Class

Adm No

Candidate Name: ______________

H

millennia institute

2023 Preliminary Examination
Pre-University 3

H2 PHYSICS **9749/03**

Paper 3 Longer Structured Questions **19 September**

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

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Do not turn over this page until you are told to do so.

Write your full name, class and Adm number 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 an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, 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.

You are advised to spend one and 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.

For Examiner's Use		
Sect A		
1		**/ 10**
2		**/ 12**
3		**/ 12**
4		**/ 12**
5		**/ 14**
Sect B		
6		**/ 20**
7		**/ 20**
Presentation		
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	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
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	$\phi = -Gm/r$
temperature	$T/\mathrm{K} = T/{}^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
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** the questions in the spaces provided.

1 An object A of mass 9.0 kg and object B of mass 1.0 kg travel towards each other along a smooth horizontal surface in a straight line and collide head-on. The initial speeds of object A and B before the collision are u and $3u$ respectively.

In Fig. 1.1, the variation with time t of momentum p is shown from t = 0 to 3.0 s for particle A and from t = 0 to 1.0 s for particle B.

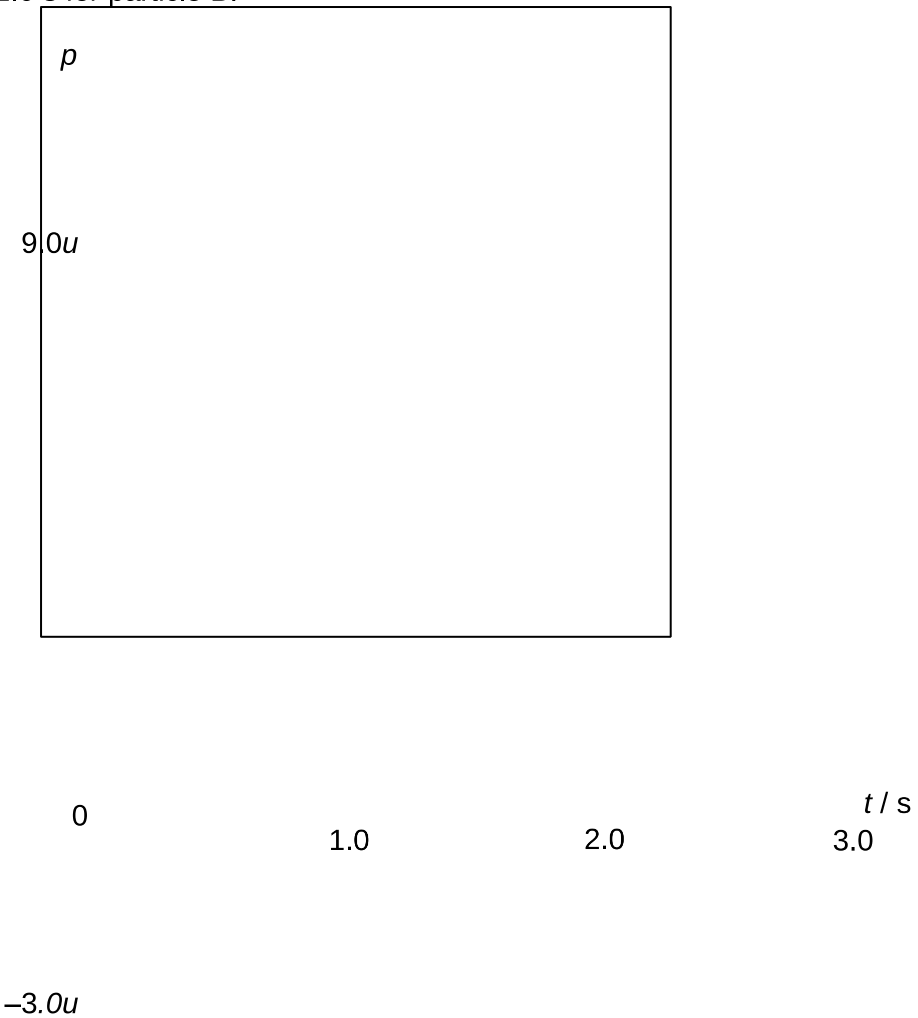


Fig. 1.1

(a) **(i)** Momentum is conserved when two objects collide or interact. State the condition under which momentum is conserved.

