**HWA CHONG INSTITUTION**
**JC2 Preliminary Examination**
**Higher 2**

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|---|---|---|---|
| **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,
$c = 3.00 \times 10^{8}\,\text{m s}^{-1}$

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

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

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 | $s = ut + \frac{1}{2}at^2$ <br> $v^2 = u^2 + 2as$ |
| 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 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. | $v = v_0 \cos \omega t$ <br> $= \pm\omega\sqrt{(x_0^2 - x^2)}$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current / voltage | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

## 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.

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.......................................................................................................... [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 $\rho$ 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.

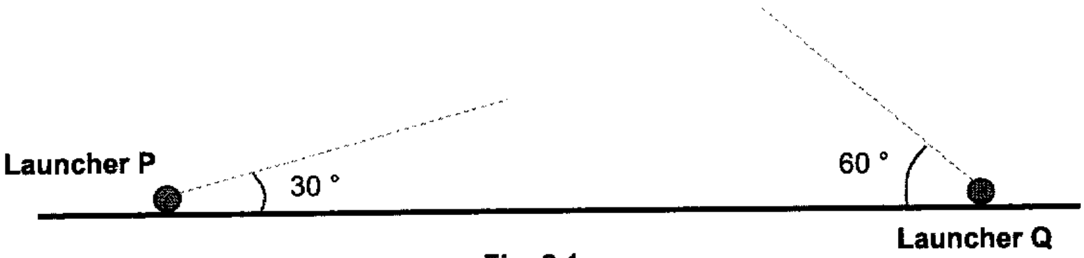


Fig. 2.1

(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° 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.

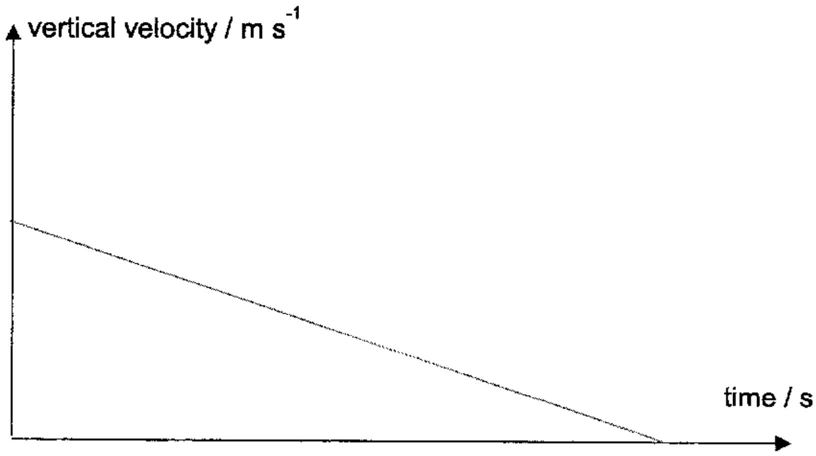


**Fig. 2.2**

[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 x 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*.

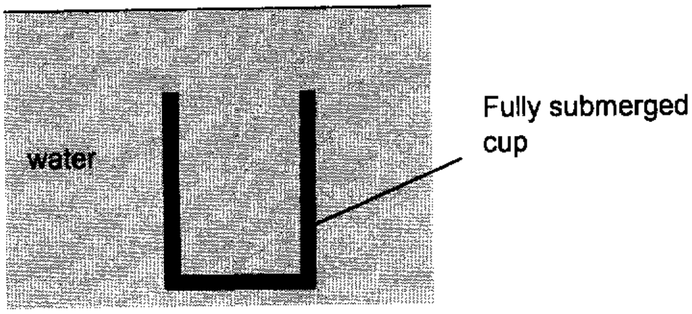


**Fig. 3.1**

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

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**(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.

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.......................................................................................................................... [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, $5.50 \times 10^{-4}$ m$^3$ of air is contained within the cup at atmospheric pressure of $1.0 \times 10^5$ 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.

