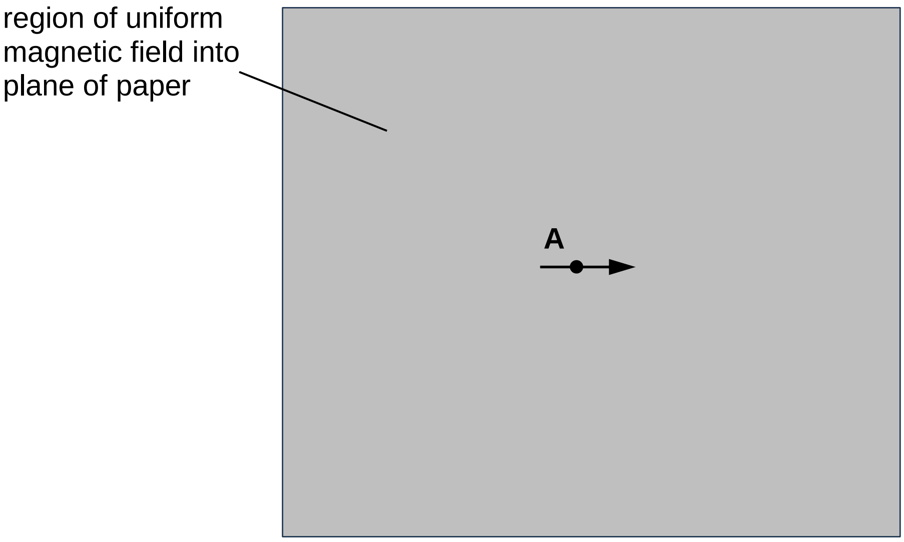

Fig. 4.1

The magnetic field is directed into the plane of the paper.

When the electron is at A, its velocity is 2.8×10^7 m s^{-1} in the direction shown. This is normal to the magnetic field.

(a) **(i)** On Fig. 4.1, sketch the path of the electron, assuming that it does not leave the region of the magnetic field. [1]

(ii) Show that the radius of the path of the electron is 13 cm.

[2]

(b) **(i)** A uniform electric field is applied in the same region so that the electron now moves undeflected through the magnetic field.

1. Draw on Fig. 4.1 the direction of the electric field. Label your arrow **E**.

2. Determine the magnitude of the electric field strength.

magnitude of electric field strength = ... $N\ C^{-1}$ [3]

(ii) If however, the direction of the uniform electric field is in the same direction as the magnetic field, describe the shape of the resultant path of the electron.

You may draw a sketch to illustrate the path if you wish.

....

.... [2]

[Total: 8]

5 Fig. 5.1 shows an a.c. power supply connected to three resistors.

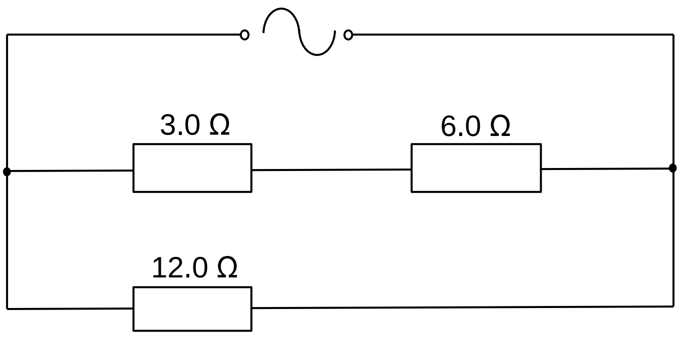

Fig. 5.1

The variation with time t of the voltage V of the power supply is given by the expression:

$$V = 15 \sin 628t$$

(a) Determine, for the power supply,

(i) the period T of the a.c. voltage,

T = ... s [1]

(ii) the root-mean-square (r.m.s.) voltage V_{rms},

V_{rms} = ... V [1]

(iii) the peak current I_0 from the power supply,

I_0 = ... A [2]

(iv) the mean power <P> dissipated in the resistor of resistance 6.0 Ω.

<P> = ... W [2]

(b) Use your answers in **(a)** to sketch, on the axes of Fig 5.2, the variation with time t of the power P transferred in the 6.0 Ω resistor, for two complete periods of the alternating potential difference. Label your axes and indicate relevant values.

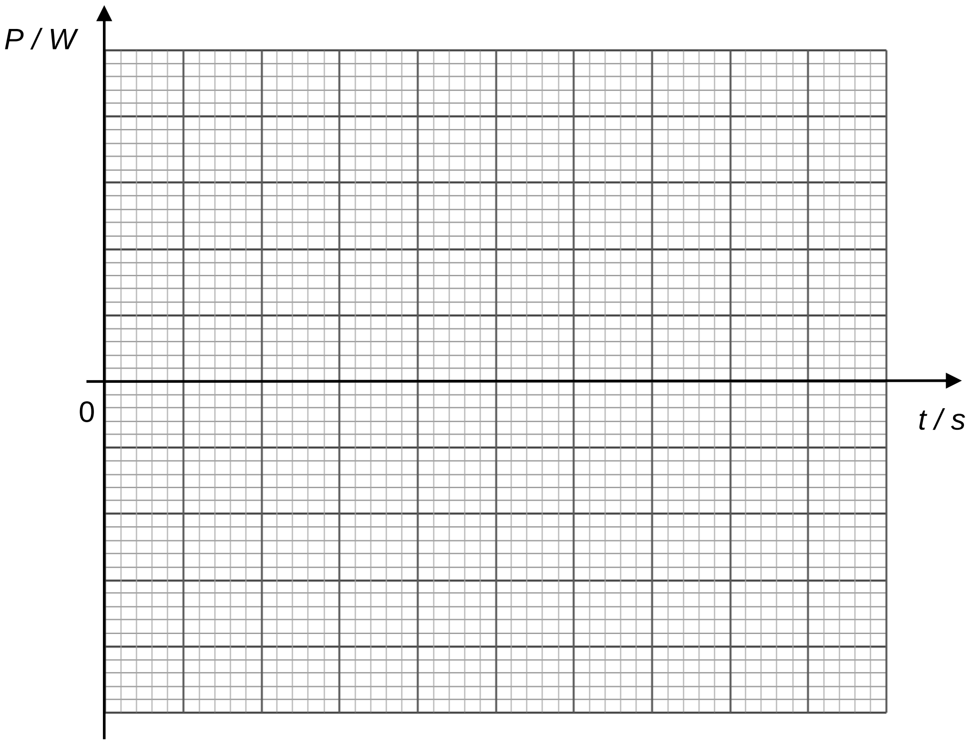

Fig. 5.2

[3]

[Total: 9]

6 Fig 6.1 shows the set-up of the Davisson and Germer experiment which was originally designed to measure the energy of electrons scattered from a nickel metal target.

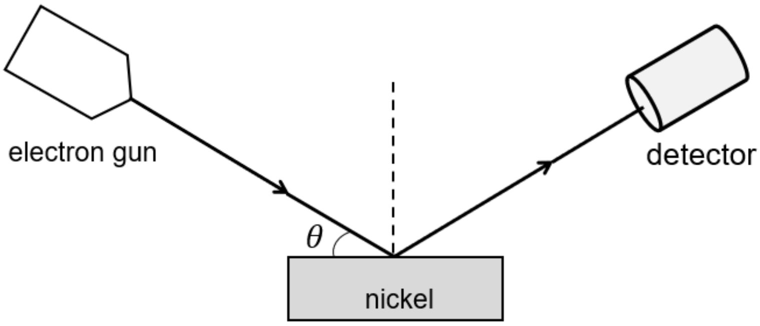

Fig. 6.1

Electrons are accelerated from rest through a potential difference of 100 V in the electron gun.

The accelerated beam of electrons, which emerge from the electron gun, is then directed at an angle θ with respect to the surface of the nickel target.

Electrons that are scattered from the nickel are collected by a detector which measures the rate I at which the charges are collected.

(a) Consider a single electron that is being accelerated inside the electron gun.

(i) Calculate the final speed attained by the electron before emerging from the gun.

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

(ii) Deduce the corresponding de Broglie wavelength of the electron.

de Broglie wavelength = ... m [2]

(b) The nickel metal has a regular crystalline geometry. Two horizontal atomic planes in the nickel metal, separated by distance d, are shown in Fig 6.2.

The electrons in the electron beam from the electron gun can take different paths to the nickel and then to the detector. Two possible paths, path 1 and path 2, are illustrated. Both paths make the same angle θ with respect to the planes.

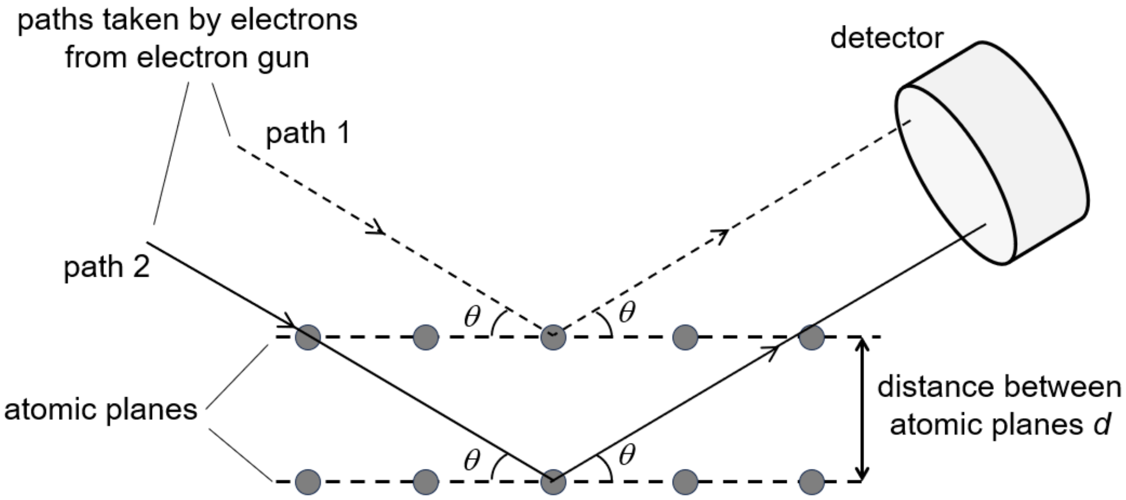

Fig. 6.2 (not to scale)

(i) Determine an expression, in terms of d and θ, for the path difference between the electrons of path 1 and path 2.

path difference = ... [1]

(ii) In a particular experiment, the angle θ that the electron beam makes with the atomic planes is kept constant while the accelerating voltage V of the electron gun is slowly increased.

Fig 6.3 shows the graph of the rate I at which the charges are detected against the square root of the accelerating voltage $\sqrt{V}$ for the experiment. The rate of charges detected fluctuates between a series of maximum and minimum values of I as V is increased.

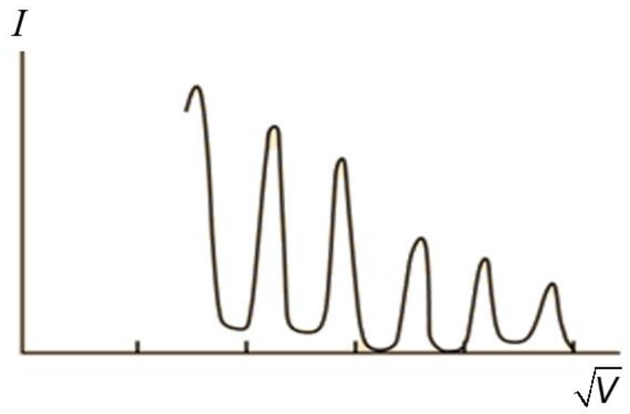

Fig 6.3

1. Describe and explain how the de Broglie wavelength of the electrons emerging from the electron gun changes as the accelerating voltage is increased.

....

....

....

....[2]

2. Hence, explain why the graph in Fig. 6.3 shows maximum values of I being detected at only certain accelerating voltages.

....

....

....

....

....

....[3]

[Total: 10]

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7 Potassium-42 is a radioactive isotope of potassium that is artificially produced in the laboratories for use in medical research studies involving potassium metabolism.

The nuclide Potassium-42 ($^{42}_{19}K$) undergoes radioactive decay to become Calcium-42 ($^{42}_{20}Ca$), a stable nuclide. A radioactive sample contains N_0 atoms of Potassium-42 at time $t = 0$. Fig. 7.1 shows the variation with time t of the number N of atoms of Potassium-42.

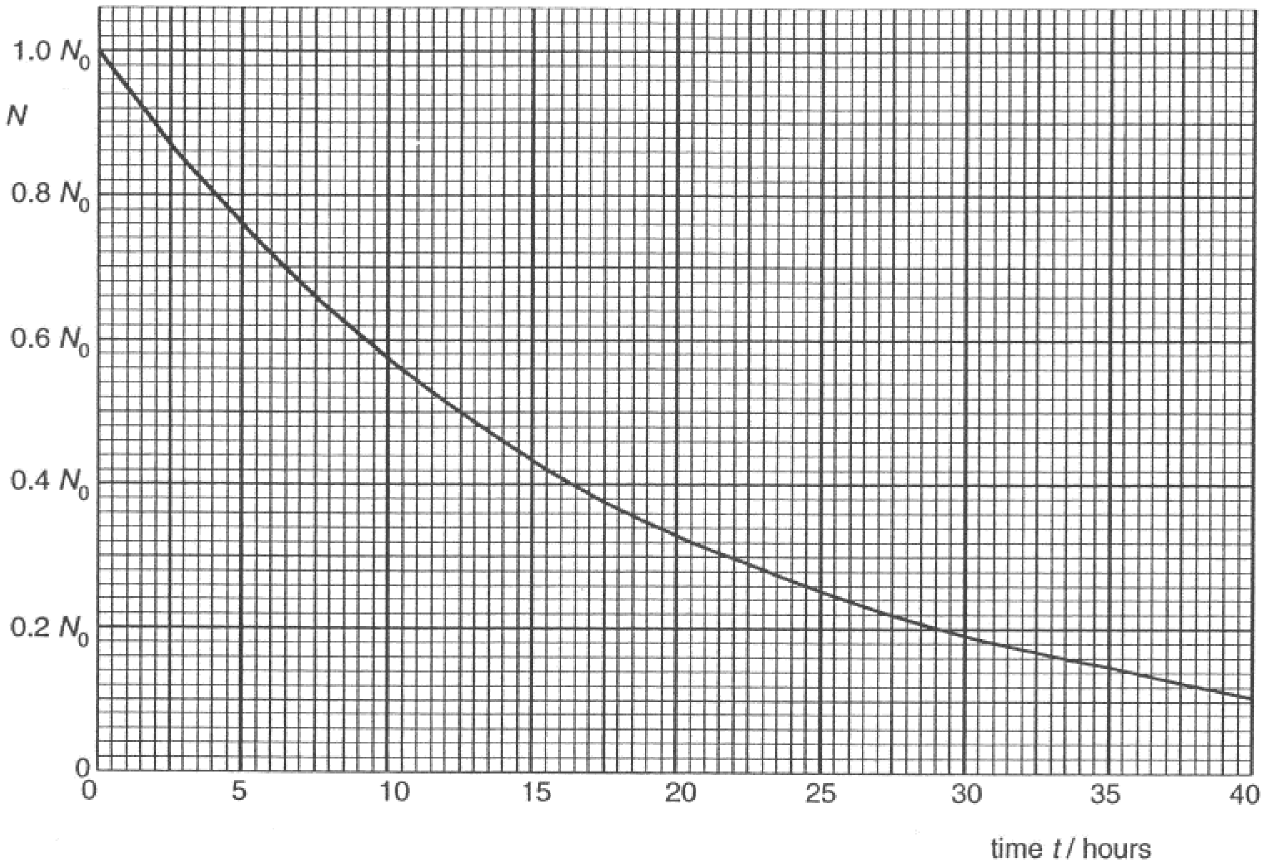

Fig. 7.1

(a) Define *half-life* of a radioactive sample.

