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

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.

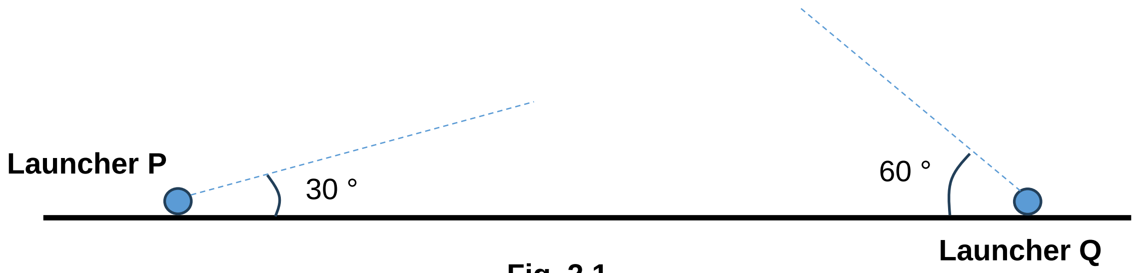

Fig. 2.1

(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.

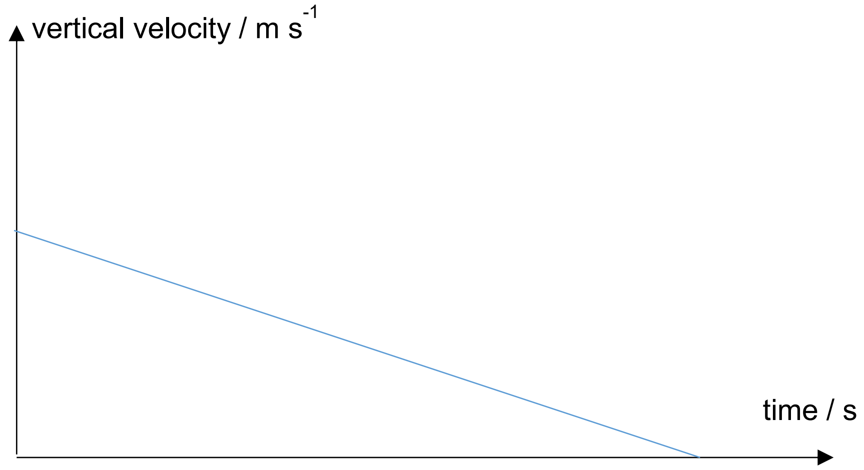

Fig. 2.2

[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*.

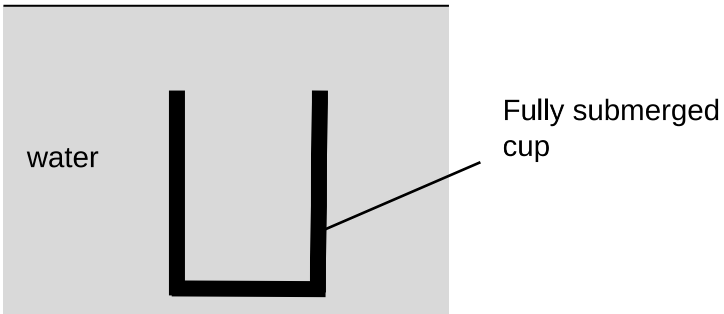

Fig. 3.1

(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.