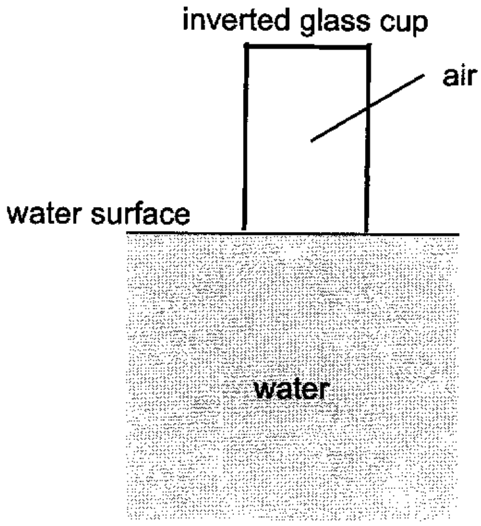


**Fig. 3.2**

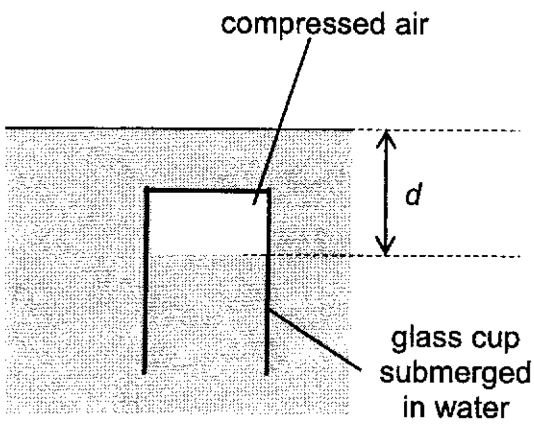


**Fig. 3.3**

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 $\rho$, as shown in Fig. 4.1. Ignoring its rounded bottom, the test-tube may be regarded as a cylinder of a cross-sectional area $A$.

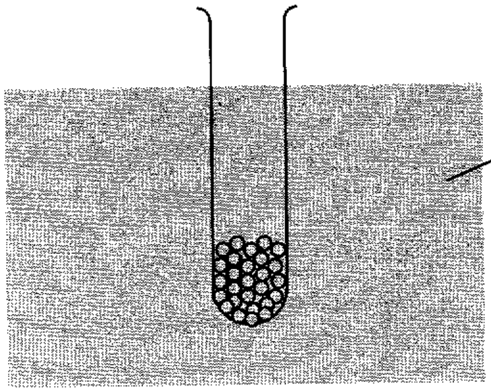


**Fig. 4.1**

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.

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

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

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

$M = 0.037$ 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.

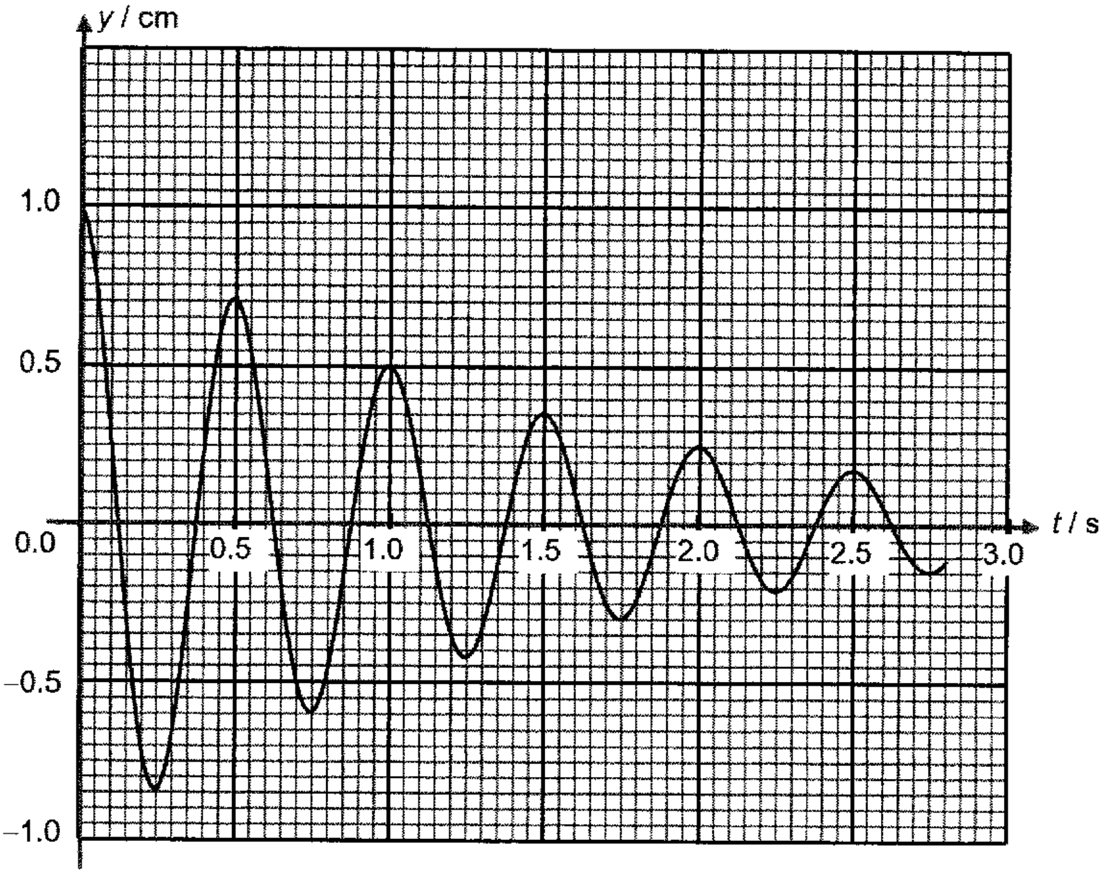


**Fig. 4.2**

(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.