....[1]

(b) Explain what is meant by the *activity* of a radioactive sample.

....[1]

(c) **(i)** Use Fig. 7.1 to determine the probability per unit time that Potassium-42 decays.

probability per unit time = ... s^{-1} [3]

(ii) Determine, in terms of N_0, the activity of Potassium-42 at t = 27.5 hours.

activity = ...N_0 Bq [2]

(d) Fig. 7.2 shows the variation of the logarithm of the activity A with time t for the decay of Potassium-42.

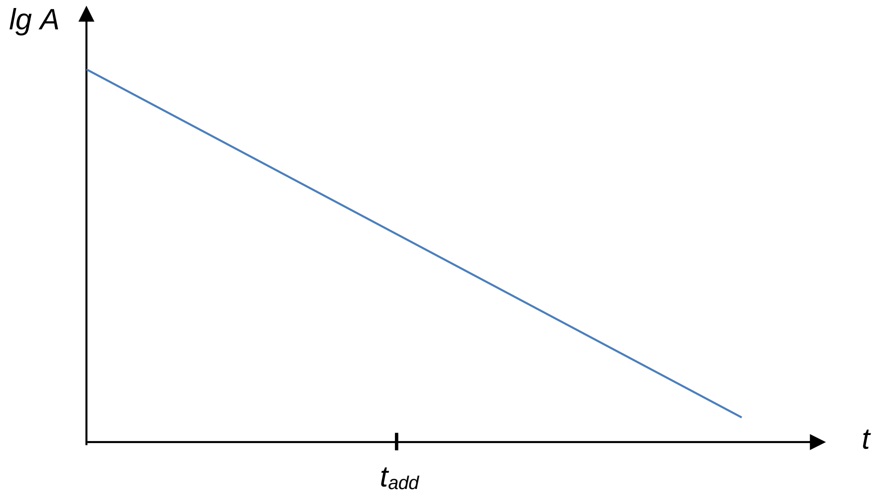

Fig. 7.2

(i) If more Potassium-42 is added to the sample at time t_{add}, sketch on Fig. 7.2 the new variation of the logarithm of A with time t. Label this graph **P**.

(ii) If instead of more Potassium-42, another nuclide of a *very much shorter* half-life were added, sketch also on Fig. 7.2 the new variation of the logarithm of A with time t. Label this graph **Q**. [2]

[Total: 9]

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

In the world of competitive cycling, every detail can make a significant difference in a rider's performance. Athletes compete with one another, trying to be a bit better by improving both their bodies and their equipment. Factors such as strategy, equipment efficiency, and physical conditioning all play crucial roles in determining the outcome of races.

Many different types of bicycles exist, with each possessing its own unique strengths. To gain an edge over the competition, bicycle designers are constantly experimenting with different bicycle designs and shapes.

Fig. 8.1 shows the propulsive power P required, for 5 different types of bicycles to travel on **flat ground** at different speeds v.

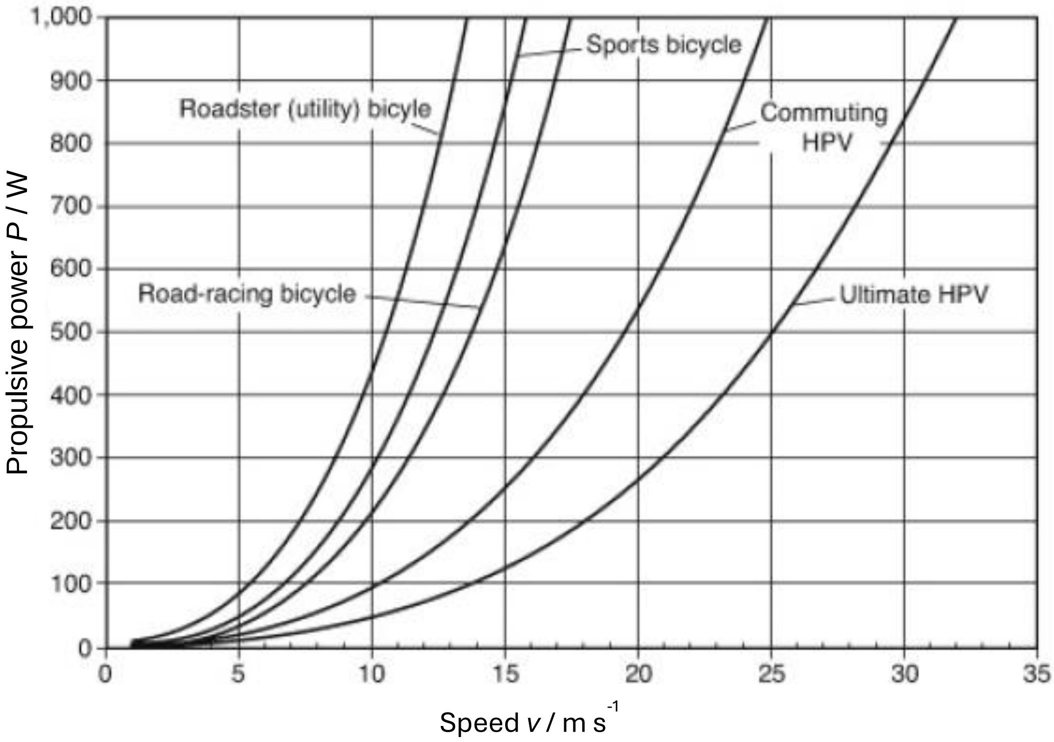

Fig. 8.1

More effort is required to ride fast against the wind or going uphill. A cyclist riding up a slope at a high speed experiences two main forces opposing his motion – slope resistance F_{slope} and air resistance F_{air} .

Slope resistance F_{slope} is related to the steepness of the road. Specifically, F_{slope} refers to the component of the rider (and bicycle)'s weight that acts parallel to the slope. The steepness of a road is commonly referred to as the slope, and is usually expressed as a percentage. Slope is calculated as a fraction ("*rise* over *run*") in which *rise* is the vertical distance and *run* is the horizontal distance. A notable example of a challenging slope is found in the Dirty Dozen bicycle race in Pittsburgh, Pennsylvania. The Canton Avenue hill section of the race is notorious for being one of the steepest in the world, boasting a distance of just 6.4 m, but with a slope of 37%!

Meanwhile, a rider moving at a greater speed experiences greater air resistance F_{air}. For a solo rider, it is suggested that F_{air} is related to the speed v by the equation

$$F_{air} = \frac{1}{2}\rho C_D A v^2$$

where ρ is the air density and the product $C_D A$ is the effective drag area.

For rider safety, the governing body, Union Cycliste Internationale, mandates the use of brakes on bicycles in their events. Brakes can be placed on the front and/or rear wheels of the bicycle, and their effectiveness is limited by the friction F between the wheel and the road.

Theory suggests that F is related to the normal contact force acting at that point N by the equation

$$F = \mu N$$

where μ is the coefficient of friction.

Consequently, both the frictional force acting on the front and rear wheels have different braking efficacy and serve different purposes in assisting the rider to brake effectively.

(a) For a competitive cyclist using an Ultimate HPV bicycle, travelling at constant speed of 25 m s^{-1} on flat ground,

(i) state the propulsive power required.

power = ... W [1]

(ii) Hence, determine the propulsive force provided by the rider.

propulsive force = ... N [2]

(iii) Calculate the effective drag area, $C_D A$ of the cyclist. You may assume that the air density is 1.0 x 10^{-3} g cm^{-3}.

effective drag area, $C_D A$ = ... m^2 [3]

(b) The competitive cyclist in **(a)** takes part in the Dirty Dozen race using the Ultimate HPV bicycle. The combined mass of the cyclist and his bike is 85 kg.

(i) Calculate the slope resistance F_{slope} that the cyclist experiences as he rides up the Canton Avenue hill section.

F_{slope} = ... N [3]

(ii) The cyclist rides up the Canton Ave hill section at a constant speed.

Determine

1. the work done against gravity for this section of the race.

work done = ... J [2]

2. the new propulsive power required by this cyclist if he wishes to maintain a constant speed of 25 m s^{-1} as he climbs the hill.

new propulsive power = ... W [3]

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(c) Fig. 8.3 shows some of the forces acting on the system of cyclist and bicycle as it *brakes*.

The combined weight of the cyclist and his bicycle is W. N_1 and N_2 are the normal contact forces acting on the front and rear wheels, respectively. Consequently, the frictional forces acting on the front and rear wheels are μN_1 and μN_2, respectively.

The centre of mass of the system is located 114 cm above the ground. The rear wheel of the bicycle is located at a horizontal distance of 43 cm from the centre of mass, and the horizontal distance between the centres of both wheels is 107 cm.

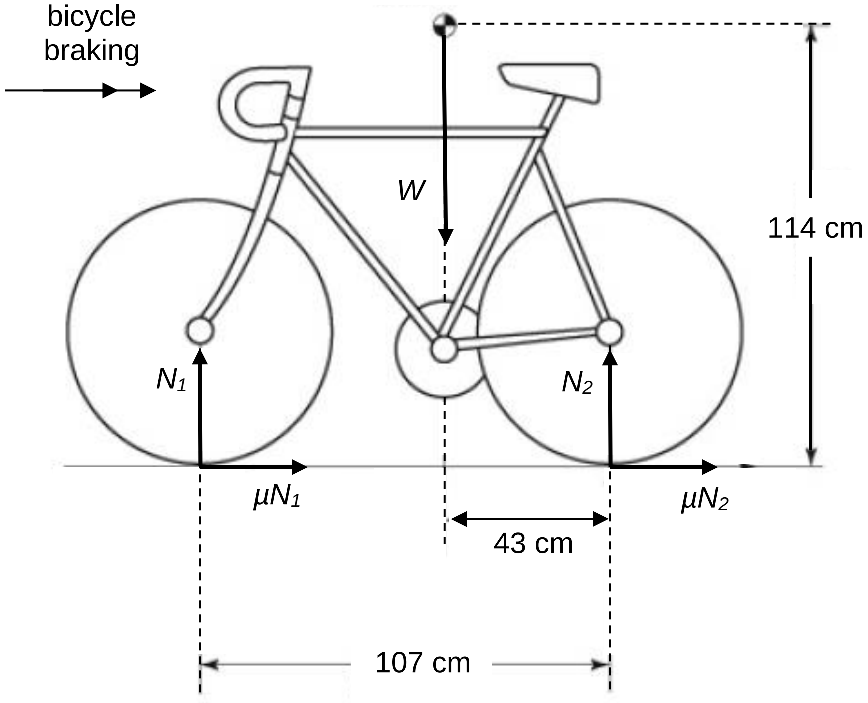


Fig. 8.3

The coefficient of friction μ between the ground and the wheels of the bicycle is 0.37.

(i) Using Newton' second law of motion, determine the magnitude of the cyclist's deceleration.

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

(ii) Taking moments about the centre of mass, show that

$$N_1 = 0.80\, W.$$

[2]

(iii) Determine the ratio of the deceleration contributed by the front wheel to that contributed by the back wheel.

ratio = ... [1]

(iv) When a cyclist brakes too quickly, his centre of mass will tend to move forward due to inertia.

By considering the torques due to individual forces about the centre of mass, explain why a cyclist will tend to flip forward.

....

....

.... [2]

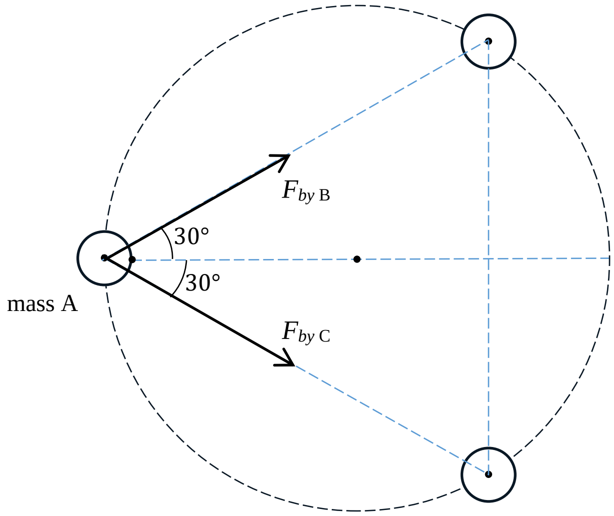
[Total: 22]

END OF PAPER

Copyright Acknowledgements: Bicycling Science, third edition (David Gordon Wilson, 2004)

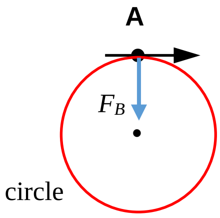
2024 HCI Preliminary Examination Paper 2 Suggested Solutions

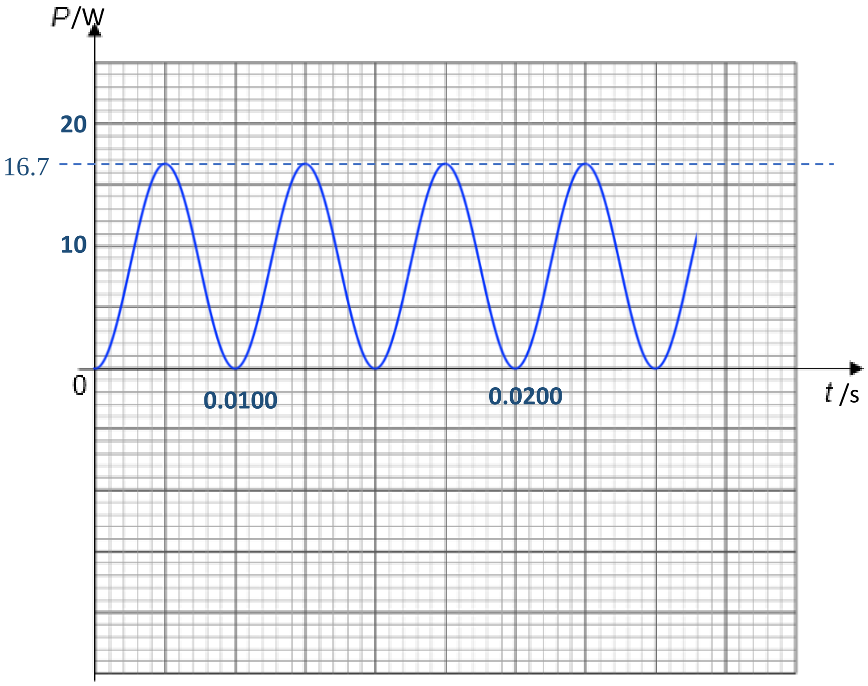
Q1		
(a)	During the collision, there are no external forces acting on the photon and electron or system, hence linear momentum is conserved.	**B1**
(b)(i)	**1.** $\sum p_x = 7.30 \times 10^{-22}$ kg m s^{-1}	**B1**
	2. $\sum p_Y = 0$ kg m s^{-1}	**B1**
(b)(ii)	By principle of conservation of linear momentum, $(\rightarrow)\ 7.3 \times 10^{-22} = (p_p)(\cos 60^o) + (p_e)(\cos 25^o)$ …(1) $(\uparrow)\ (p_e)(\sin 25^o) = (p_p)(\sin 60^o)$ …(2) Solving (1) and (2) gives, $\dfrac{(p_p)(\sin 60°)}{(p_p)(\cos 60°)} = \tan 60° = \dfrac{(p_e)(\sin 25°)}{(7.3 \times 10^{-22}) - (p_e)(\cos 25°)}$ $\Rightarrow p_e = 6.35 \times 10^{-22}$ 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 $= 2 \times \frac{GM^2}{d^2} \times \cos 30° = 2 \times \left(\frac{6.67 \times 10^{-11} (6.20\ x\ 10^{24})^2}{(1.32 \times 10^9\ )^2} \right) \times \cos 30° = 2.5487 \times 10^{21}$ N $=2.55 \times 10^{21}$ 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
	$F = m\omega^2 R$ $\omega = \sqrt{\frac{F}{mR}} = \sqrt{\frac{2.5487 \times 10^{21}}{6.20 \times 10^{24} \times 7.60 \times 10^8}} = 7.3546 \times 10^{-7}$ rad s^{-1} $T = \frac{2\pi}{\omega} = \frac{2\pi}{7.3546 \times 10^{-7}} = 8.54 \times 10^6$ 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