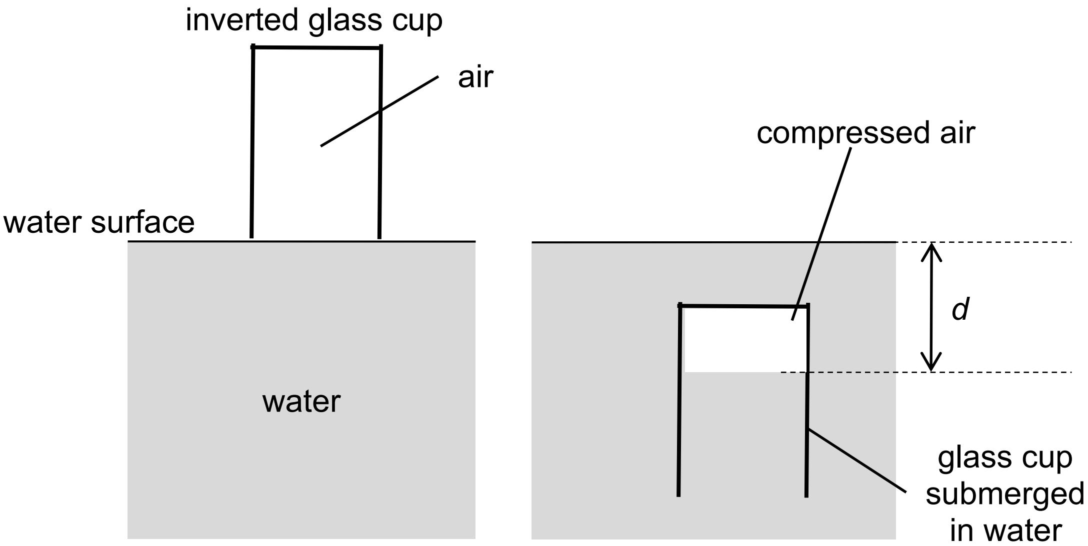

Fig. 3.2 **Fig. 3.3**

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.

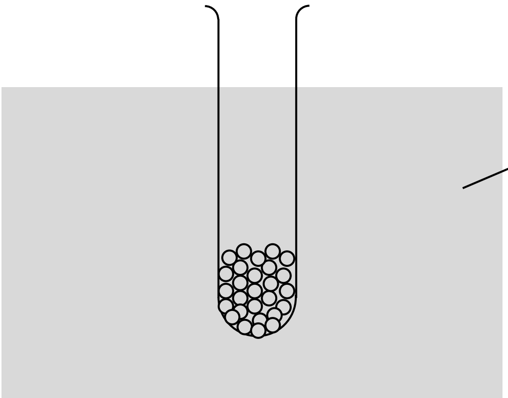

Fig. 4.1

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: $\rho = 1.00 \times 10^3$ 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.