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[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 $1.0 \times 10^5$ Pa is $2.3 \times 10^6$ 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.

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[Total: 9]

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

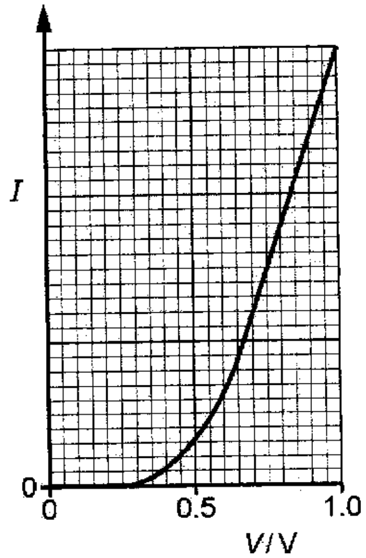


**Fig. 6.1**

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.

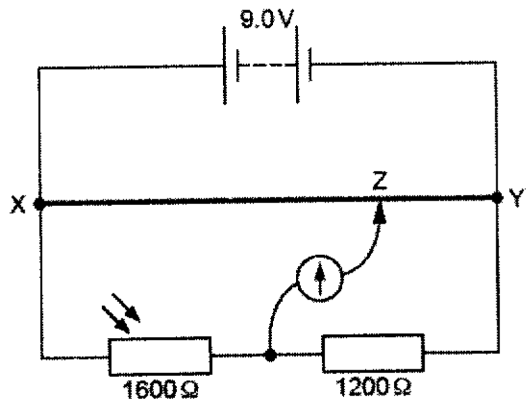


**Fig. 6.2**

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.

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**2.** the total power supplied by the battery.

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.......................................................................................... [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.

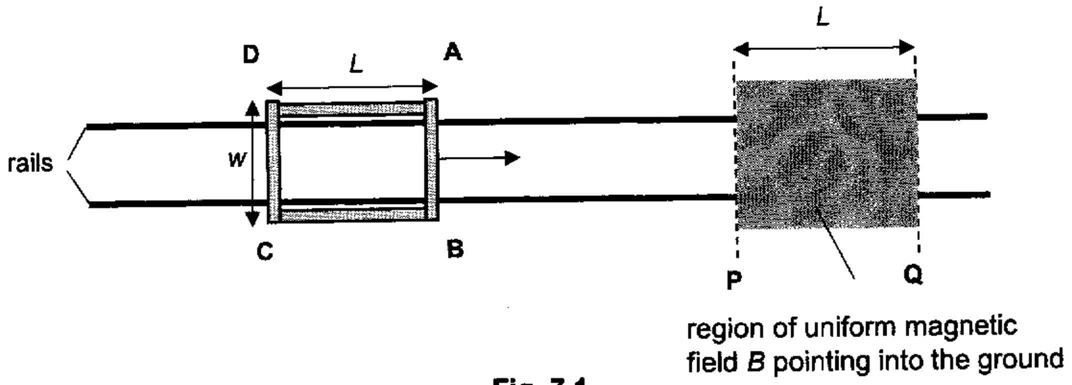


**Fig. 7.1**

**(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.

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**(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.

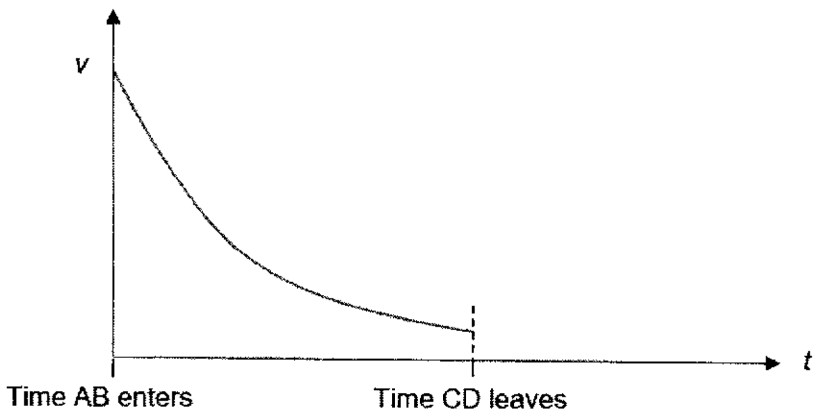


**Fig. 7.2**

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.