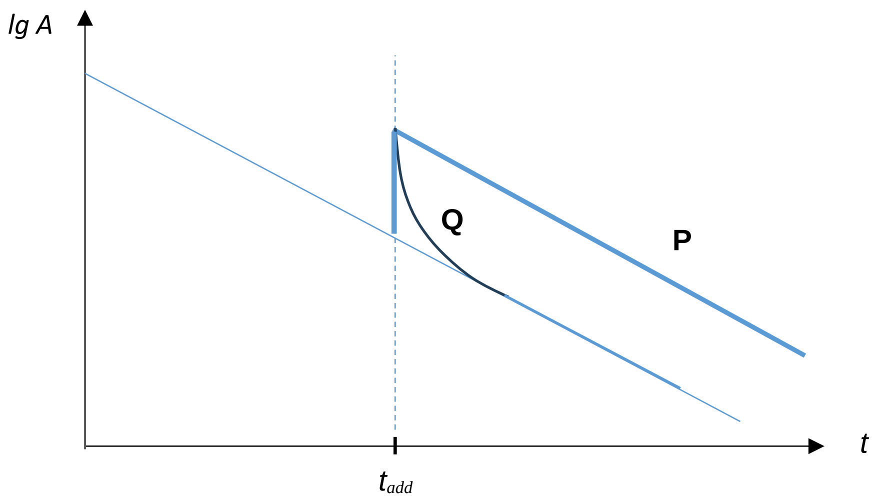
	Since gravitational force is **attractive** in nature, (positive) **work is done by an external agent to bring a (test) mass from the point** (in the field if these 3 planets) **to infinity**, hence the (initial) potential is therefore (lower than at infinity and hence) negative.	**B1**
(b)(iv)	$U = U_{AB} + U_{AC} + U_{BC}$ $= -\frac{Gm^2}{d} + \left(-\frac{Gm^2}{d}\right) + \left(-\frac{Gm^2}{d}\right)$ $= 3 \times \left(-\frac{6.67 \times 10^{-11} \left(6.20\ x\ 10^{24}\right)^2}{1.32 \times 10^9}\right)$ $= -5.83 \times 10^{30}$ 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. θ = 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. $qvB = qE$ $\Rightarrow \quad E = vB = (2.8\times10^{7})(1.2\times10^{-3})$ $= 3.36\times10^{4}\text{ N C}^{-1}$	**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 (sin^2 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 $\frac{1}{2}mv^2 - 0 = eV$ $v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2(1.6 \times 10^{-19})(100)}{9.11 \times 10^{-31}}} = 5.93 \times 10^6 \text{ m s}^{-1}$	**M1** **A1**
(a)(ii)	$\lambda = \frac{h}{p} = \frac{(6.63 \times 10^{-34})}{(9.11 \times 10^{-31})(5.93 \times 10^6)}$ $= 1.23 \times 10^{-10} \text{ m}$	**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 average time taken for half of the original number 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 $= \frac{\ln 2}{\text{half-life}} = \frac{\ln 2}{45000}$ $= 1.54 \times 10^{-5}\ s^{-1}$	B1 M1 A1
(c)(ii)	$A = \lambda N = \frac{\ln 2}{T_{1/2}}(0.22N_0) = \frac{\ln 2}{(12.5 \times 60 \times 60)}(0.22N_0)$ $= 3.39 \times 10^{-6} N_0$ 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, $a = \mu g = (0.37)(9.81) = 3.63 \text{ m s}^{-2}$	**A1**
(c)(ii)	Taking moments about the CG, by principle of moments Sum of anticlockwise moments = Sum of clockwise moments $(43)N_2 \quad + \quad (114)\mu N_1 \quad + \quad (114)\mu N_2 \quad = \quad (107-43)N_1$ $\Rightarrow \quad 43N_2 + 42.18W = 64N_1 \qquad \text{......(1)}$ 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**

HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	23S
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS — 9749/03

Paper 3 Longer Structured Questions — **13 September 2024**

Candidates answer on the Question Paper. — **2 hours**

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

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

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

Section A

Answer **all** questions.

Section B

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

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

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

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

For Examiner's Use		
Section A		
1		**5**
2		**8**
3		**8**
4		**8**
5		**9**
6		**8**
7		**8**
8		**6**
Section B (choose ONE)		
9		**20**
10		**20**
Deductions		
Total		**80**

Data

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

Formulae

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

Section A

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

1 **(a)** Distinguish between random error and systematic error in a set of measurements of a physical quantity.

....

....

....

.... [2]

(b) The power P required by a car to overcome the drag force acting on it when it is travelling at a speed v in turbulent condition is given by the equation

$$P = k\rho A^p v^q$$

where A is the frontal area of the car and ρ is the density of the air.

Given that k is a quantity with no units, determine the values of p and q.

p = ...

q = ... [3]

[Total: 5]

2 **(a)** Define acceleration.

……………………………………………………………………………………………………….. [1]

(b) Two projectile launchers are facing each other on horizontal ground as shown in Fig 2.1.

Launcher P fires a projectile at an angle of 30° from the horizontal, at an initial speed of 210 m s^{-1}. Air resistance is negligible.

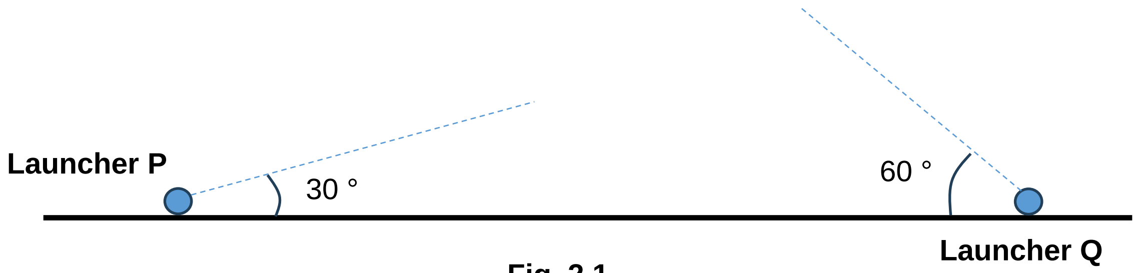


Fig. 2.1

(i) Determine the maximum height the projectile fired from launcher P reaches.

maximum height = ………………. m [2]

(ii) Determine the time of flight for the projectile to reach this maximum height.

time of flight = ………………. s [2]

(iii) A short time after launcher P fires, launcher Q too fires a projectile at an initial speed of 210 m s^{-1} and an angle of 60^{o} from the horizontal.

Both projectiles collide when the projectile from launcher P reaches its maximum height.

1. Show that the projectile from launcher Q has been in flight for 3.4 s when the two projectiles collide.

[1]

2. Fig. 2.2 shows the variation of the vertical velocity with time of the projectile from launcher P from its launch to when it has reached its highest point.

On Fig. 2.2, sketch another graph to show the variation of the vertical velocity with time of the projectile from launcher Q.

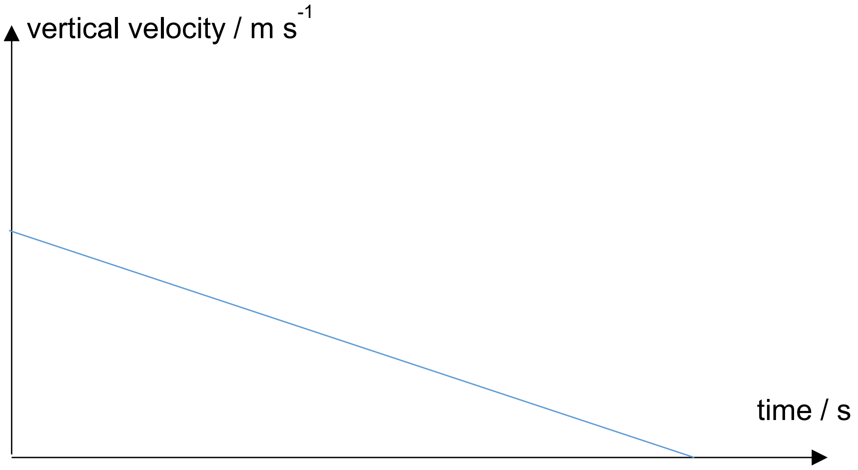


Fig. 2.2

[2]

[Total: 8]

3 Fig. 3.1 shows a thick glass cup submerged in water. The glass has a density of 2200 kg m^{-3} and displaces 6.8×10^{-5} m^3 of water when it is submerged as in Fig 3.1. Water has density 1000 kg m^{-3}.

The glass cup is held stationary by an external force *F*.

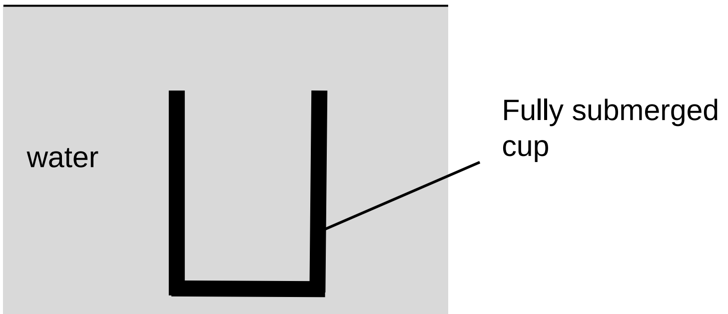


Fig. 3.1

(a) **(i)** Explain why the liquid exerts an upthrust on the cup.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………….. [2]

(ii) By considering the forces acting on the cup, show that the external force *F* needed to keep the cup stationary is 0.80 N.

[2]

(iii) The cup is pushed further down into the water.

Explain how the upthrust acting on the cup will change.

……………………………………………………………………………………………..

…………………………………………………………………………………………….. [1]

(b) Fig. 3.2 shows the same glass cup now inverted and held right at the surface of the water. When placed this way, 5.50×10^{-4} m^3 of air is contained within the cup at atmospheric pressure of 1.0×10^5 Pa.

The cup is then pushed slowly into the water, trapping and compressing the air within the cup, as shown in Fig. 3.3. The cup is again held stationary by an external force such that the water surface is at a distance *d* above the water level in the cup.

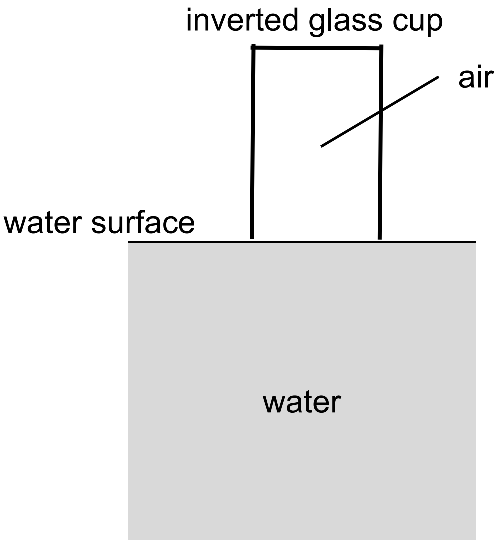


Fig. 3.2

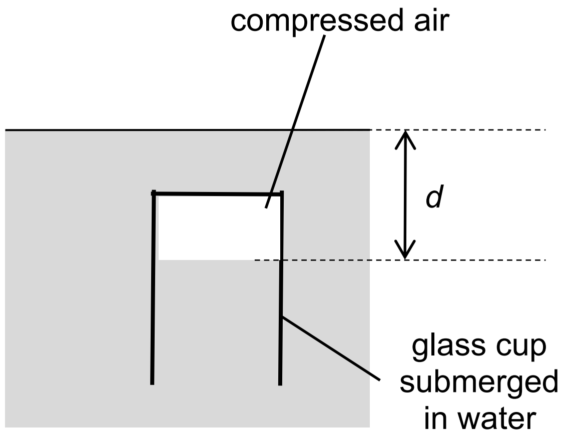


Fig. 3.3

Assuming that air is an ideal gas that is insoluble in water, and that the temperature of the trapped air remains unchanged, calculate the volume of the compressed air within the cup in Fig. 3.3 when d = 30.0 cm.

volume = ………………………….. m^3 [3]

[Total: 8]

4 A test-tube with a total mass M is able to float upright in water of density ρ, as shown in Fig. 4.1. Ignoring its rounded bottom, the test-tube may be regarded as a cylinder of a cross-sectional area A.

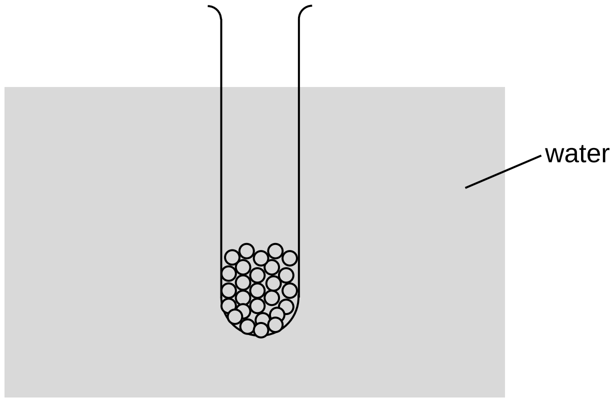


Fig. 4.1

The test-tube is displaced vertically by a small displacement y and then released.

The acceleration of the test-tube is given by

$$a = -\left(\frac{\rho A g}{M}\right) y$$

where g is the acceleration of free fall.

(a) Define simple harmonic motion.

……………………………………………………………………………………………………..

…………………………………………………………………………………………………….. [2]

(b) Given: $\rho = 1.00 \times 10^{3}\ \text{kg m}^{-3}$,

$A = 6.0 \times 10^{-4}\ \text{m}^{2}$,

$M = 0.037\ \text{kg}$,

show that the period of oscillation of the test-tube is 0.50 s.

[2]

(c) The test-tube is given a displacement of 1.0 cm and allowed to oscillate. The variation with time t of the vertical displacement y of the test-tube is shown in Fig. 4.2.