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

(ii) On Fig. 1.1, draw the variation with t of p from 1.0 s to 3.0 s for object B. [2]

(iii) Explain how the principle of conservation of momentum is used to complete the graph in **(a)(ii)**.

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

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

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

(b) Explain, with appropriate working, whether the collision between objects A and B is elastic.

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

…………………………………………………………………………………………………… [3]

(c) **(i)** Show that the magnitude of the force acting on object A during the collision is $7.2u$.

[1]

(ii) Explain how the graphs in Fig. 1.1 are consistent with Newton's third law of motion during the collision.

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

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

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

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

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

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

[Total: 10]

2 **(a)** The kinetic theory of gases is based on a number of assumptions about the molecules of a gas. State the assumption that is related to the volume of the molecules of the gas.

....

.... [1]

(b) An ideal gas occupies a volume of 950 cm^3 at a pressure of 2.10×10^5 Pa and a temperature of 280K. Each molecule has a diameter of approximately 3×10^{-10} m. Estimate the total volume of the gas molecules.

[3]

volume = ...m^3

(c) With reference to your answer in **(b)**, suggest why the assumption in **(a)** is justified.

....

.... [1]

(d) The ideal gas undergoes the cycle of changes PQRP as shown in Fig. 2.1.

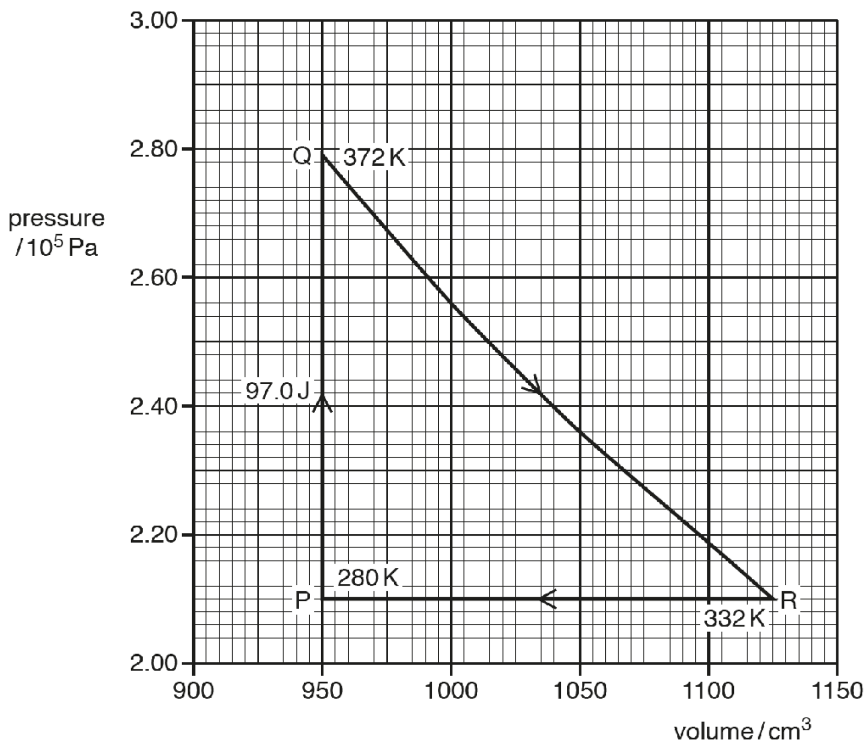


Fig. 2.1

Some energy changes during one complete cycle of PQRP are shown in Table. 2.1.

	change P → Q	change Q → R	change R → P
thermal energy transferred to gas / J	+97.0	0	....
work done on gas / J	....	–42.5	....
increase in internal energy of gas / J	....	....	....

Table. 2.1

(i) State the total change in internal energy of the gas during one complete cycle PQRP. Explain your answer.

....

....

.... [2]

(ii) Complete Table 2.1 to show the energy changes for the gas.
Show your working clearly in the space below.