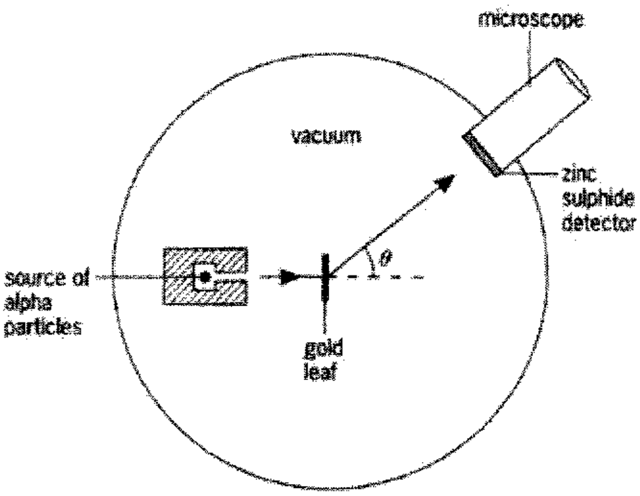


**Fig. 8.1**

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

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

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

1. the nucleus is small,

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2. the nucleus is massive and charged.

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**(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:

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

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

[1]

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

..........................................................................................................

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

**(iii)** In reality, more than $1.9 \times 10^{-13}$ 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.

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.......................................................................................................................... [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.

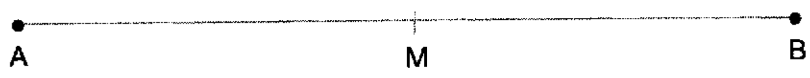


**Fig. 9.1**

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

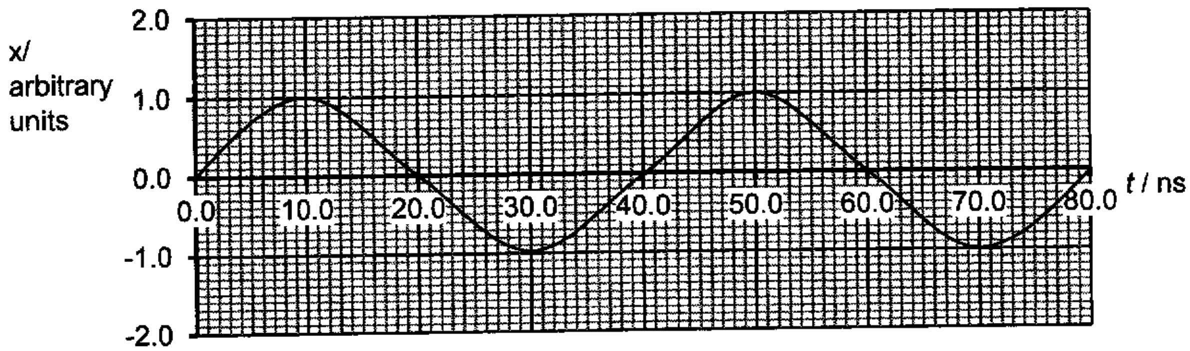


**Fig. 9.2**

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.

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.......................................................................................................... [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 $\lambda$ 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 $x$.