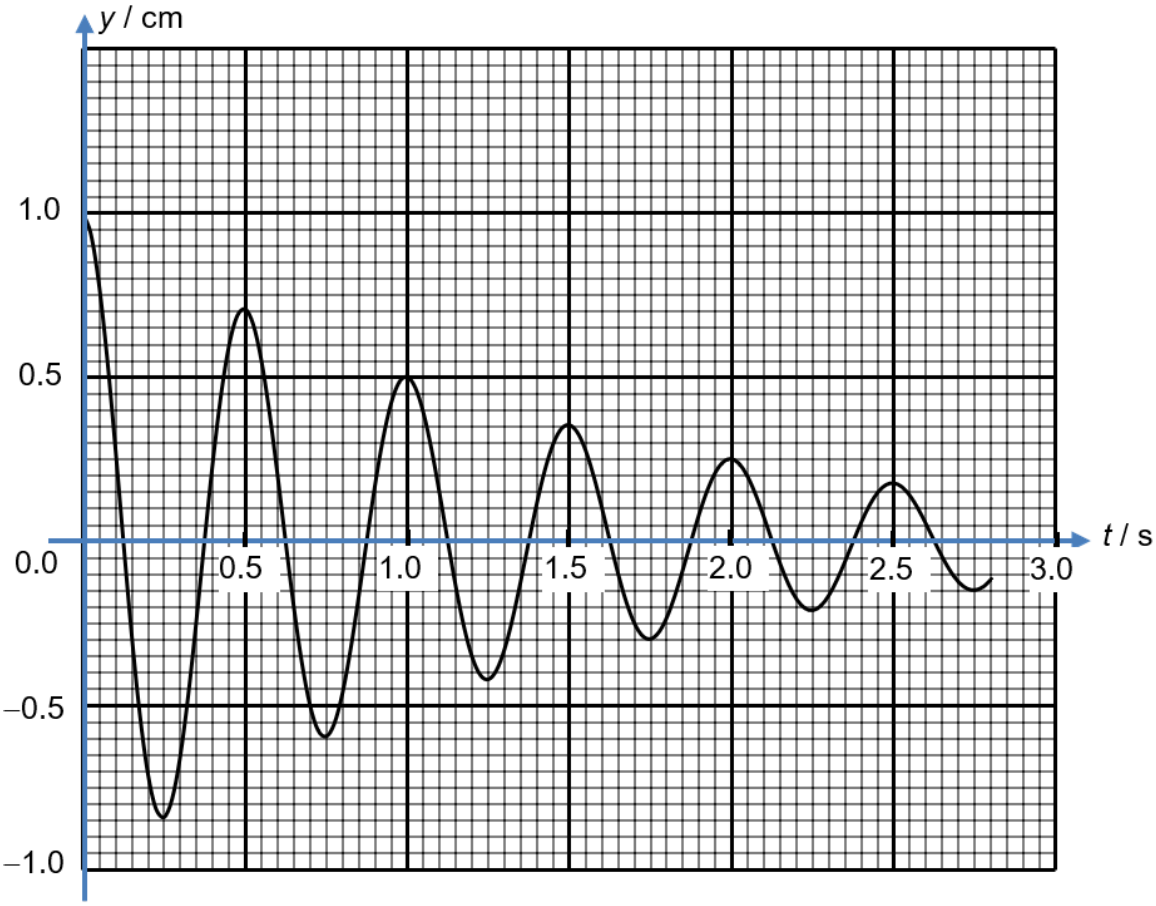


Fig. 4.2

(i) Estimate the time when the *energy of oscillation* has decreased by 75 % of its original value.

time = ... s [2]

(ii) To sustain the oscillations of the test-tube, low-amplitude water waves of frequency 1.0 Hz are generated on the surface of the water. It is observed that the amplitude of the vertical oscillations of this test-tube is rather small while oscillating at 1.0 Hz.

Using information from earlier in the question, explain this observation.

....

....

....

.... [2]

[Total: 8]

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5 A mass of 0.37 kg of water at 100 °C is provided with the thermal energy needed to vaporise all the water at atmospheric pressure. The specific latent heat of vaporisation of water at atmospheric pressure of 1.0×10^5 Pa is 2.3×10^6 J kg^{-1}.

(a) **(i)** Calculate the thermal energy Q supplied to the water.

Q = ………………………….J [1]

(ii) The mass of 1.0 mol of water is 18 g.

Show that the volume of water vapour produced is 0.64 m^3. Assume that water vapour can be considered to behave as an ideal gas.

[3]

(iii) The initial volume of the liquid water is negligible compared with the volume of water vapour produced.

Determine the work done by the water in expanding against the atmosphere when it vaporises.

work done = ………………… J [1]

(iv) Determine the increase in the internal energy of the water when it vaporises at 100 °C.

increase in internal energy = …………………. J [2]

(b) State and explain what happens to the internal energy of the water during the phase change process.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

[Total: 9]

6 **(a)** The variation with potential difference V of the current I in a semiconductor diode is shown in Fig. 6.1.

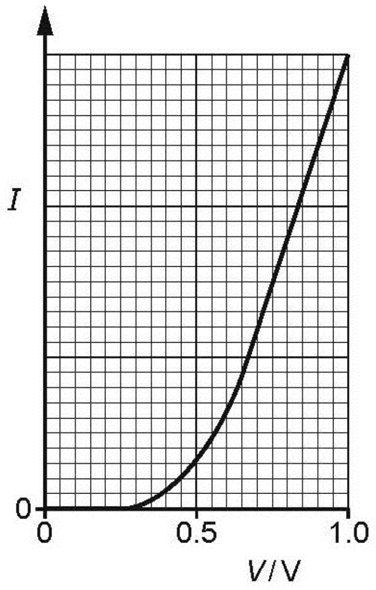

Fig. 6.1

Use Fig. 6.1 to describe qualitatively,

(i) the resistance of the diode in the range V = 0 to V = 0.25 V.

.... [1]

(ii) the variation, if any, in the resistance of the diode as V changes from V = 0.75 V to V = 1.0 V.

.... [1]

(b) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected to a uniform resistance wire XY, a galvanometer, a light-dependent resistor (LDR) and a fixed resistor of 1200 Ω, as shown in Fig. 6.2.

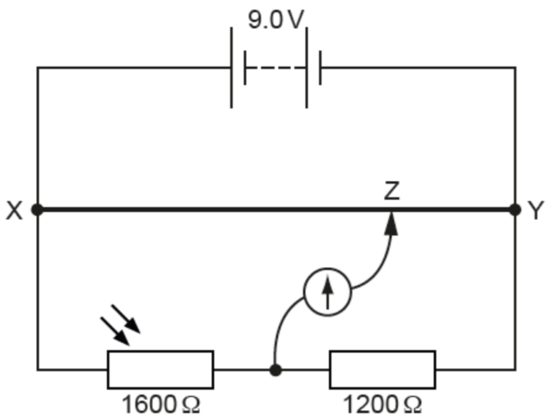

Fig. 6.2

The length of the wire XY is 1.2 m. The movable connection Z is positioned on the wire XY so that the galvanometer gives a zero reading.

(i) Calculate the length XZ along the resistance wire when the LDR has a resistance of 1600 Ω.

length XZ = ……….……………… m [2]

(ii) The intensity of the light illuminating the LDR is now increased.

State and explain whether there is a decrease, increase or no change to:

1. the length XZ so that the galvanometer reads zero.

…………………………………………………………………………………..…

…………………………………………………………………………..……

…………………………………………………………………………………..

………………………………………………………………………………….. [2]

2. the total power supplied by the battery.

………………………………………………………..…………………………

…………………………………………………………..……………………

……………………………………………………..……………………………

…………………………………………………………..…………………… [2]

[Total: 8]

7 The plan view of a train braking system is illustrated in Fig 7.1. The train carriage is mounted on a rectangular metal frame ABCD of length L and width w. The effective resistance of the frame is R.

The train carriage is initially moving at a constant speed along the rails.

A uniform magnetic field B is directed perpendicularly into the ground over a rectangular region of length L. Line P denotes the start of this region while line Q denotes the end of the region.

After passing through the magnetic field, the train speed is expected to be reduced to a very low value after which brakes can be applied to stop it completely. Air resistance and friction may be neglected.

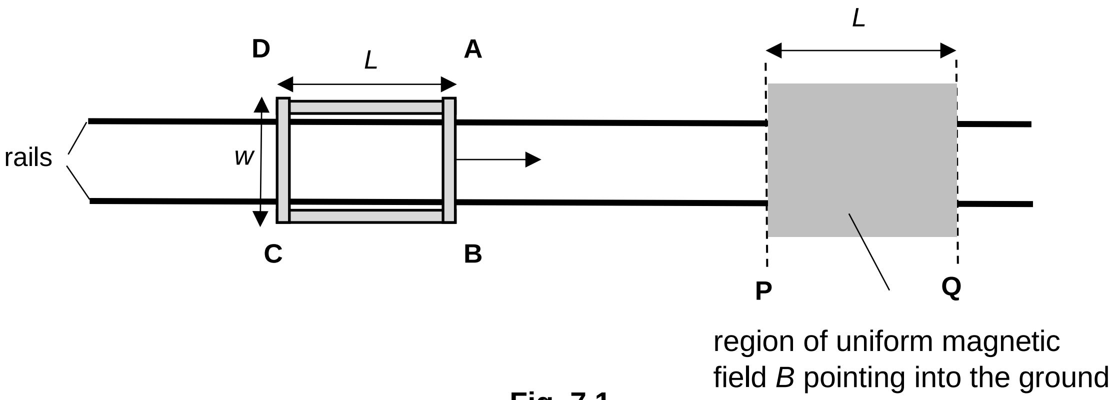

Fig. 7.1

(a) Show that as the frame enters the region of magnetic field, the e.m.f. induced in it, E, is given by $E = Bwv$ where v is the speed of the train carriage. Explain your working clearly.

[2]

(b) **(i)** Explain why the train carriage slows down as AB moves through the magnetic field from P to Q.

....

....

....

....

....

....

.... [3]

(ii) The graph in Fig 7.2 shows the velocity of the train carriage as it moves through the magnetic field, from the instant AB crosses line P to the instant CD crosses line Q.

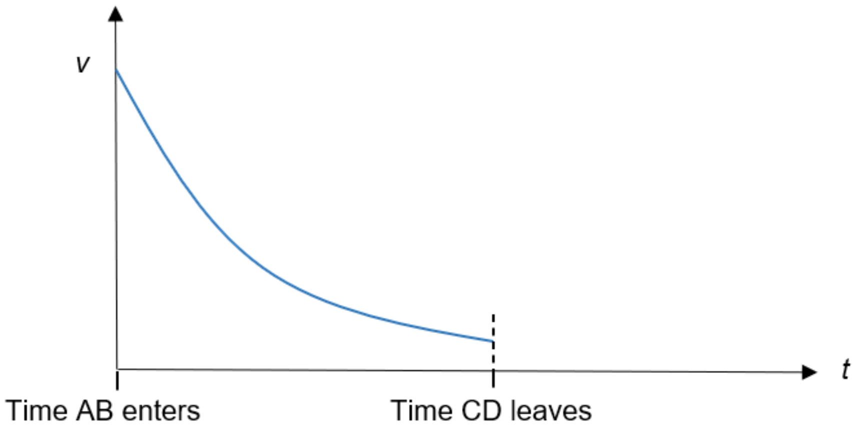

Fig. 7.2

The length of the magnetic field is now reduced by *moving Q closer to P* so that the distance PQ is now smaller than *L*.

Sketch on Fig 7.2 the new variation of the velocity of the train carriage with time as it passes through the magnetic field from the instant AB crosses line P to the instant CD crosses line Q. [3]

[Total: 8]

8 **(a)** In Rutherford's α-particle scattering experiment, α-particles from a radioactive source were directed towards a sheet of gold foil in a vacuum chamber as shown in Fig. 8.1.

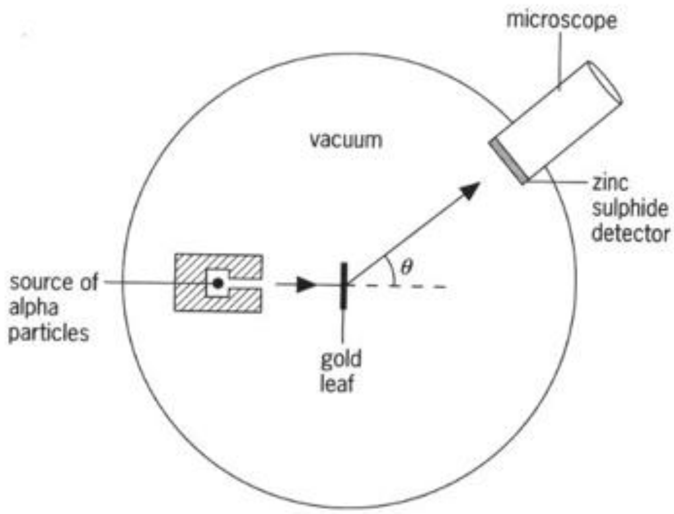

Fig. 8.1

(i) Explain why it is necessary for the radioactive source to be placed in vacuum.

…………………………………………………………………………………………………..

………………………………………………………………………………………………… [1]

(ii) State the experimental observation obtained from Rutherford's experiment which suggested that

1. the nucleus is small,

…………………………………………………………………………………………..

………………………………………………………………………………………….. [1]

2. the nucleus is massive and charged.

…………………………………………………………………………………………..

………………………………………………………………………………………….. [1]

(b) A common nuclear reaction that can be induced in a laboratory is represented by the following equation:

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

In this reaction, stationary nitrogen nuclei were bombarded with helium nuclei, forming oxygen and hydrogen.

The total rest masses of the reactant and the product nuclei are as follows:

$$^{14}_{7}N + ^{4}_{2}He = 18.00568\ u$$
$$^{17}_{8}O + ^{1}_{1}H = 18.00696\ u$$

(i) Deduce that the change in rest-mass energy in this reaction is 1.9×10^{-13} J.

[1]

(ii) With reference to energy, suggest how it is possible for this reaction to occur.

....

.... [1]

(iii) In reality, more than 1.9×10^{-13} J of energy is required for the reaction to occur.

Suggest why this might be so.

....

.... [1]

[Total: 6]

Section B

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

9 **(a)** State the principle of superposition for waves.

....

....

.... [2]

(b) Two identical radio wave point sources A and B placed 12.0 m apart emit waves which are in phase. An interference pattern is detected along the line AB. Point M is the mid-point between A and B.

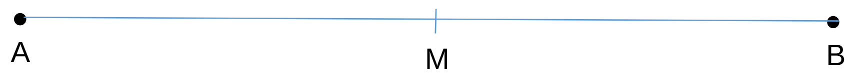

Fig. 9.1

Fig. 9.2 shows the variation with time *t* of the displacement *x* of the signal picked up by a detector placed at M.

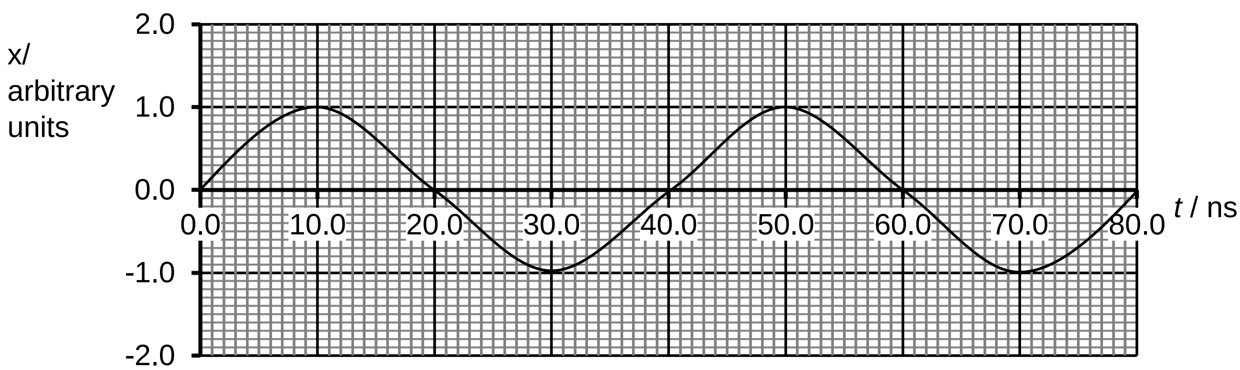

Fig. 9.2

Using the above information,

(i) show that the frequency *f* of the waves from source A and B is 25.0 MHz.