[5]

[Total: 12]

3 A small wooden block (cuboid) of mass m floats in water, as shown in Fig. 3.1.

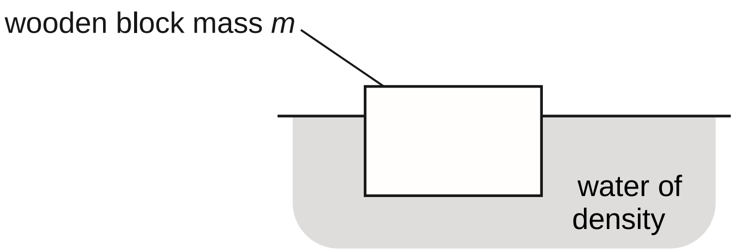


Fig. 3.1

The top face of the block is horizontal and has area A. The density of the water is ρ.

(a) State the names of the two forces acting on the block when it is stationary.

.... [1]

(b) The block is now displaced downwards as shown in Fig. 3.2 so that the surface of the water is higher up the block.

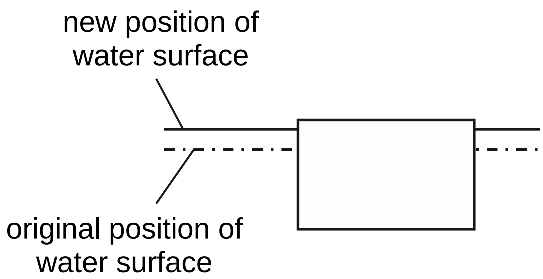


Fig. 3.2

State and explain the direction of the resultant force acting on the wooden block in this position.

....

.... [1]

(c) The block in **(b)** is now released so that it oscillates vertically.

The resultant force F acting on the block is given by

$$F = -Ag\rho x$$

where g is the gravitational field strength and x is the vertical displacement of the block from the equilibrium position.

(i) Explain why the oscillations of the block are simple harmonic.

....

....

....

.... [2]

(ii) Show that the angular frequency 7of the oscillations is given by

$$\omega = \sqrt{\frac{A\rho g}{m}}$$

[2]

(d) The block is now placed in a liquid with a greater viscosity. The block is displaced and released so that it oscillates vertically. The variation with displacement *x* of the acceleration *a* of the block is measured for the first half oscillation, as shown in Fig. 3.3.

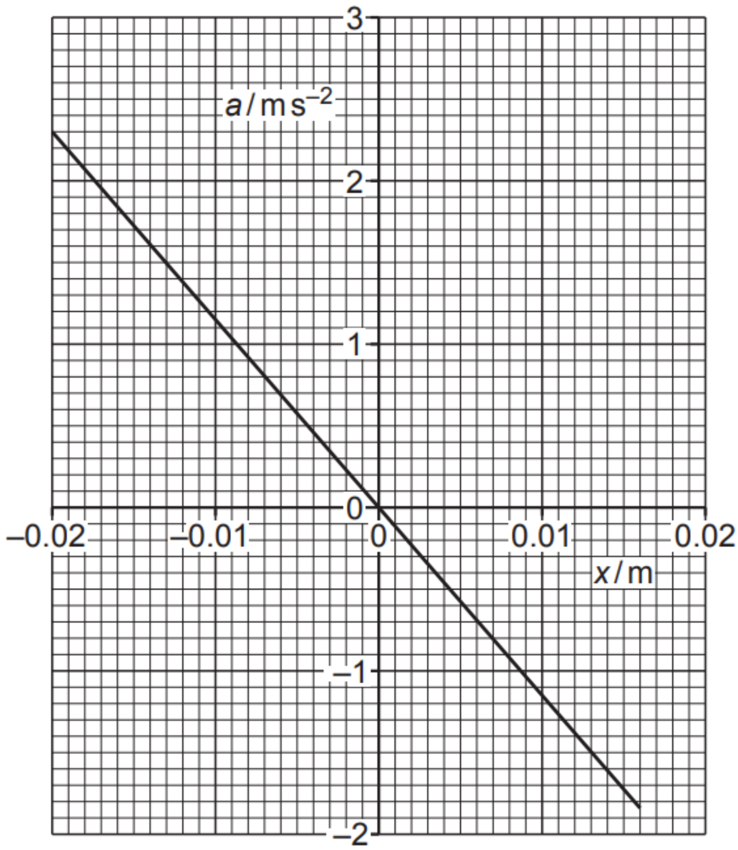


Fig. 3.3

(i) Explain why the maximum negative displacement of the block is not equal to its maximum positive displacement.