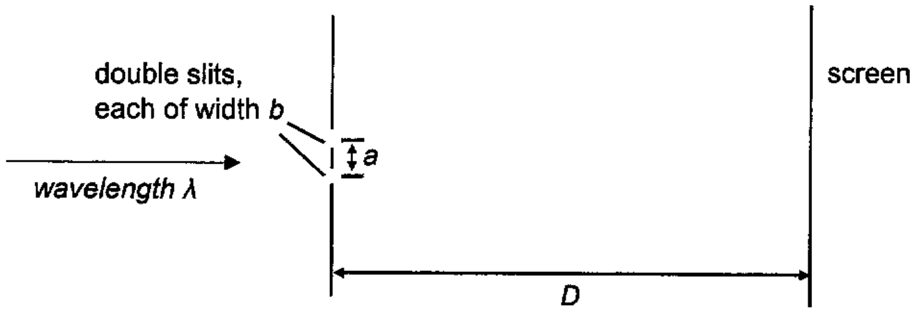


**Fig. 9.3**

**(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.

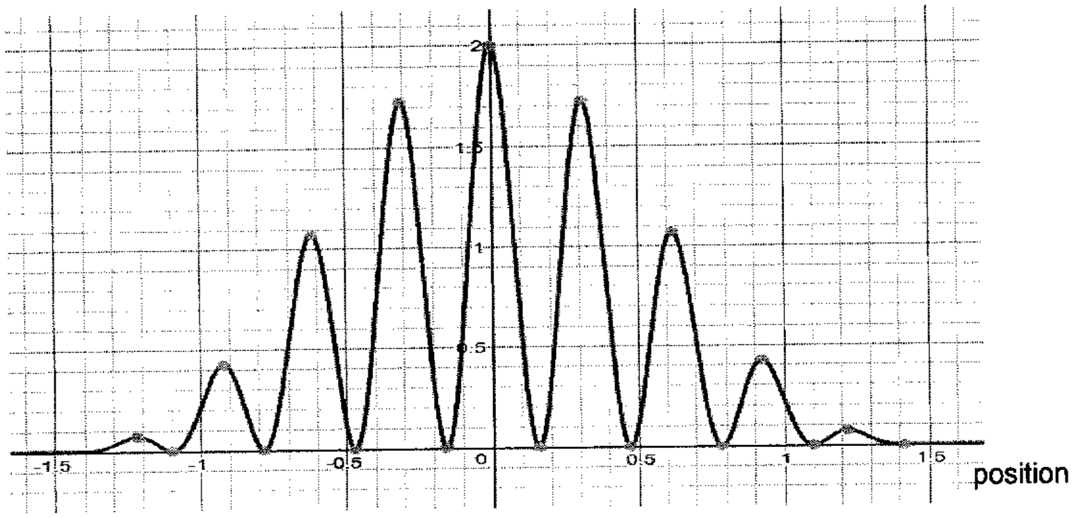


**Fig. 9.4**

**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.

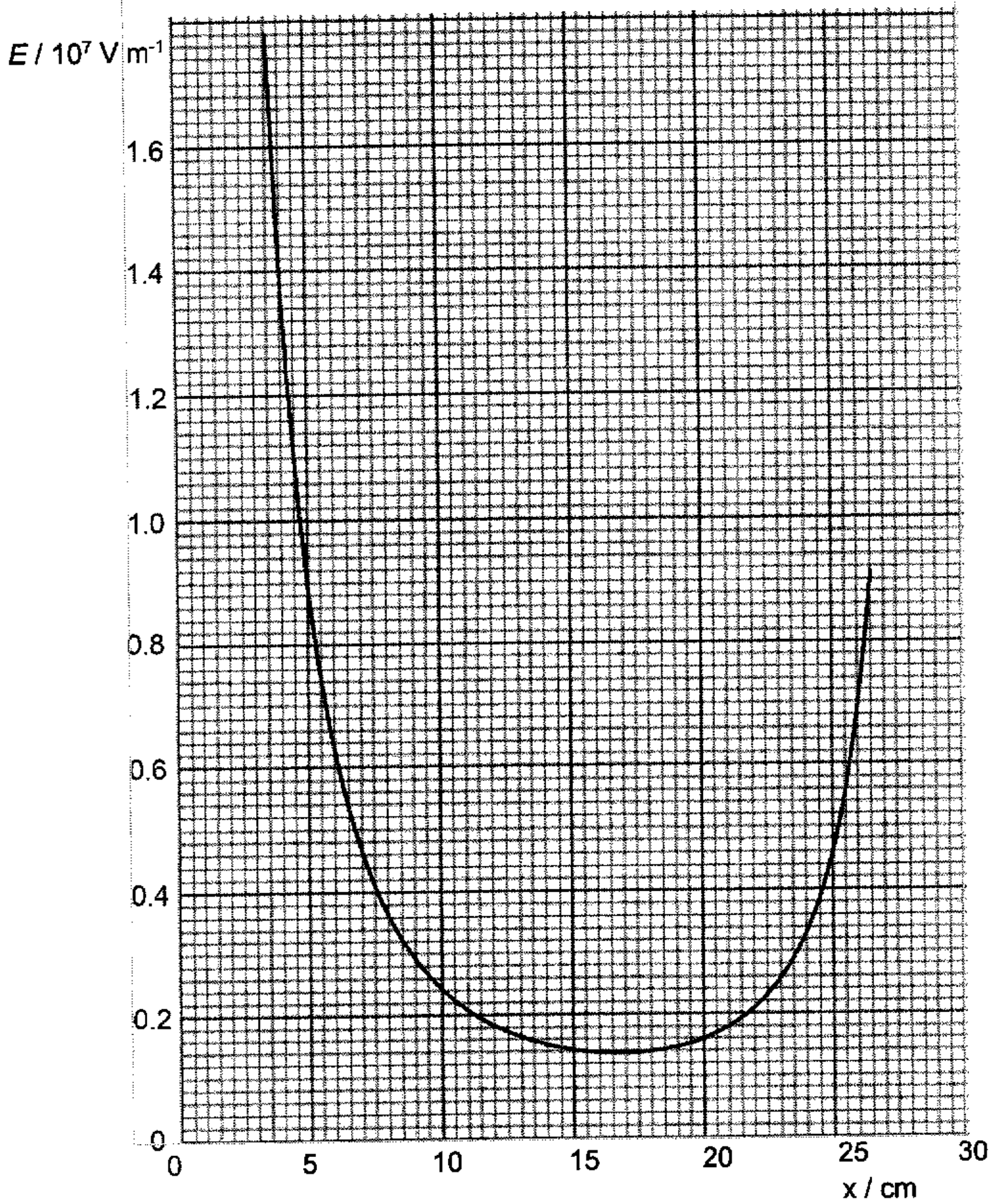



**Fig. 10.2**

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 $3.0 \times 10^{5}$ m s$^{-1}$.