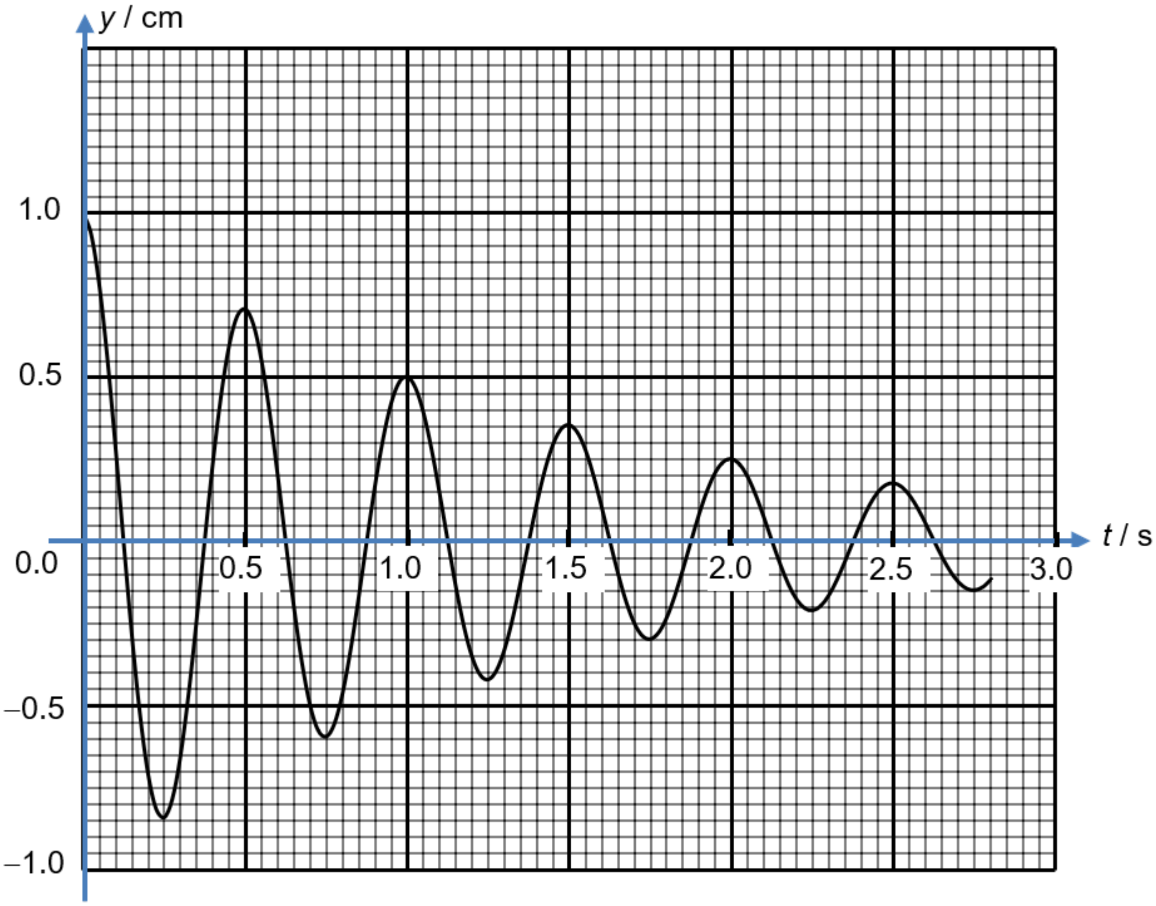

Fig. 4.2

(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.

....

....

....

.... [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.

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…………………………………………………………………………………………………… [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.

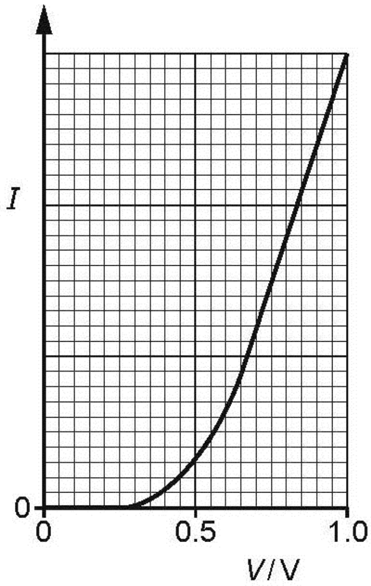

Fig. 6.1

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.

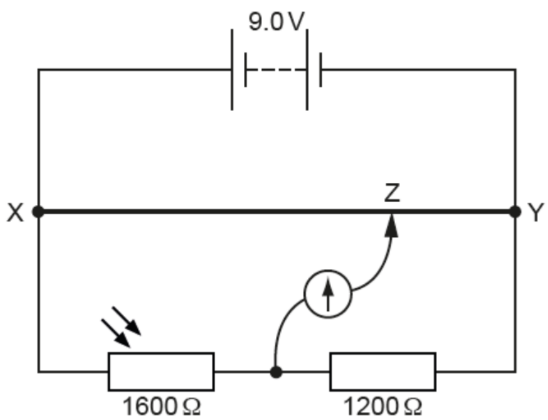

Fig. 6.2

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.

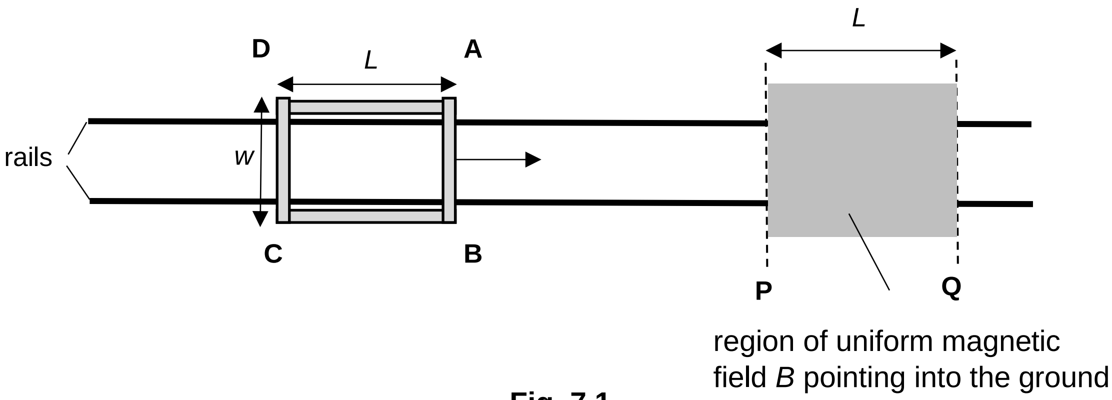

Fig. 7.1

(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.