....

....

....

[1]

(ii) Use Fig. 3.3 to determine the frequency of the block.

frequency = ... Hz [2]

(iii) The mass of the block is 0.57 kg.

Use Fig. 3.3 to determine the decrease ⊗*E* in energy of the oscillation for the first half oscillation.

⊗*E* = ... J [3]

[Total: 12]

4 Two small charged metal spheres A and B are situated in a vacuum. The distance between the centres of the spheres is 12.0 cm, as shown in Fig. 4.1.

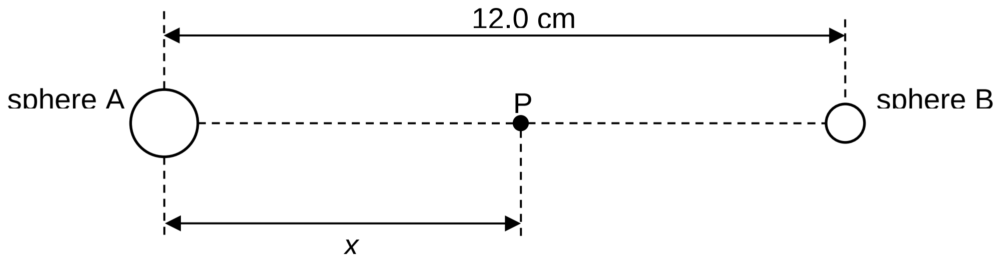


Fig. 4.1

The charge on each sphere may be assumed to be a point charge at the centre of the sphere. Point P lies on the line joining the centres of the two spheres. P is at a distance *x* from the centre of sphere A.

The variation with distance *x* of the electric field strength *E* at point P is shown in Fig. 4.2.