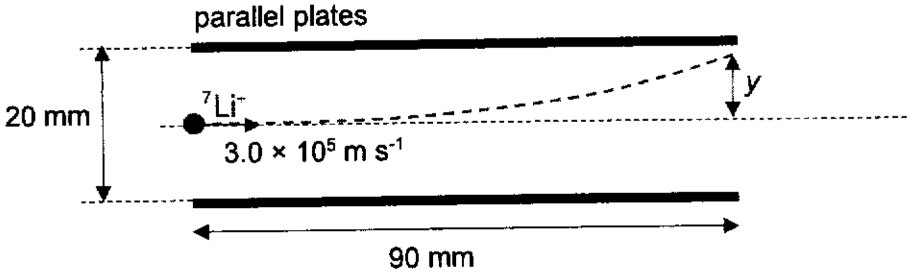



**Fig. 10.3**

**(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.

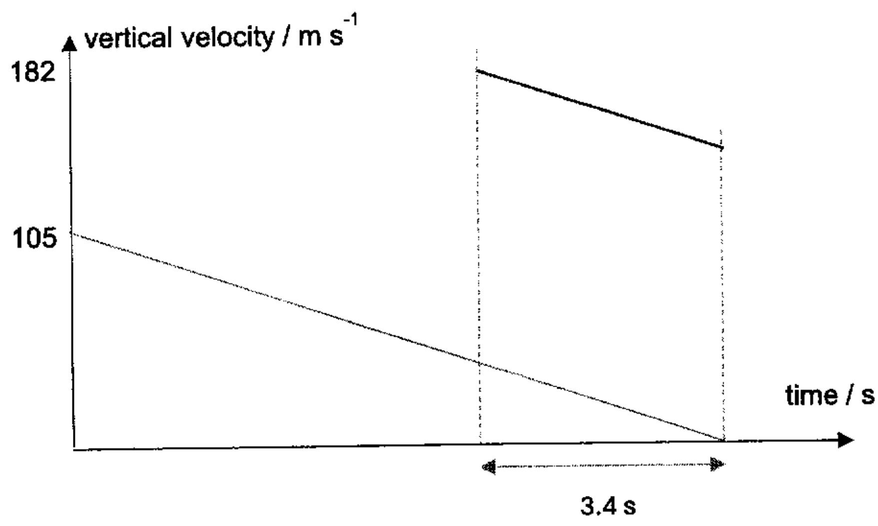
$y$ = ........................................ mm [3]

[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. | B1 |
| | Systematic errors are deviations of the mean value from the true value, with same sign and similar magnitude. | B1 |
| (b) | The units of $P$ are $\frac{(\text{kg m s}^{-2})(\text{m})}{\text{s}}$= kg m$^2$ s$^{-3}$ | M1 |
| | The units of $k\rho A^p v^q$ are (1) $(\frac{\text{kg}}{\text{m}^3})(\text{m}^2)^p(\text{m s}^{-1})^q = \text{kg m}^{-3+2p+q}\text{s}^{-q}$ | M1 |
| | 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:<br>seconds: $-q = -3 \Rightarrow q = 3$<br>metres: $-3 + 2p + q = 2 \Rightarrow p = 1$ | A1 |