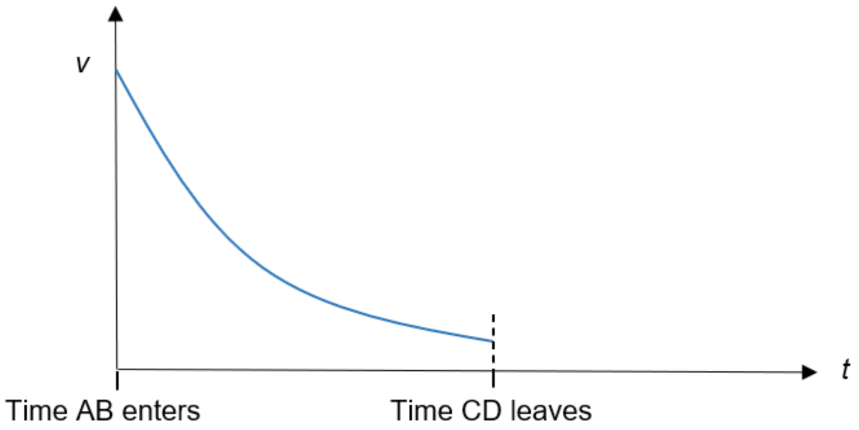

Fig. 7.2

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.

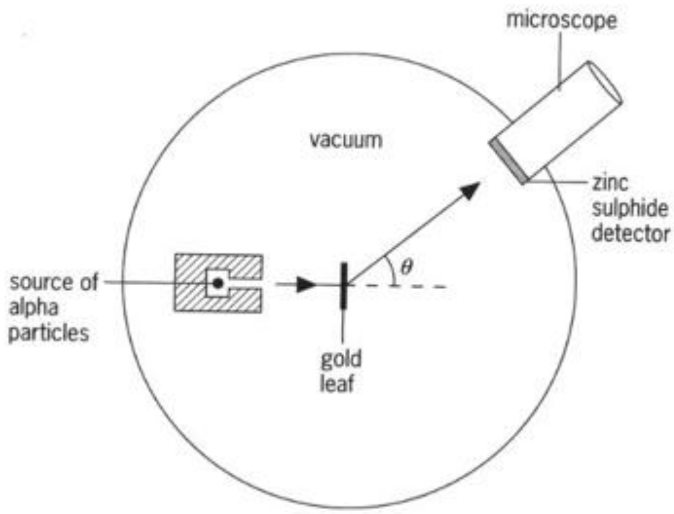

Fig. 8.1

(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:

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

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

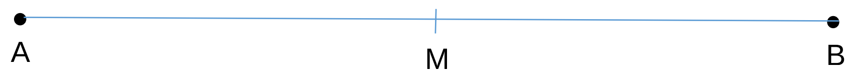

Fig. 9.1

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

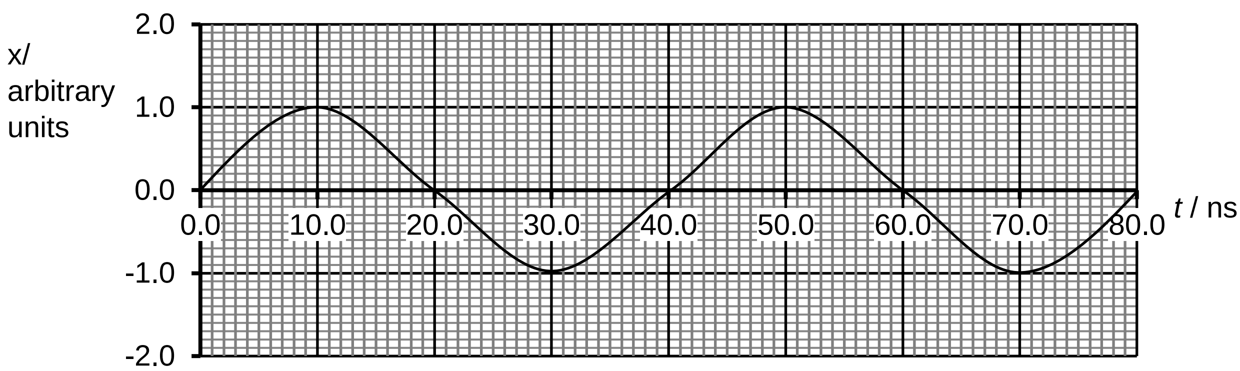

Fig. 9.2

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.