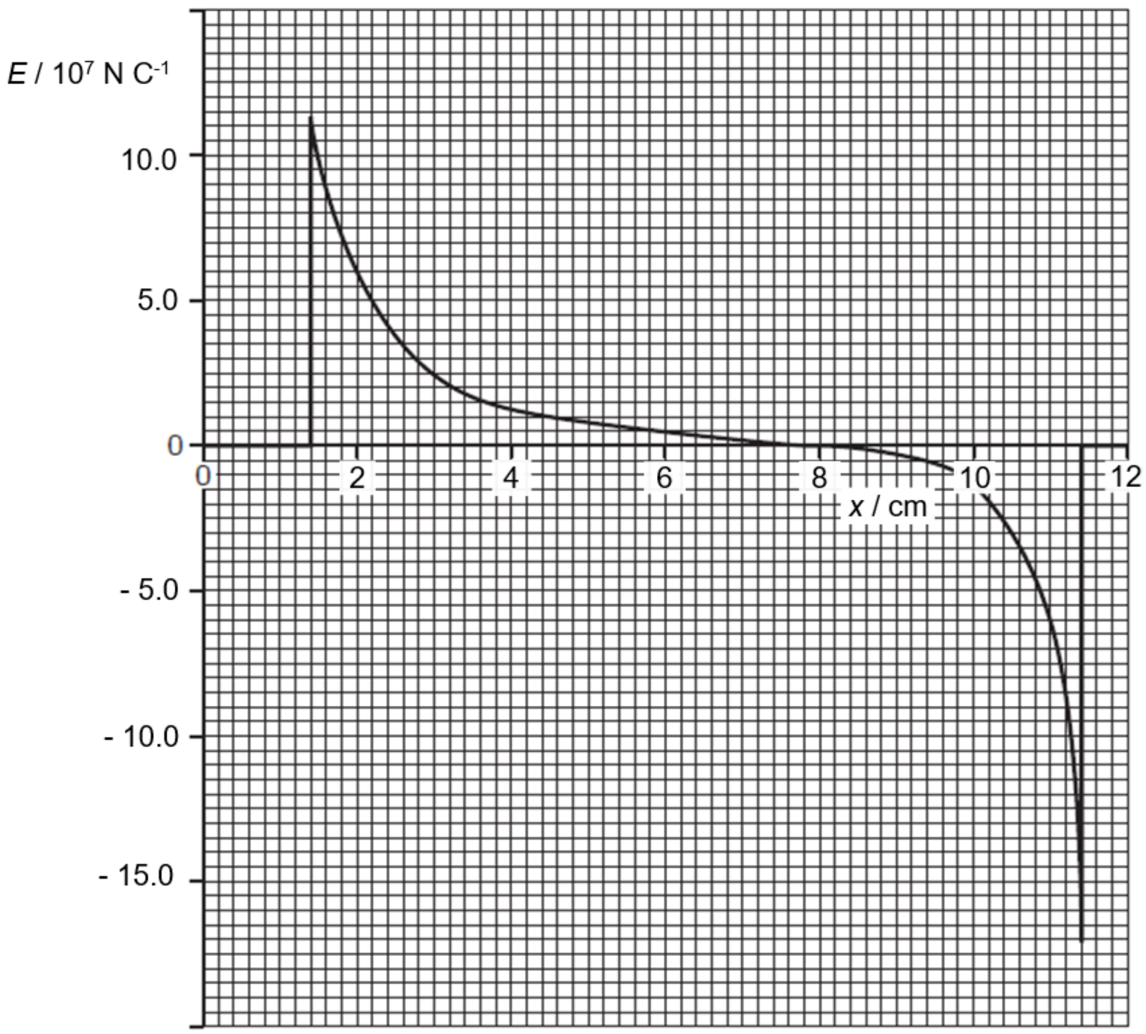


Fig. 4.2

(a) State the evidence provided by Fig. 4.2 that the spheres are conductors.

.... [1]

(b) State and explain whether the polarity of the charges on the spheres are of the same sign.

....

....

.... [2]

(c) Use Fig. 4.2 to determine the ratio $\dfrac{\text{charge on sphere A}}{\text{charge on sphere B}}$.

ratio = ... [3]

(d) Hence, on Fig. 4.3, sketch the electric field lines due to these two charges.

Fig. 4.3 [3]

(e) A proton moves along the line joining the centres of the two spheres.
Estimate the change in energy of the proton as it moves from the point where x = 3.0 cm to the point where x = 1.4 cm.

energy = ……………………… J [3]

[Total: 12]

5 **(a)** When a star has fused all its hydrogen to helium, it will start to fuse helium into carbon through the following reaction.

$$24He \; + \; 24He \; + \; 24He \; \rightarrow \; 6\;12C$$

The binding energy per nucleon of helium and carbon are given in Fig. 5.1.

nuclide	binding energy per nucleon / MeV
$6\;12C$	7.680
$24He$	7.074

Fig. 5.1

(i) Calculate the energy, in MeV, produced from this fusion reaction.

energy produced = …………………… MeV [2]

(ii) A star in the milky way gives off energy at a rate of 2.75 x 10^{26} W solely due to the fusion of helium into carbon in its core.

Calculate the number of helium nuclei *N*, that reacted in one second.

N = ……………………….. s^{-1} [3]

(b) The nuclide $^{14}_{6}C$ (carbon-14) is unstable and undergoes β decay, emitting a high-energy electron and a neutrino to form a nuclide X.

(i) The equation for this decay is shown.

$$^{14}_{6}\mathrm{C} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{X} + {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{e} + {}^{0}_{0}\nu$$

Complete the equation. [2]

(ii) Neutrinos were first proposed to exist more than 20 years before they were directly detected, in order to explain a particular experimental observation about β-decay.

1. State an observation about β-decay that is explained by the existence of neutrinos.

…………………………………………………………………………………………

[1]

…………………………………………………………………………………………

2. Suggest how the existence of neutrinos explains the observation in **(b)(i)1**.

…………………………………………………………………………………………

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

…………………………………………………………………………………………...

(c) The variation with time t of the number N of undecayed nuclei in a sample of a radioactive isotope is shown in Fig. 5.2.