[1]

(ii) Draw in Fig. 9.2 the displacement of the wave which will be detected at point M if source A is switched off while source B remains on.

Label this graph as **Y**.

Explain your answer.

....

....

....

....

.... [3]

(iii) With both wave sources A and B switched on, the detector is moved toward the right from M. The first minimum is detected at point N.

Show that MN is 3.00 m.

[2]

(iv) When the point sources are operated *separately*, the intensity detected at point M is I.

Show that

1. the intensity of the wave from source A arriving at point N, I_A is 0.444 I.

2. the intensity of the wave from source B arriving at point N, I_B is 4.00 I.

[3]

(v) Using the result from **(b)(iv)**, calculate the amplitude of the signal detected at N when both sources are switched on.

amplitude = …………………. arbitrary units [3]

(c) A typical Young's double-slit experiment involves a coherent source of monochromatic light of wavelength *λ* which is directed at the double slits. The slit separation is *a* and each slit has a width of *b*.

A screen is set up at a distance of *D* away from the double slits as shown in Fig. 9.3. The expected interference pattern to be observed on the screen is regularly spaced bright and dark fringes. The fringe separation is *x*.

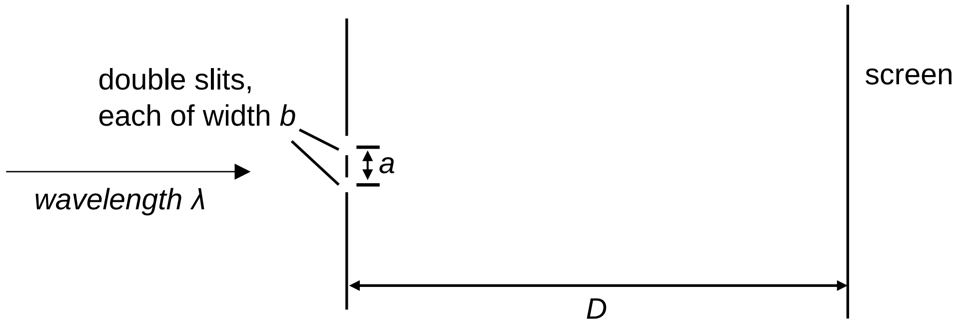

Fig. 9.3

(i) Using the variables defined above, state the two necessary inequality conditions for the set-up such that the detected fringes are regularly spaced.

1. ………………………………………………………………………………………..

2. ……………………………………………………………………………………….. [2]

(ii) Write down the expression for the fringe separation *x* using some of the variables defined above.

………………………………………………………………………………………………... [1]

(iii) Fig. 9.4 shows the variation of the intensity of light on a screen at positions around the zeroth order maxima for a particular experiment. The units are arbitrary.

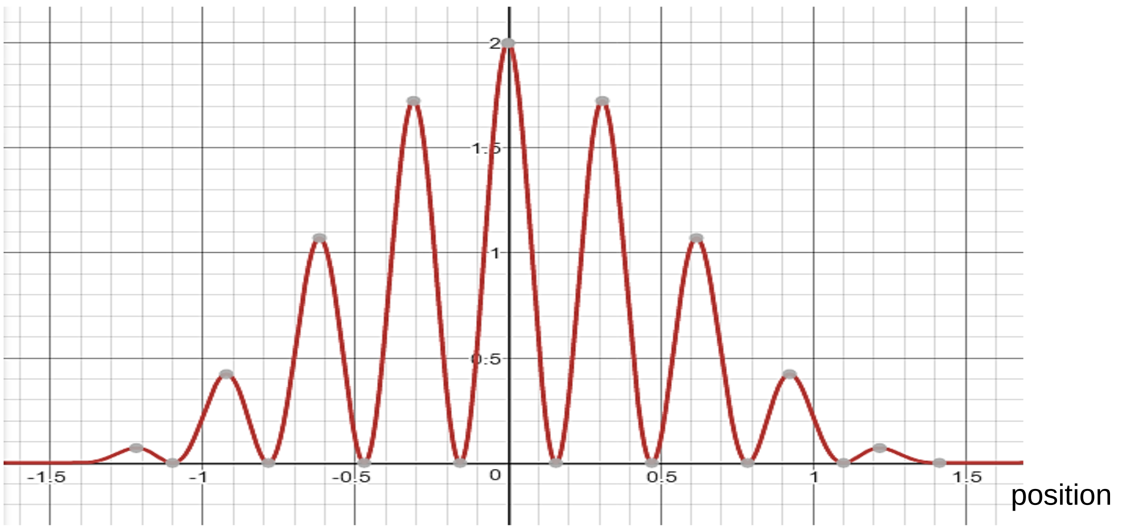

Fig. 9.4

1. Suggest why there is no 5th order maxima detected.

……………………………………………………………………………………….

………………………………………………………………………………………. [1]

2. Sketch in Fig. 9.4 the new pattern that will be detected when the slit width *b* is reduced. [2]

[Total: 20]

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10 (a) Define electric field strength.

....

.... [1]

(b) Fig. 10.1 shows two very small charged spheres S and T. Their centres are separated by a horizontal distance of 30.0 cm. Sphere S carries a charge of -2.4 μC, while sphere T carries a charge of 1.2 μC.

Fig. 10.1

(i) On Fig. 10.1, draw field lines to show the electric field pattern between the two spheres. [3]

(ii) **1.** Given that the mass of sphere T is 0.036 kg, calculate the angle the string makes with the vertical.

angle = ………………….. ° [3]

2. Determine the magnitude of the acceleration of the sphere the moment the string is cut.

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

(iii) Fig. 10.2 shows how the electric field strength varies in a portion of the space between the spheres. x = 0 represents the centre of sphere S.

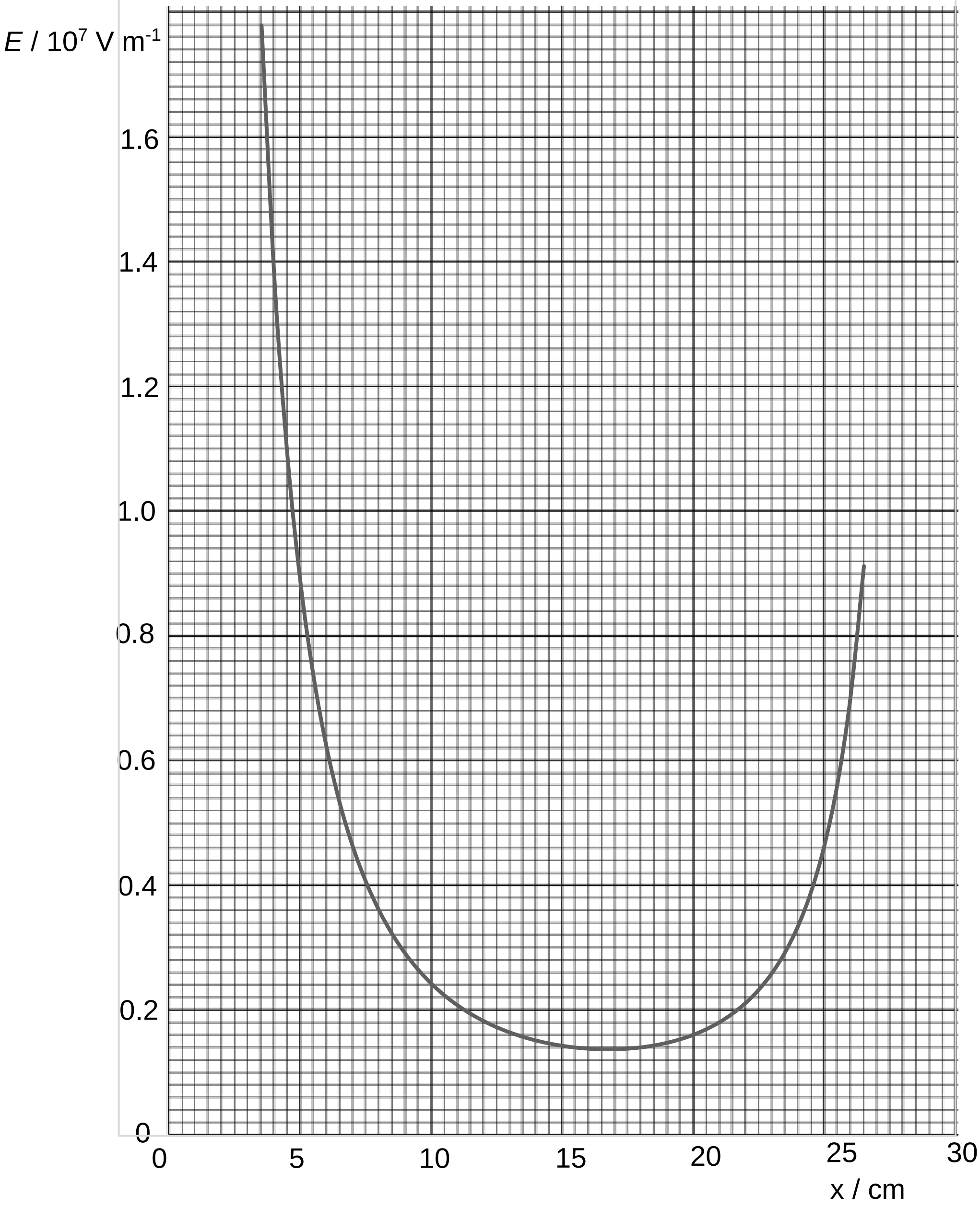


Fig. 10.2

If a helium nucleus is released from rest at x = 25 cm, determine its kinetic energy when it reaches x = 15 cm.

kinetic energy = ………………………….. J [4]

(c) A uniform electric field is set up between two parallel plates of length 90 mm and spaced 20 mm apart. A potential difference of 150 V is applied between the plates.

A singly-charged lithium ion ($^{7}Li^{+}$) of mass 6.941u is projected horizontally into the electric field with a speed of 3.0×10^{5} m s^{-1}.

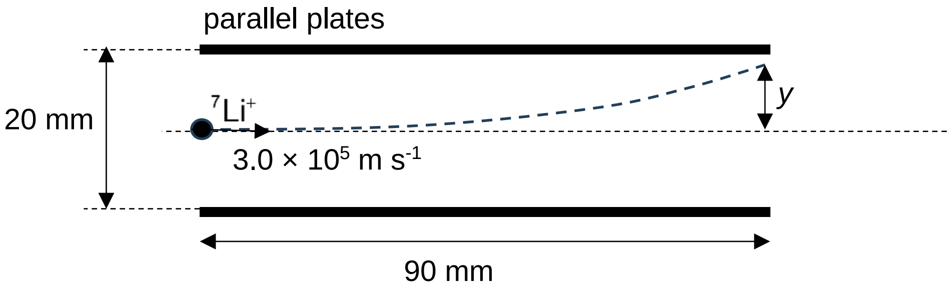


Fig. 10.3

(i) Show quantitatively that the weight of the lithium ion is negligible compared to the electric force it experiences.

[3]

(ii) Calculate the deflection y of the lithium ion as it exits the plates.

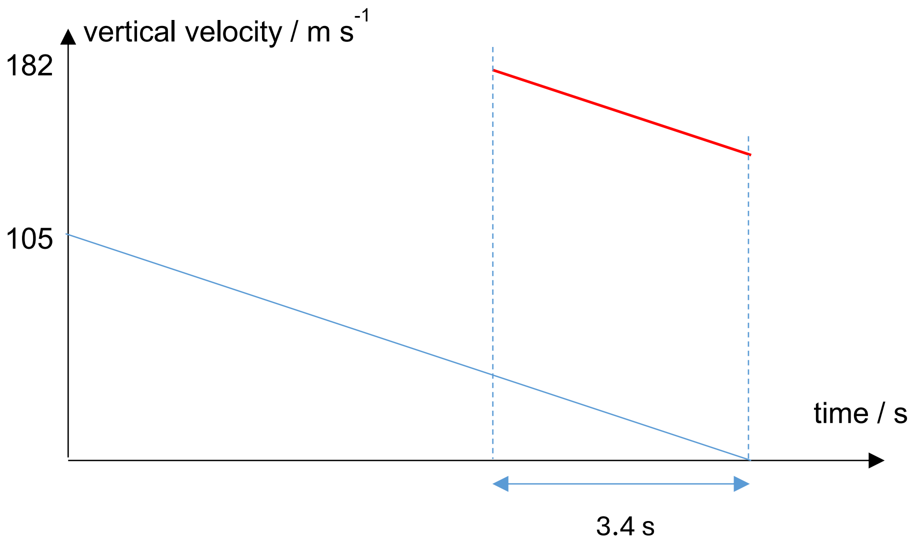
y = …………………………………. mm [3]

[Total: 20]

End of Paper

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) $(\frac{\text{kg}}{\text{m}^3})(\text{m}^2)^p(\text{m s}^{-1})^q = \text{kg m}^{-3+2p+q}s^{-q}$ 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**

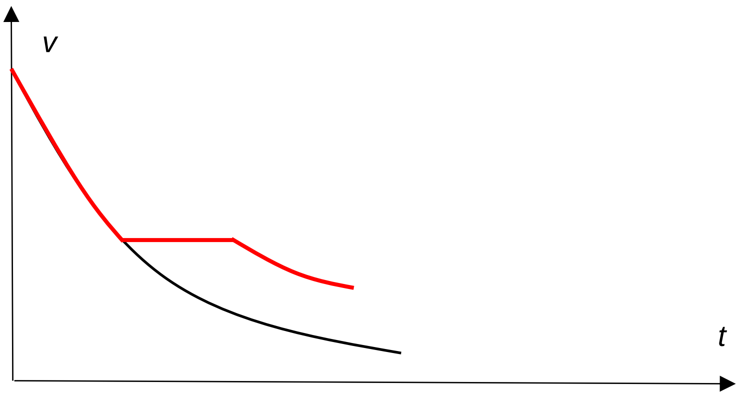
Q2		
(a)	The **acceleration** of an object is its **rate of change of velocity** with respect to time.	**A1**
(b)(i)	Taking upward to be positive and using $v_y^2 = u_y^2 + 2a_y s_y$, where v_y is the vertical component of the final velocity, u_y is the vertical component of the initial velocity, a_y 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 (30º))^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 (30º)) + (-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 (60º))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**. 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** **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 Weight of cup $= V\rho_{cup}\,g$ $= (6.8 \times 10^{-5}) \times (2200) \times (9.81)$ $= 1.4676$ N 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	 **M1** **M1** **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. or The **difference in pressure between the upper and lower surface remains the same** and therefore the upthrust stays constant.	**B1** **B1**
(b)	Pressure of compressed air = pressure at depth d = (atmospheric pressure) + (hydrostatic pressure) $= p_{atm} + \rho\,g\,d$ $= (1.0 \times 10^5) + (1000) \times (9.81) \times (0.30)$ $= 1.02943 \times 10^5$ Pa Applying $p\,V$ = constant, since temperature is unchanged, $(1.0 \times 10^5)\,(5.50 \times 10^{-4}) = (1.02943 \times 10^5)\,V$ $V = 5.3429 \times 10^{-4}\ \mathrm{m^3}$ $= 5.3 \times 10^{-4}\ \mathrm{m^3}$	 **B1** **M1** **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