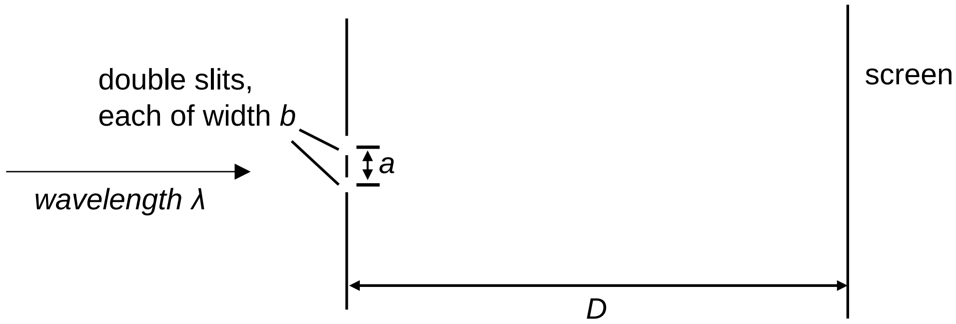

Fig. 9.3

(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.

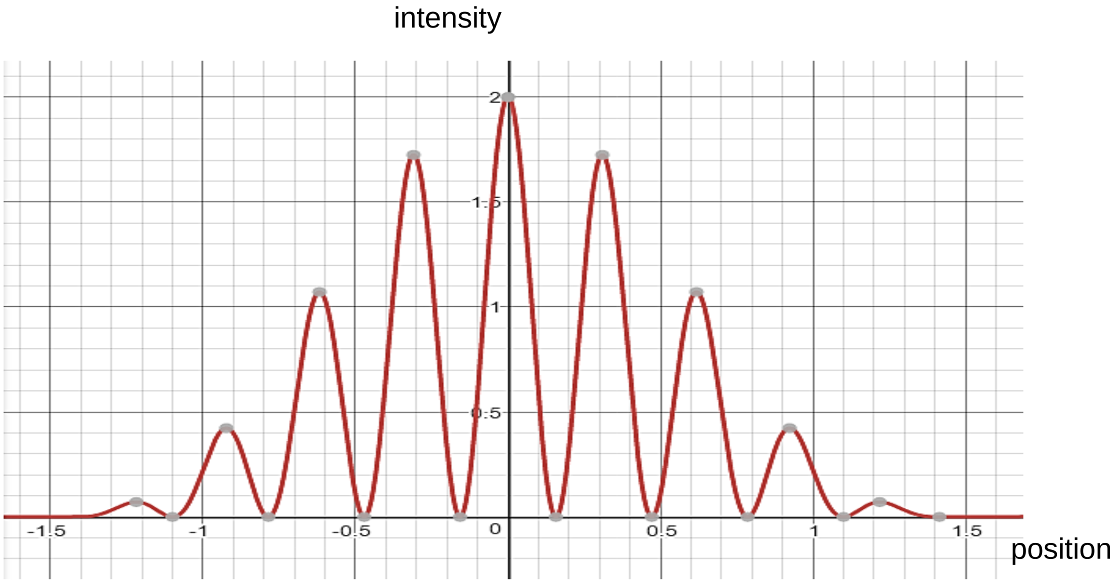

Fig. 9.4

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.