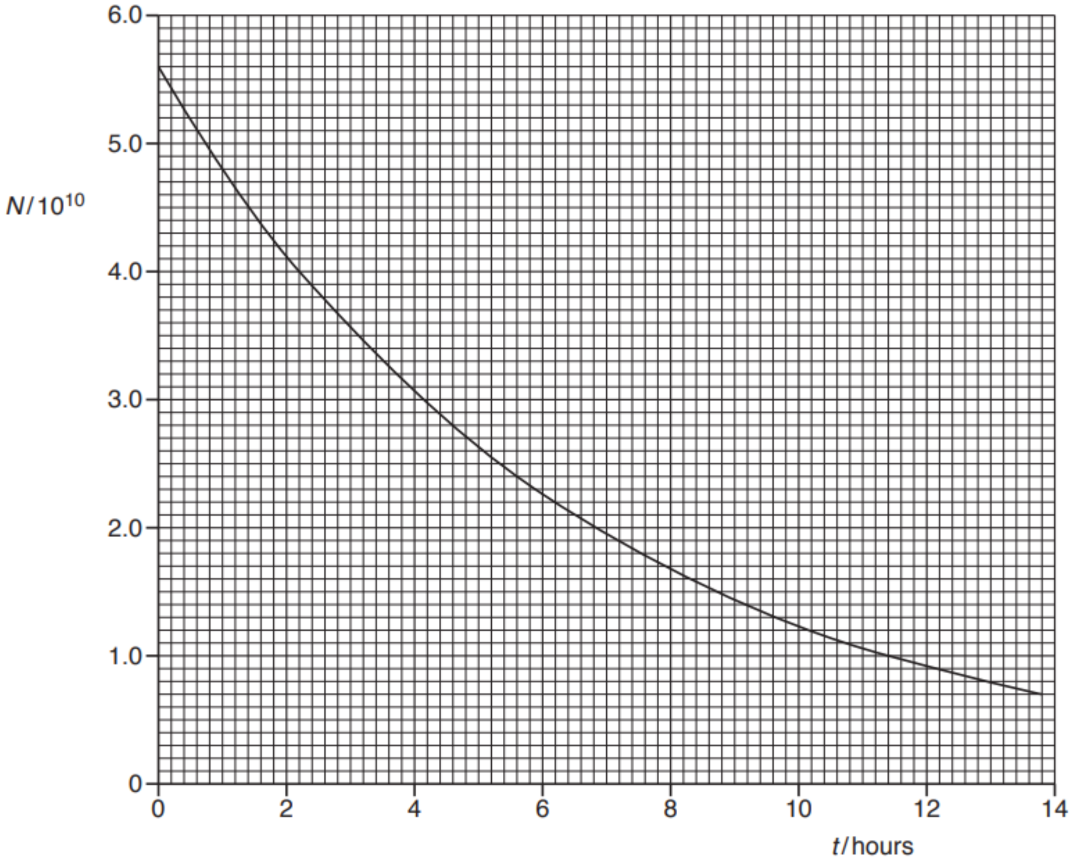


Fig. 5.2

(i) Using Fig. 5.2, determine the activity, in Bq, of the sample at time t = 4.0 hours.

activity = ... Bq [2]

(ii) Use your answer in **(c)(i)** to show that the decay constant λ of the isotope is approximately $4 \times 10^{-5}\ s^{-1}$

[2]

[Total: 14]

S

6 **(a)** State what is meant by the *wavelength* of a progressive wave.

....

.... [1]

(b) A cathode-ray oscilloscope (CRO) is used to analyse a sound wave. The screen of the CRO is shown in Fig. 6.1.

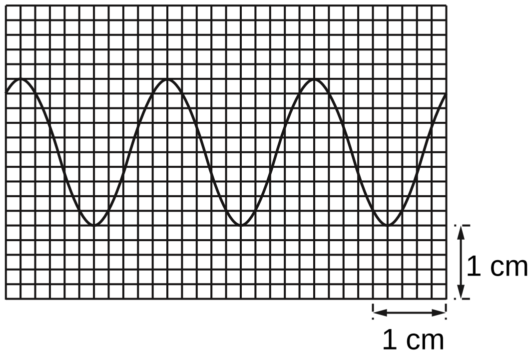


Fig. 6.1

The time-base setting of the CRO is 2.5 ms cm^{-1}.