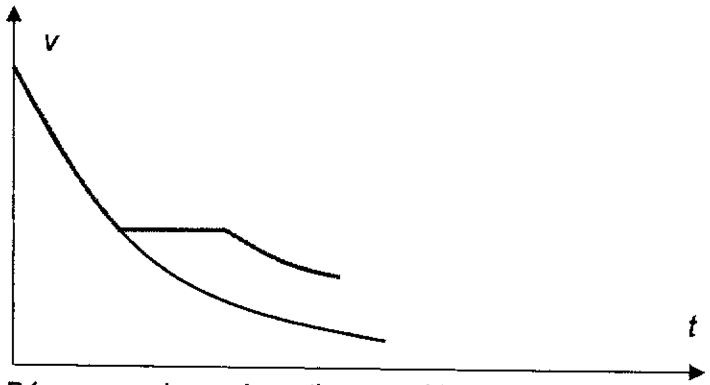
| Q2 | | |
|---|---|---|
| (a) | The **acceleration** of an object is its **rate of change of velocity** with respect to time. | A1 |
| (b)(i) | Taking upward to be positive and using $v_y^2 = u_y^2 + 2a_y s_y$, where<br>$v_y$ is the vertical component of the final velocity,<br>$u_y$ is the vertical component of the initial velocity,<br>$a_y$ is the vertical component of the acceleration and<br>$s_y$ is the vertical component of the displacement.<br>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,<br>$0 = (210 \sin(30°))^2 + 2(-9.81)\,h$<br>$h = 561.9$ m = 560 m (1, 2 or 3 s.f.) | M1<br><br>A1 |
| (b)(ii) | Taking upwards as positive and using $v_y = u_y + a_y t$<br>$0 = (210 \sin(30°)) + (-9.81)\,t$<br>$t = 10.703$ s = 11 s (1, 2 or 3 s.f.) | M1<br>A1 |
| (b)(iii) | From (b)(i), we know that the highest point for P is 561.9 m. Using $s_y = u_y t + \frac{1}{2} a_y t^2$,<br>$561.9 = (210 \sin(60°))t_Q + (0.5)(-9.81)\,t_Q^2$<br>$t = 3.4$ s or $t = 33.7$ s<br>Since $t$ must be less than 10.7 [from part (b)(ii)], $t = 33.7$ s should be rejected.<br>$t = 3.4$ s (shown) | B1<br><br>A0 |
| (b)(ii) | <br>B1 – **parallel to** and **above** original line.<br>(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)<br>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**.<br>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<br>B1 |
| (a)(ii) | Upthrust on cup = weight of water displaced<br>$= V \rho_{water} g$<br>$= (6.8 \times 10^{-5}) \times (1000) \times (9.81) = 0.66708$ N<br>Weight of cup $= V \rho_{cup} g$<br>$= (6.8 \times 10^{-5}) \times (2200) \times (9.81)$<br>$= 1.4676$ N<br>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.<br>Since the cup is held in equilibrium, the net force acting on the cup is zero. Hence,<br>$F + U = W_{cup}$<br>$F = W_{cup} - U$<br>$= 1.4676 - 0.66708$<br>$= 0.800496$<br>$= 0.80$ N | M1<br>M1<br>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.<br>or<br>The **difference in pressure between the upper and lower surface remains the same** and therefore the upthrust stays constant. | B1<br>B1 |
| (b) | Pressure of compressed air = pressure at depth $d$<br>= (atmospheric pressure) + (hydrostatic pressure)<br>$= p_{atm} + \rho g d$<br>$= (1.0 \times 10^{5}) + (1000) \times (9.81) \times (0.30)$<br>$= 1.02943 \times 10^{5}$ Pa<br>Applying $pV$ = constant, since temperature is unchanged,<br>$(1.0 \times 10^{5})(5.50 \times 10^{-4}) = (1.02943 \times 10^{5})\, V$<br>$V = 5.3429 \times 10^{-4}$ m$^3$<br>$= 5.3 \times 10^{-4}$ m$^3$ | B1<br>M1<br>A1 |

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

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

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

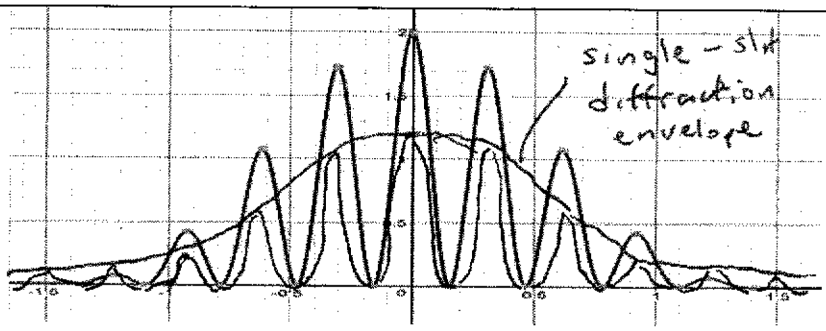
| Q7 | | |
|---|---|---|
| (a) | The magnetic flux (linkage) is given by $\Phi = NBA = B(wx)$ where $x$ is the distance AB has moved past P.<br><br>Hence the induced emf is given using **Faraday's Law** by $E = \frac{d\Phi}{dt} = Bw\frac{dx}{dt}$<br><br>$Bw\frac{dx}{dt} = Bwv$ | B2 |
| (b)(i) | As AB 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.** | B1 |
| | **By Lenz's Law**, an **induced current** will flow **such that it opposes the increase in magnetic flux linkage.** (current flows in anticlockwise direction) | B1 |
| | Consequently, a **magnetic force acts on AB towards the left**, causing it to slow.<br>(Using Fleming's Left Hand Rule) | B1 |
| | <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**. | B1 |
| | There is **induced current** in the full circuit **in the anticlockwise direction**. (or electrons in the clockwise direction) | B1 |
| | Consequently, a **magnetic force acts on AB towards the left**, causing it to slow. | B1 |
| | B1 – why there is an induced emf<br>B1 – how is the direction of induced current determined<br>B1 – effect on AB/frame | |
| (b)(ii) | <br>B1 – same slope where the speed is the same as the original graph<br>B1 – plateau<br>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.<br>**OR**<br>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.<br>(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 | One of the following:<br>A few α-particles were scattered by large angles.<br>**OR**<br>A few α-particles backscattered.<br>(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) | $E = \Delta m\, c^2$<br>$= [(18.00696 - 18.00568) \times 1.66 \times 10^{-27}] \times (3.0 \times 10^8)^2$<br>$= 1.91232 \times 10^{-13}$ J<br>$= 1.9 \times 10^{-13}$ 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),<br>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**<br>**B1** |
| (b)(i) | From graph,<br>Period of waves = $40.0 \times 10^{-9}$ s<br>Frequency = $1/40.0 \times 10^{-9} = 25.0 \times 10^{6}$ Hz<br>= 25.0 MHz | <br><br>**B1**<br>**A0** |
| (b)(ii) | At M, the waves arrive in phase / path difference is zero, hence constructive interference occurs<br>Resultant wave amplitude = 2A (where A is the amplitude due to an individual wave),<br>A = 0.5 units<br><br>When only one source is on, the amplitude is 0.5 units.<br>Diagram of waveform with same period, phase and amplitude = 0.5 units drawn.<br><br>B1 – explain why constructive interference<br>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.<br>B1 – correct graph drawn | **B1**<br><br>**B1**<br><br><br><br>**B1** |
| (b)(iii) | Distance from M to N = distance between an antinode to a node<br>= ¼ λ<br>= ¼ (c/f)<br>= ¼ ($3.00 \times 10^{8} / 25.0 \times 10^{6}$)<br>= 3.00 m<br>M1 – relating MN to λ/4<br>M1 – for finding λ using c=f λ<br>Alternative:<br>Let the distance moved be *x* so that the path difference increased by half a wavelength.<br>(AN – BN) = ½ λ<br>$(6.00 + x) - (6.00 - x) = (0.5)(3.00 \times 10^{8} / 25.0 \times 10^{6})$ where *x* is distance from M to N.<br>*x* = 3.00 m | <br>**M1**<br><br>**M1**<br>**A0** |