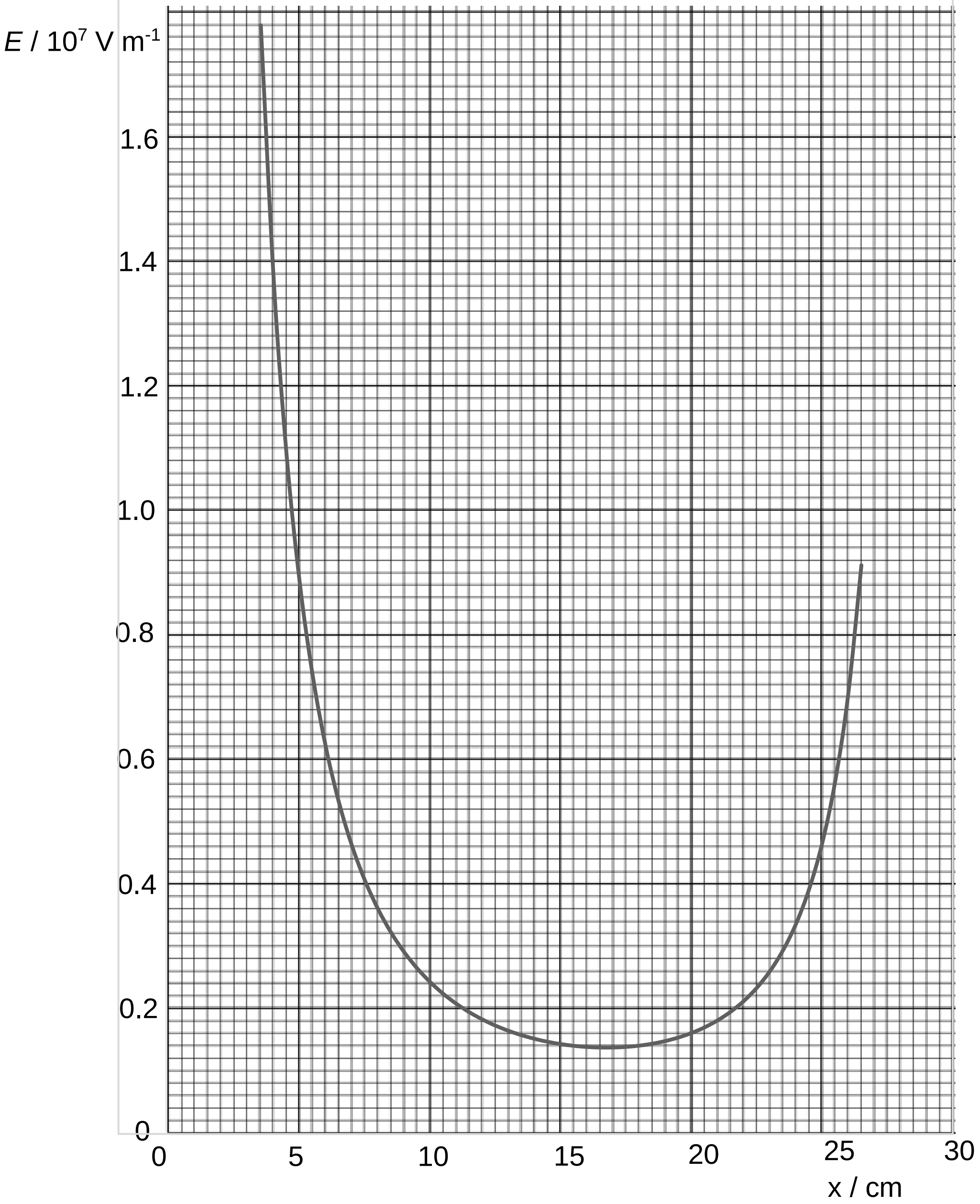

Fig. 10.2

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}.

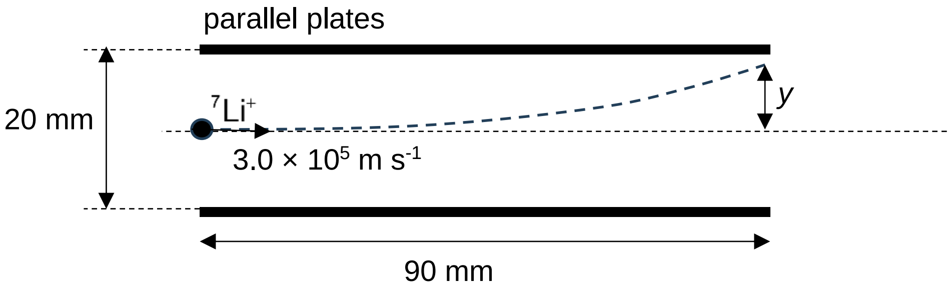

Fig. 10.3

(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