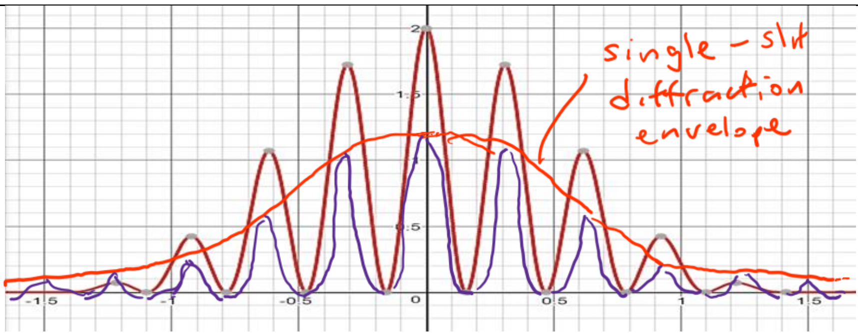
Q6		
(a)(i)	The resistance is infinite.	**B1**
(a)(ii)	The resistance decreases as *V* increases.	**B1**
(b)(i)	Method 1: When the galvanometer reads zero, $V_{XZ} = V_{LDR} = \frac{R_{LDR}}{R_{LDR} + R} E = \frac{1600}{1600 + 1200}(9.0) = 5.143 \text{ V}$ For the wire, $\frac{V_{XZ}}{V_{XY}} = \frac{L_{XZ}}{L_{YZ}} \quad \Rightarrow L_{XZ} = \frac{V_{XZ}}{V_{XY}} L_{YZ} = \frac{5.143}{9.0}(1.2) = 0.6857$ $= 0.69 \text{ m}$ Method 2: $\frac{V_{XZ}}{V_{ZY}} = \frac{V_R}{V_{LDR}} \Rightarrow \frac{kL_{XZ}}{kL_{ZY}} = \frac{I \times 1600}{I \times 1200} = \frac{4}{3}$ $L_{XZ} = \frac{4}{7} \times 1.2$ $= 0.69 \text{ m}$	**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 $= \frac{1}{4}\lambda$ $= \frac{1}{4}(c/f)$ $= \frac{1}{4}(3.00 \times 10^{8} / 25.0 \times 10^{6})$ = 3.00 m M1 – relating MN to $\lambda/4$ M1 – for finding λ using $c=f\lambda$ Alternative: Let the distance moved be x so that the path difference increased by half a wavelength. $(AN - BN) = \frac{1}{2}\lambda$ $(6.00 + x) - (6.00 - x) = (0.5)(3.00 \times 10^{8} / 25.0 \times 10^{6})$ 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, $I = \dfrac{\text{Power from source}}{4\pi r^2}$ (As power from sources are equal and constant), Hence $I \propto \dfrac{1}{r^2}$ $\dfrac{I_A}{I} = (\dfrac{6.00}{9.00})^2$ $I_A = 0.4444I$ = 0.444 I (shown) $\dfrac{I_B}{I} = (\dfrac{6.00}{3.00})^2$ 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. $\dfrac{0.444I}{I} = (\dfrac{A_A}{0.5})^2$ A_A = 0.333 units $\dfrac{4I}{I} = (\dfrac{A_B}{0.5})^2$ 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)	$x = \dfrac{\lambda D}{a}$ (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)** • **5th order maxima** should be **visible** (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.	**A1** **A1**

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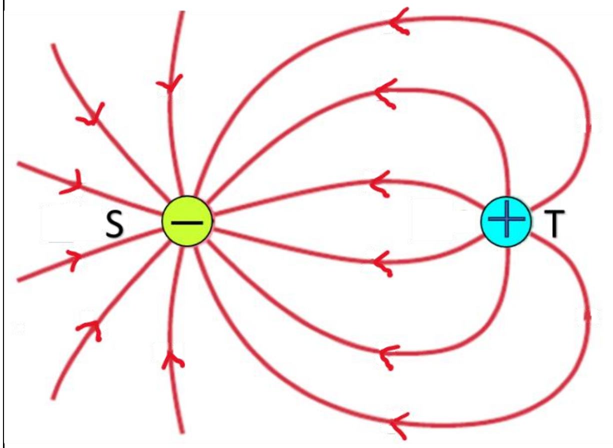
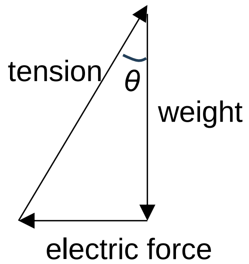
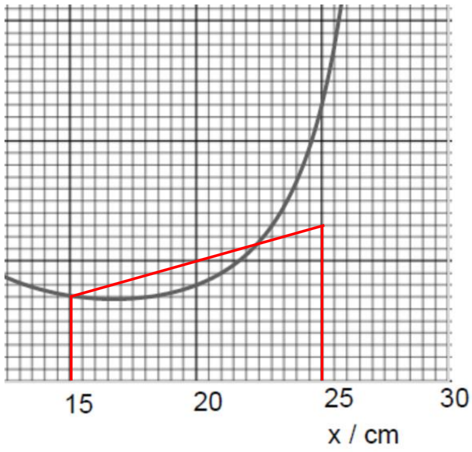
Q10		
(a)	Electric field strength at a point is the **electric force per unit positive charge** on a small test charge placed at the point.	**B1**
(b)(i)	 Correct direction. Correct ratio of lines (2:1). Correct asymmetry.	**B1** **B1** **B1**
(b)(ii)1	Consider the force-diagram of sphere T. The electric 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. $\Delta V = \frac{1}{2}(0.10)\left[(0.14+0.26)\times10^{7}\right]$ $= 2.0\times10^{5}$ V (accept +/- 10%)  From 25 cm to 15 cm, the positive helium nucleus loses potential energy and gains kinetic energy. Gain in KE = $q\Delta V = 2(1.60\times10^{-19})(2.0\times10^{5}) = 6.4\times10^{-14}$ J	**B1** **M1** **M1** **A1**
(c)(i)	Weight of lithium ion = $mg = 6.941\times1.66\times10^{-27}\times9.81 = 1.13\times10^{-25}$ N Electric force on ion = $qE = 1.60\times10^{-19}\times\left(\frac{150}{0.020}\right) = 1.2\times10^{-15}$ 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 = $\frac{0.090}{3.0\times10^{5}} = 3.0\times10^{-7}$ s Applying $s = ut + \frac{1}{2}at^{2}$ in the vertical direction, $y = \frac{1}{2}\left(\frac{1.2\times10^{-15}}{6.941\times1.66\times10^{-27}}\right)(3.0\times10^{-7})^{2}$ y = 4.7 mm	**M1** **M1** **A1**

HWA CHONG INSTITUTION
C2 Preliminary Examination
Higher 2

A

CANDIDATE NAME		**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.

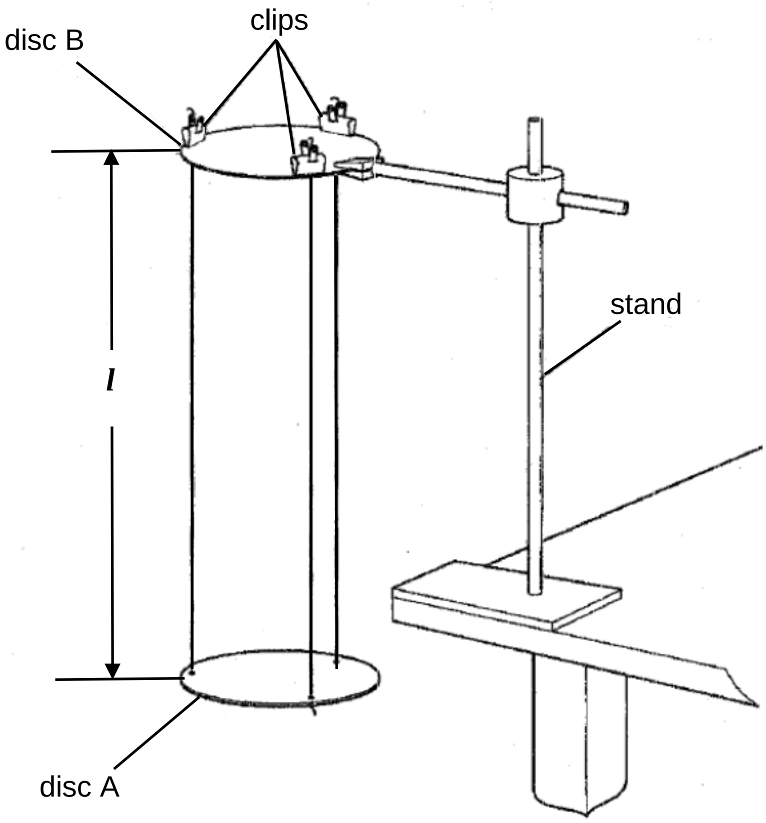

Fig. 1.1

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.

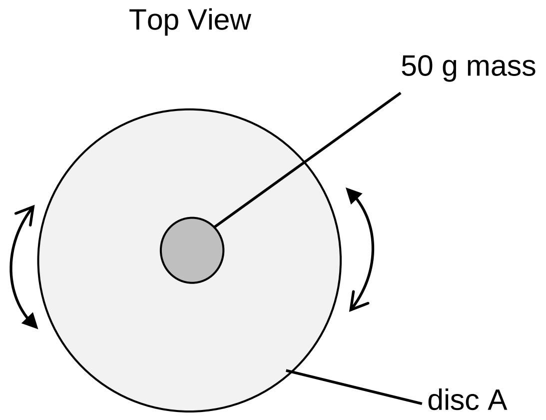

Fig. 1.2

Determine and record *T*.

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.

[4]

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(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.

k = ...

n = ...
[6]

[Total: 12]

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

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

The length of the rubber band is L_0.

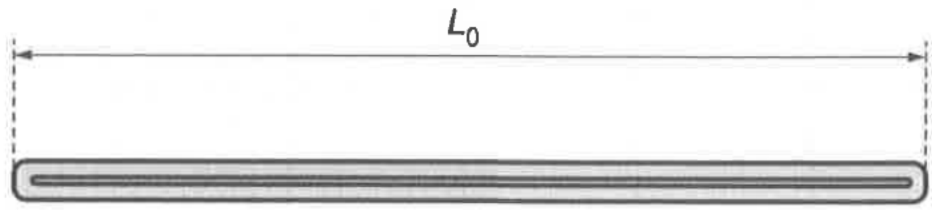


Fig. 2.1

Measure and record L_0 for your rubber band.

L_0 = ... [1]

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

V = ... [1]

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

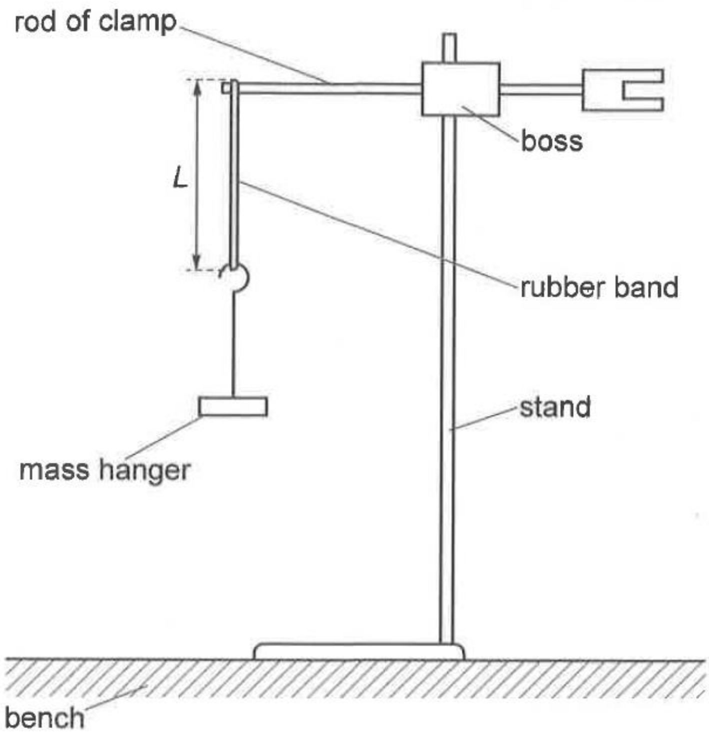


Fig. 2.2

The extended length of the rubber band is L.

Calculate the extension e of the rubber band where:

$$e = L - L_0.$$

Record your answer in metres.

e = ... m

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

$$F = mg$$

Where m is the mass, in kg, suspended from the rubber band and g = 9.81 N kg^{-1}.

Calculate and record F.

F = ... N

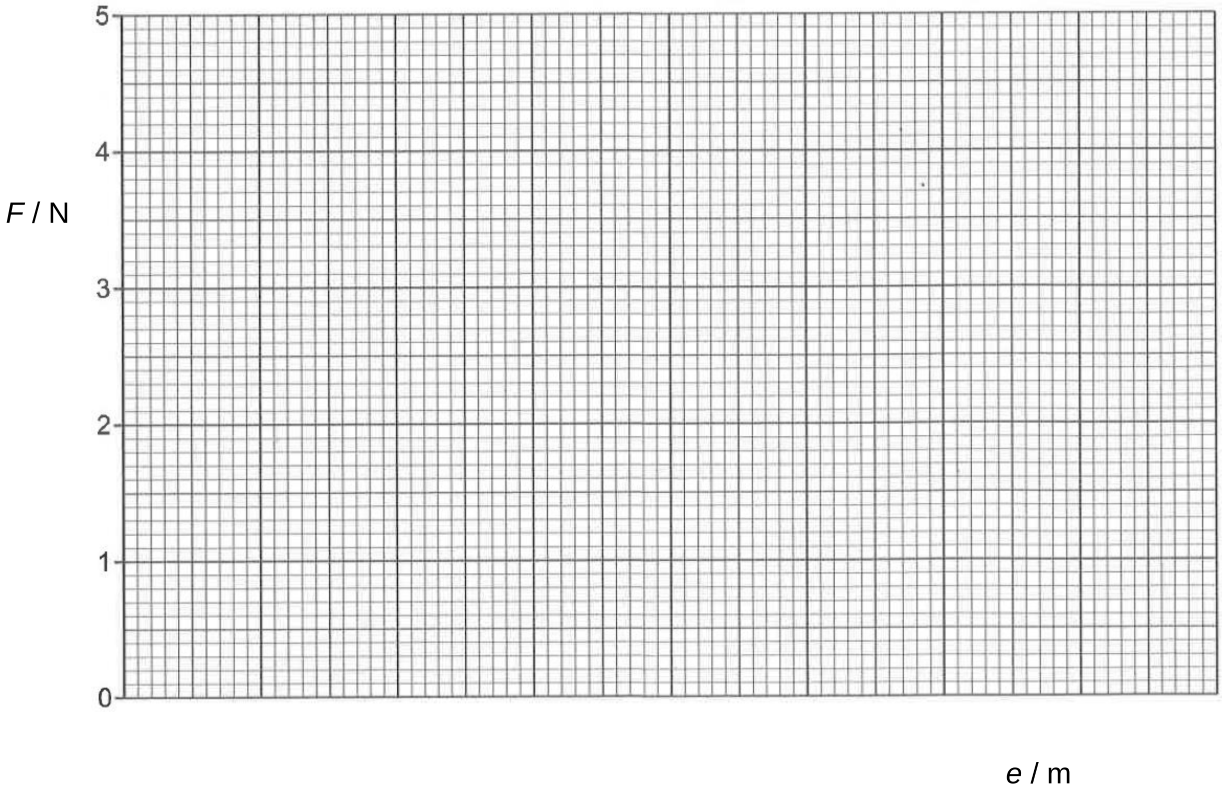
[1]

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

Present your results clearly.