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

**(c)(iv)**



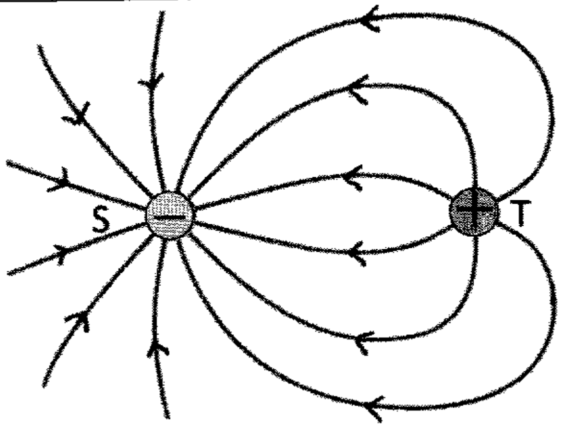
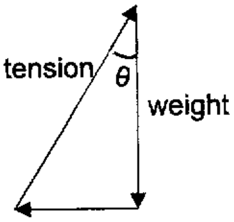

Marking points:

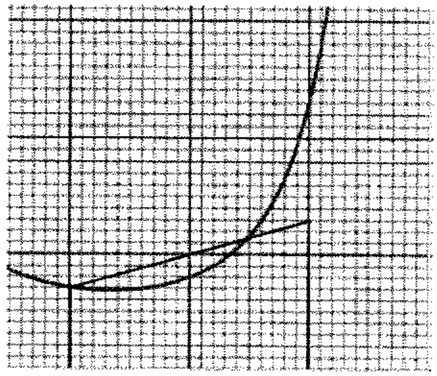
- All **fringes** should be clearly shown to **occur at the same position as original** diagram. (As fringe separation *x* does not change.) **(This mark must be awarded for the next mark to be awarded)** — **A1**
- **5th order maxima** should be **visible** — **A1**

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

Additional points (not assessed)

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

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

| | | |
|---|---|---|
| **(b)(iii)** | Area under the graph is **change** in potential.<br>$\Delta V = \frac{1}{2}(0.10)\left[(0.14+0.26)\times10^{7}\right]$<br>$= 2.0\times10^{5}$ V<br>(accept +/- 10%)<br>From 25 cm to 15 cm, the positive helium nucleus loses potential energy and gains kinetic energy.<br><br><br>Gain in KE = $q\Delta V = 2(1.60\times10^{-19})(2.0\times10^{5}) = 6.4\times10^{-14}$ J | B1<br>M1<br>M1<br>A1 |
| **(c)(i)** | Weight of lithium ion = $mg = 6.941\times1.66\times10^{-27}\times9.81 = 1.13\times10^{-25}$ N<br>Electric force on ion = $qE = 1.60\times10^{-19}\times\left(\frac{150}{0.020}\right) = 1.2\times10^{-15}$ N<br>The electric force is about $10^{10}$ times larger or 10 orders of magnitude larger than the gravitational force or weight. | M1<br>M1<br>A1 |
| **(c)(ii)** | Time taken to travel through plates = $\frac{0.090}{3.0\times10^{5}} = 3.0\times10^{-7}$ s<br>Applying $s = ut + \frac{1}{2}at^2$ in the vertical direction,<br>$y = \frac{1}{2}\left(\frac{1.2\times10^{-15}}{6.941\times1.66\times10^{-27}}\right)(3.0\times10^{-7})^2$<br>$y$ = 4.7 mm | M1<br>M1<br>A1 |