Determine the frequency of the sound wave.

frequency = ...Hz [1]

(c) The source emitting the sound in **(b)** is placed near the bottom opening of a vertical tube of length 0.80m. The tube is open at both ends, as shown in Fig. 6.2.

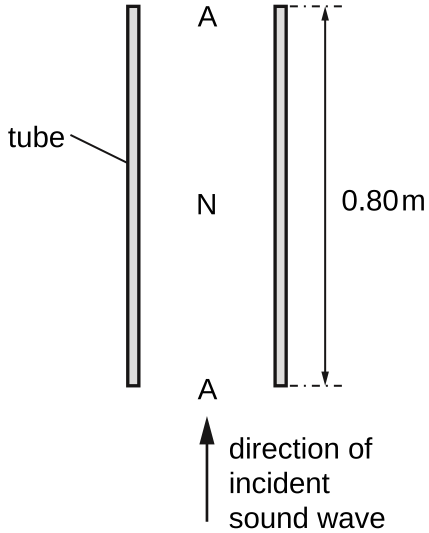


Fig. 6.2

A stationary wave is then formed in the air column in the tube with antinodes A at both ends and a node N at the midpoint.

(i) Explain how the stationary wave is formed from the incident sound wave.

....

....

....

.... [2
]

(ii) On Fig. 6.3, sketch a graph to show the variation of the amplitude of the stationary wave with height *h* above the bottom of the tube.

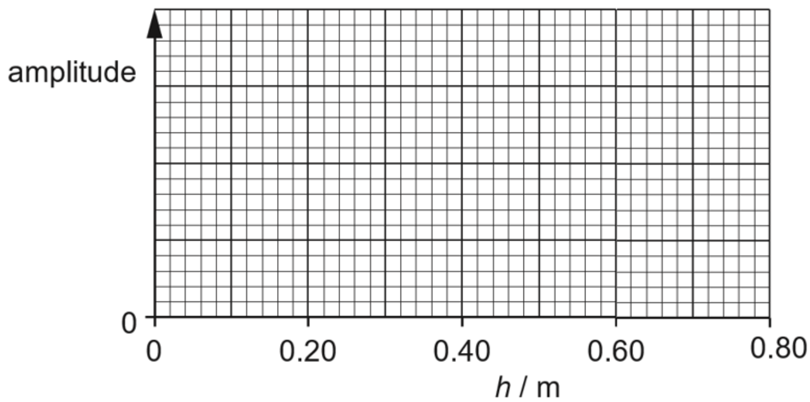


Fig. 6.3

[2
]

(iii) For the stationary wave, state

1. the direction of the oscillations of an air particle at a height of 0.15 m above the bottom of the tube

.... [1]

2. the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = ... ° [1]

(iv) Determine the wavelength of the sound wave.

wavelength = ... m [1]

(d) The source emitting the sound in **(b)** is then placed at point A as shown in Fig. 6.4.

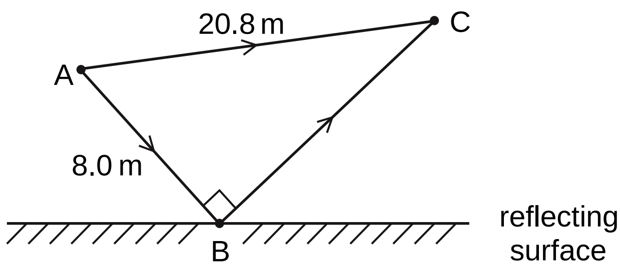


Fig. 6.4 (not to scale)

The sound waves travel from the source to point C along two different paths, AC and ABC. Distance AB is 8.0 m and distance AC is 20.8 m. Angle ABC is 90°.

Assume that there is no phase change of the sound wave due to the reflection at point B.

(i) Show that the waves meeting at C have a path difference of 6.4 m

[1]

(i) Explain why an intensity maximum is detected at point C.

....

………………………………………………………………………………………………

[2]

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

(ii) Determine the difference between the time taken for the sound waves to travel from the source to point C along the two different paths.

time difference = ...s [2
]

(iii) The wavelength of the sound is gradually increased. Calculate the wavelength of the sound when an intensity maximum is next detected at point C.

wavelength = ...m [2
]

(e) Fig. 6.5 shows an ideal polarizer A arranged so that its polarizing direction is vertical. Polariser B is oriented with its plane parallel to that of A and with its polarizing direction at 45° to the vertical.