[3]

(iii) Plot your results on the grid below.



[1]

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

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

energy stored = ... J [1]

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

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

[Total: 9]

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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.

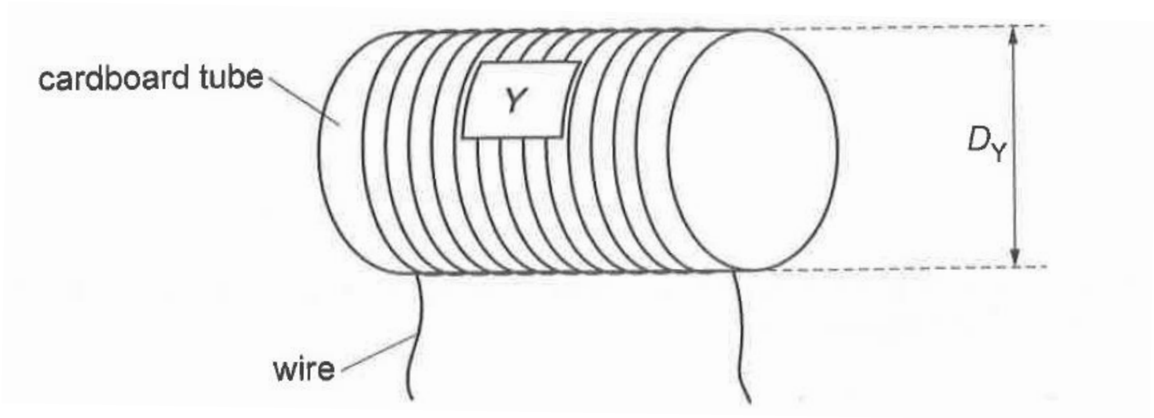

Fig. 3.1

Measure and record D_Y and d_Y.

D_Y = ………………………………………….... cm

d_Y = …………………………………………… mm
[2]

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

Estimate and record your value for L_Y.

Show your working.

L_Y = ……………………………………………….... cm [2]

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

percentage uncertainty in L_Y = ... [1]

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

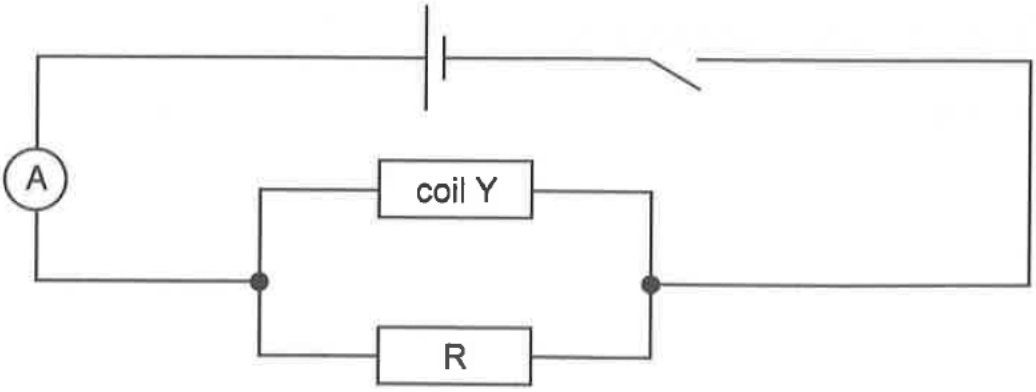

Fig. 3.2

Close the switch.

Note and record R and the ammeter reading I.

R = ... Ω

I = ... A

[1]

Open the switch.

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

Present your results clearly.

[3]

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

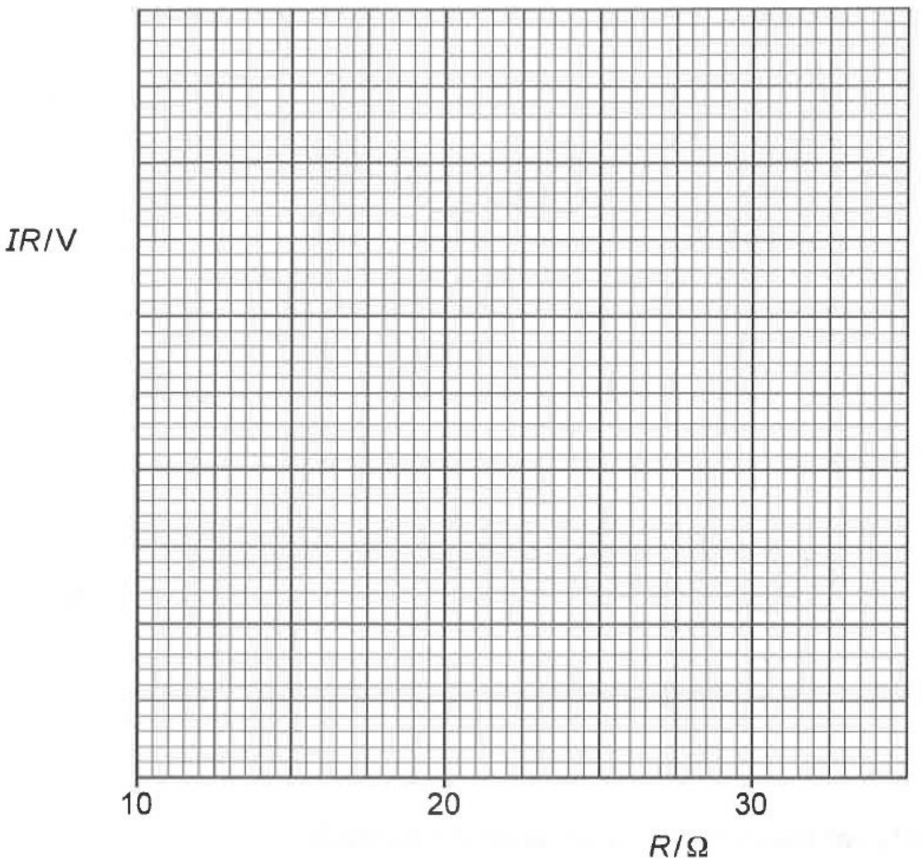

Fig. 3.3

I and R are related by the expression:

$$IR = GR + H$$

where G and H are constants.

The resistance X_Y of coil Y is given by:

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

Use your graph to determine X_Y.

X_Y = ... Ω [3]

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

(i) Measure and record D_Z and d_Z.

D_Z = ………………………………………….... cm

d_Z = ………………………………………….... mm

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

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

Calculate L_Z.

L_Z = ………………………………………….... cm
[1]

(ii) The resistance of coil Z is X_Z.

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

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

X_Z = ………………………………………….... Ω
[2]

(iii) Use a digital multimeter to measure X_Z.

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

difference ……………………………………………………………………………………..

reason ………………………………………………………………………………………

………………………………………………………………………………………………
[1]

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

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

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

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

first value of k = ...

second value of k = ...
[1]

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

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

....

....

....

....

.... [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.

....

....

....

....

.... [1]

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

....

....

....

....

....

....

....

....

....

....

....[3]

[Total: 22]

HWA CHONG INSTITUTION
C2 Preliminary Examination
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

....

....

....

....

....

[Total: 12]

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.

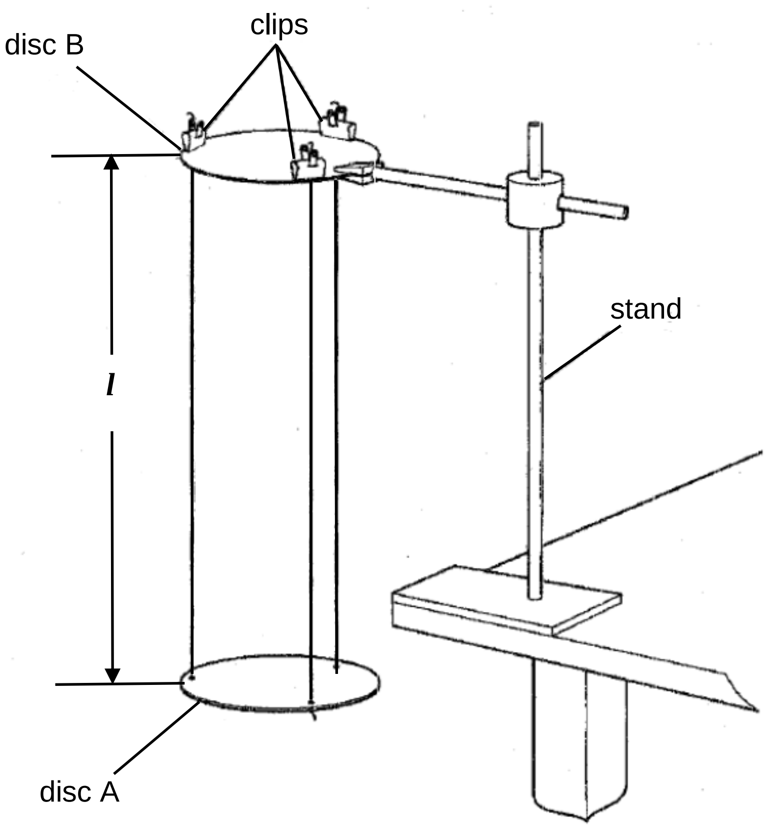


Fig. 1.1

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.

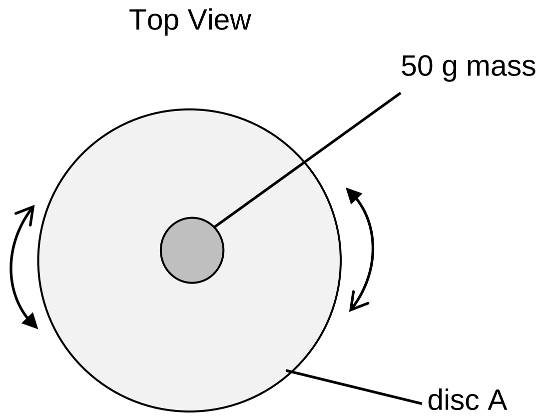


Fig. 1.2

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.

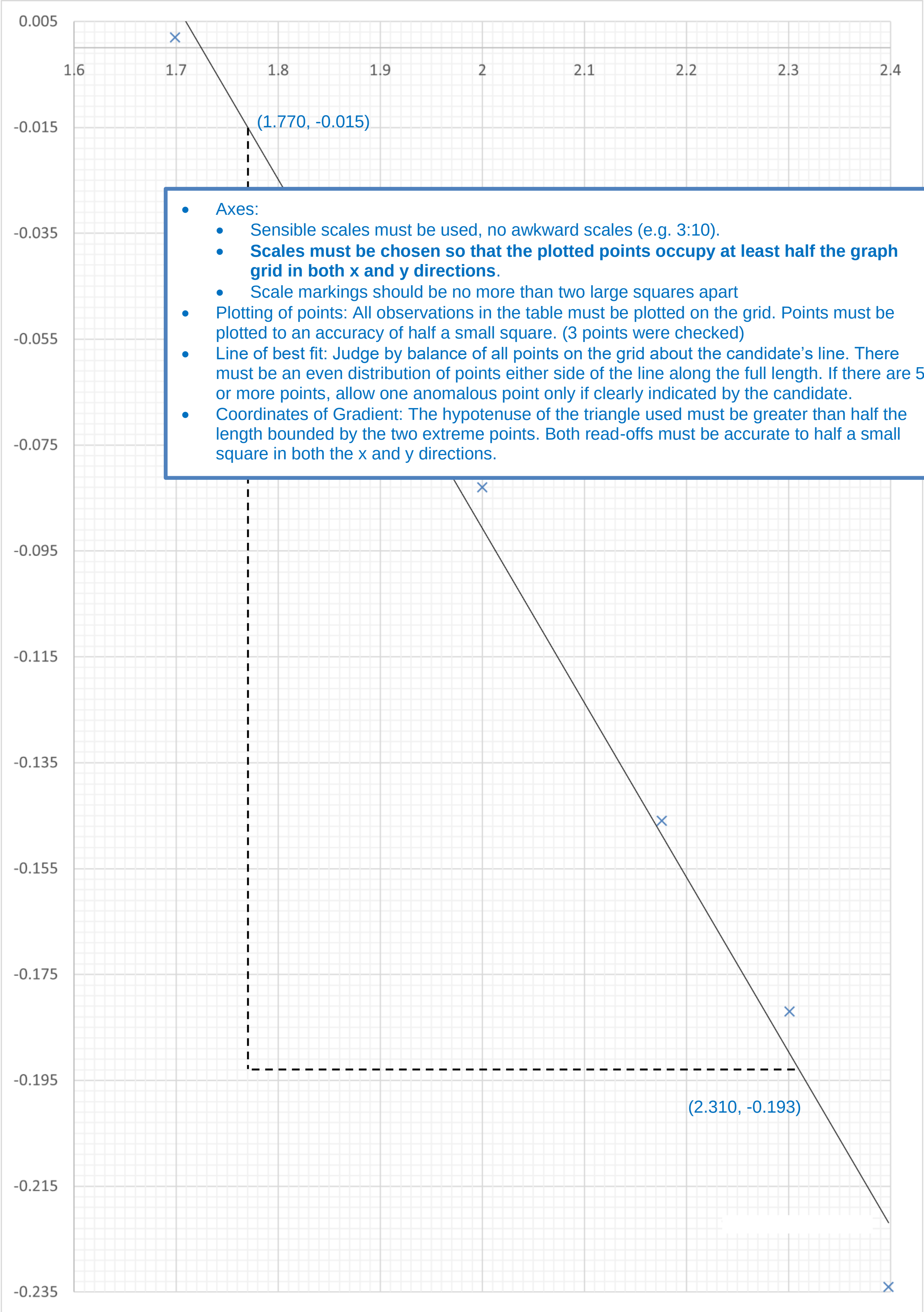
Since lg T = n lg m + lg k
By plotting a graph of lg T vs lg m, a straight line graph should be obtained with gradient = n and y-intercept = lg k

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.

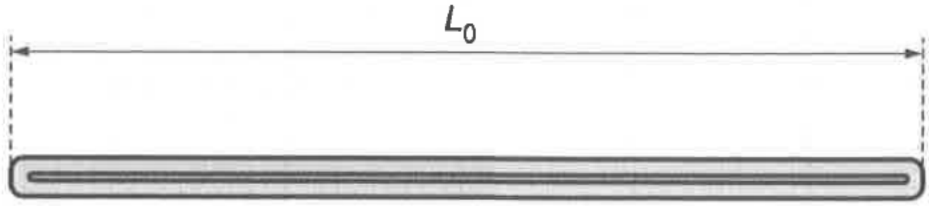


Fig. 2.1

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 x L_0 x w x 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.

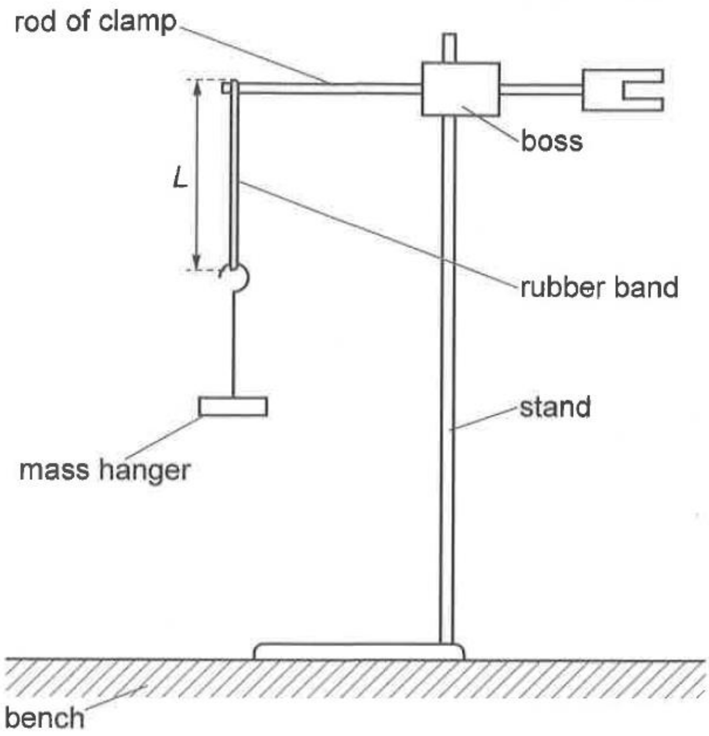


Fig. 2.2

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 $g = 9.81\ \text{N kg}^{-1}$.

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 = ...$F = 0.100 \times 9.81 = 0.981$ N........ N

[1]

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

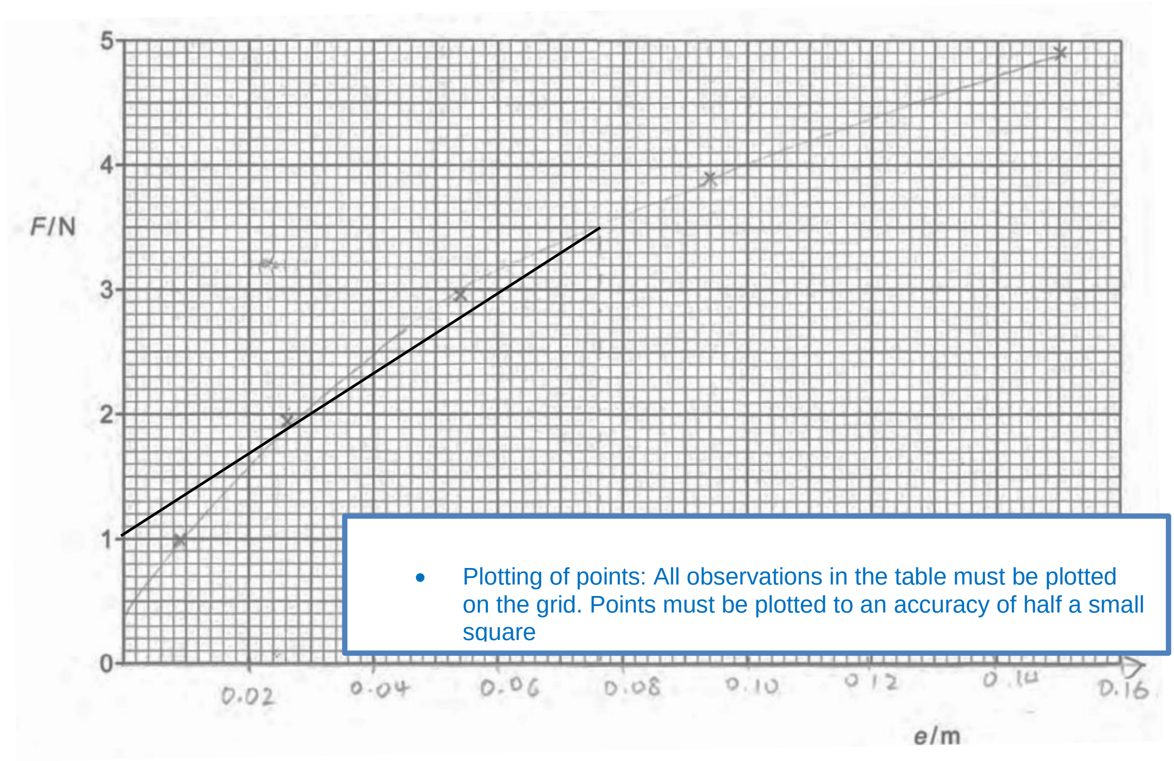
Present your results clearly.

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

= $0.095 / 3.4 \times 10^{-7}$

= $2.8 \times 10^{5}\ \text{J m}^{-3}$

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.

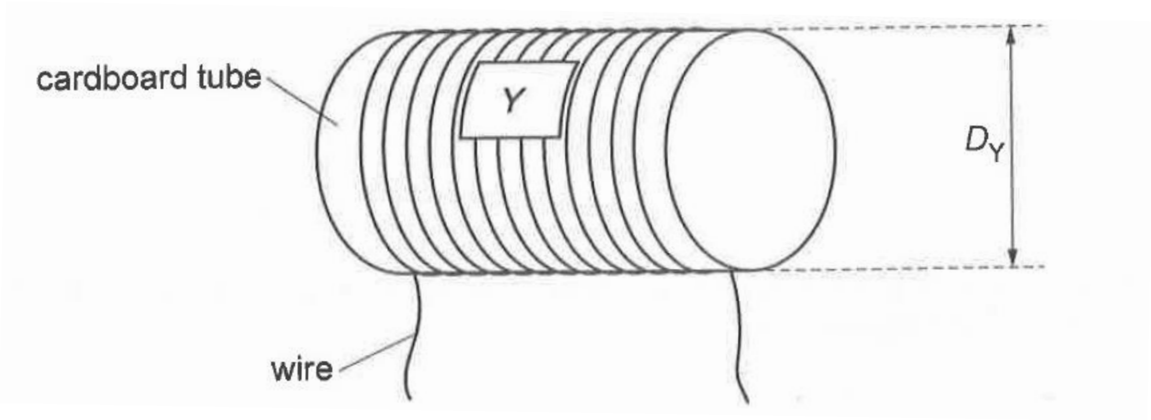


Fig. 3.1

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
- $180 \text{ cm} \le L_Y \le 220 \text{ cm}$
- 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.

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

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

- $1\% < (\Delta Ly/Ly) \times 100\% \le 10\%$
- 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.

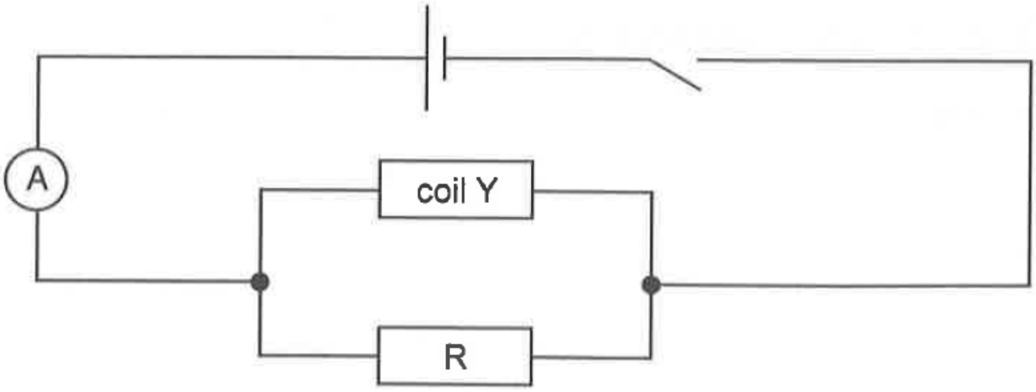


Fig. 3.2

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)**.

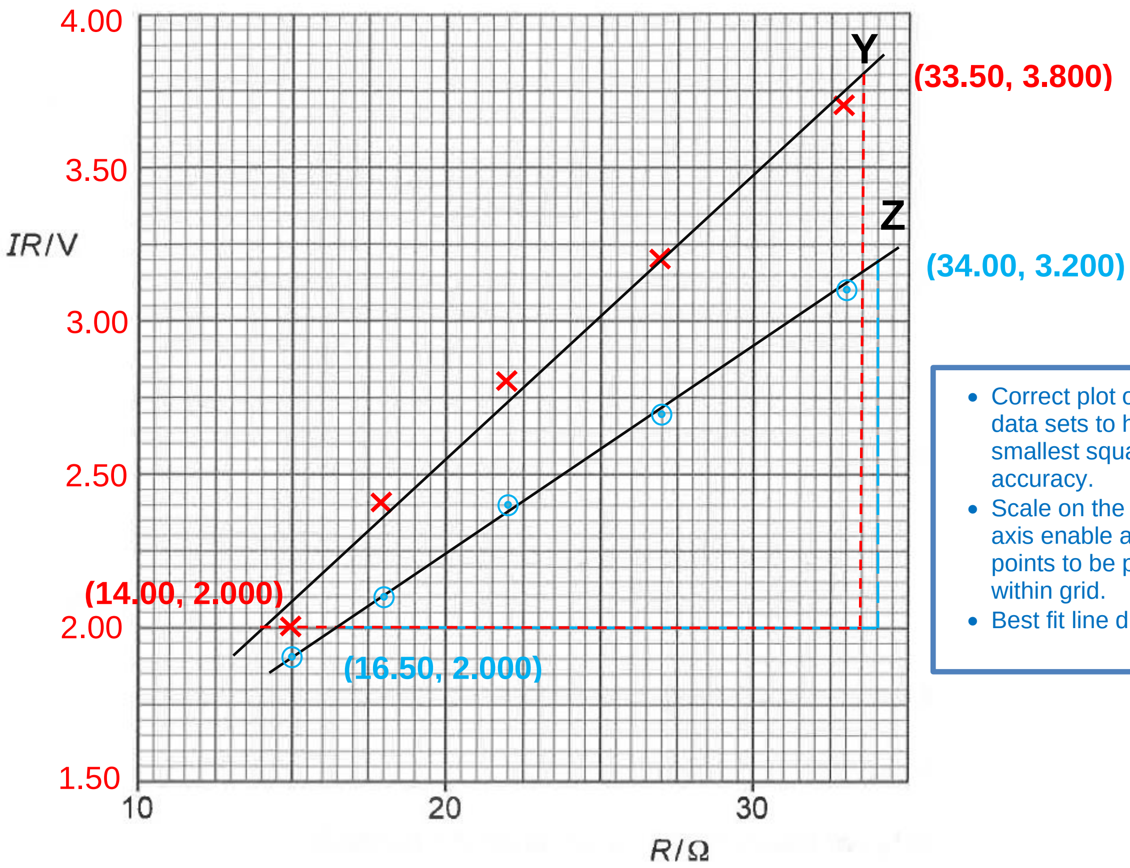
(d) Present your results clearly.

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 = 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 D_Y
- 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

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

<u>Plot of line Z on Fig. 3.3</u>

- 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)**.

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

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.

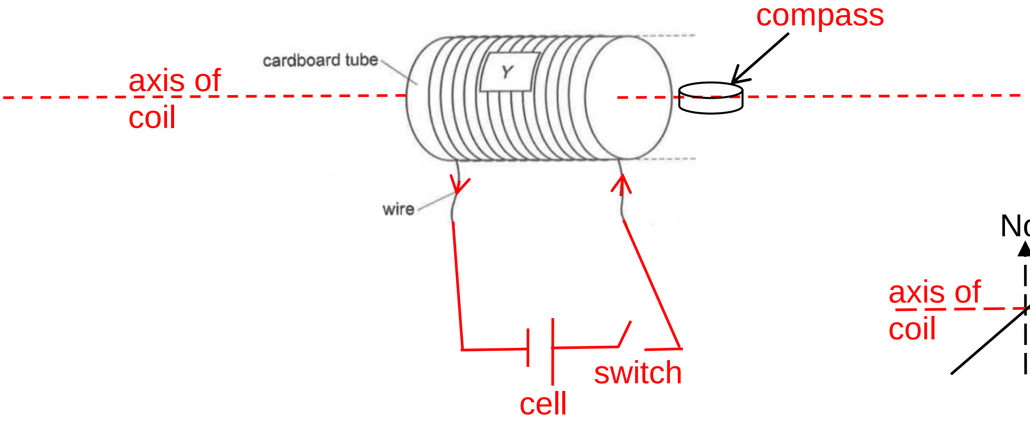
$n_Y > n_Z$, and since $X_Z > X_Y$, $I_Y > I_Z$. Hence the magnetic flux density at the end of tube Y is greater.

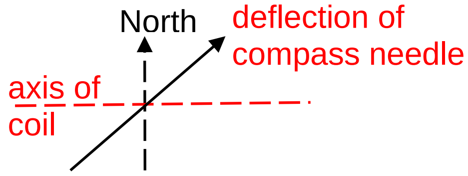
- Tube Y produces a greater magnetic flux density
- Tube Y has a greater number of coil per unit length (n)
- Tube Y has a higher current flow (I) through it

[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
C2 Preliminary Examination
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

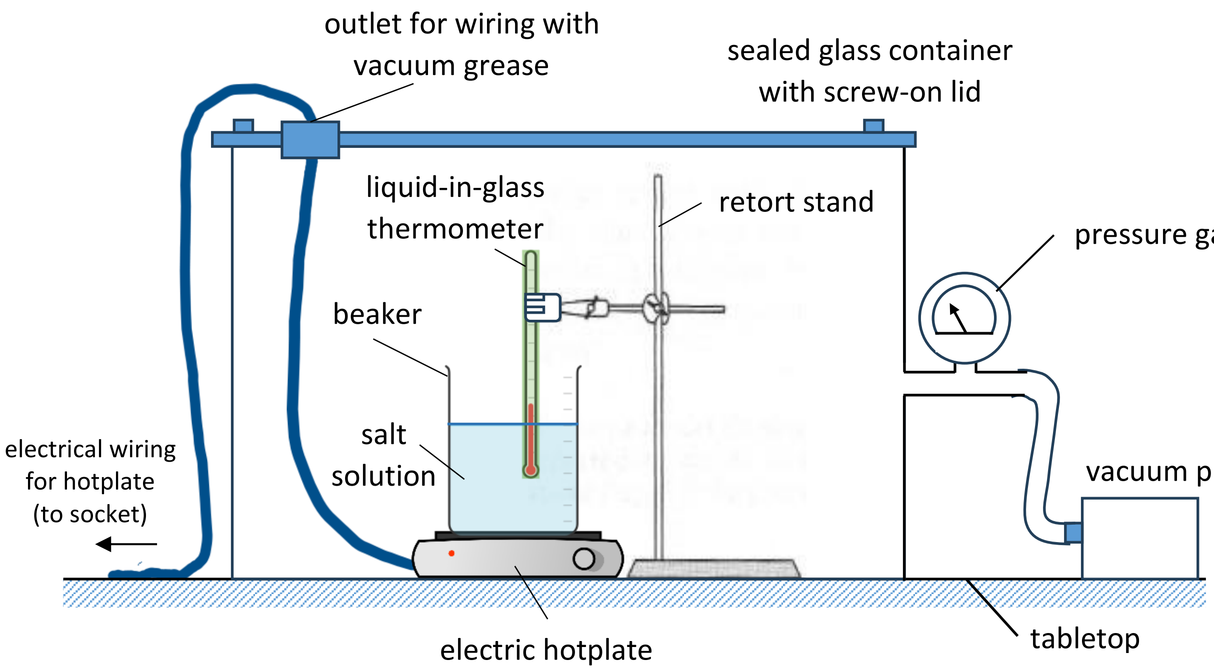


Fig. 1

<u>Aim:</u> 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: <u>Keep P constant, vary σ and determine θ</u>

- *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: <u>Keep σ constant, vary P and determine θ</u>

- *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.*

<u>Apparatus and Method to Measure the Various Quantities:</u>

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.*