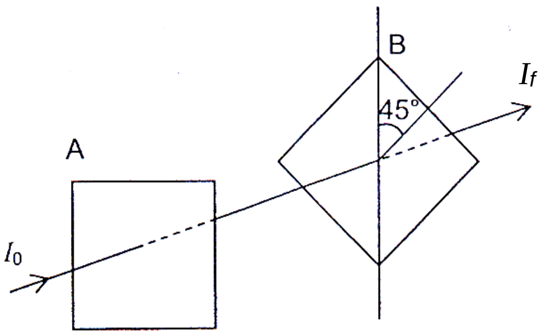


Fig. 6.5 a

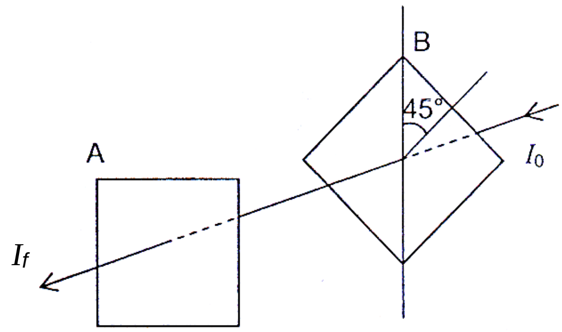


Fig. 6.5 b

A beam of vertically-polarised light, of initial intensity I_o, passes through the polarisers in turn.

Determine the intensity I_f and the orientation of the emergent beam when the beam passes through the polarizer system

(i) in the direction from A to B (Fig. 6.5a),

intensity I_f = ……………………………….

orientation to the vertical =………………………………

[2]

(ii) in the direction from B to A (Fig. 6.5b).

intensity I_f = ……………………………….

orientation to the vertical =………………………………

[2]

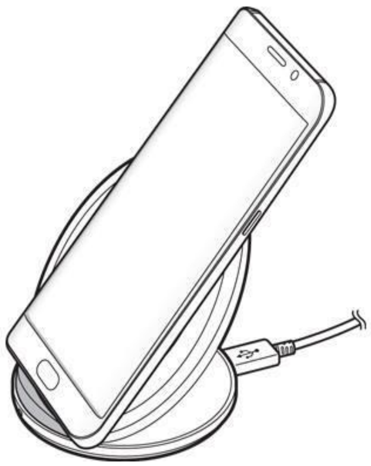
[Total: 20]

7 (a) (i) State *Faraday's law of electromagnetic induction.*

....

.... [1
]

(ii) An application of electromagnetic induction is inductive charging. In inductive charging, the device to be charged is placed on a charging plate as shown in Fig. 7.1.



charging plate

device to be charged

Fig. 7.1

Using the laws of electromagnetic induction, suggest how inductive charging works.

....

....

....

....

.... [3
]

....

(iii) Suggest one advantage and one disadvantage of inductive charging.

Advantage:

....

.... [1
]

Disadvantage:

....

....

[1]

(b) The charging plate must be connected to an alternating power supply. The variation with time t of the supply voltage V is given by

$$V = 340\sin(377t)$$

where V is measured in volts and t in seconds.

(i) Calculate the frequency of the supply voltage.

frequency = ………………………. Hz [2]

(ii) Calculate the root-mean-square value of the supply voltage.

root-mean-square value = ……………………………. V [2]

(iii) With reference to heating effect, explain what is meant by the root-mean-square value calculated in **(b)(ii)**.

……………………………………………………………………………………….

……………………………………………………………………………………….

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

(c) Two conducting rods, AB and CD, are placed on two horizontal, parallel and smooth metal rails of negligible resistance as shown in Fig 7.2. The two rails are 10.0 cm apart. A uniform magnetic field of flux density 0.54 T is applied perpendicularly into the plane of the rails.

10.0 cm

2.3 m s^{-1}

metal rails

A

B

C

D

Fig. 7.2 (plan view)

Rod AB has a resistance of 0.83 ∧ while rod CD has negligible resistance. Both rods have the same mass of 34 g.

Rod CD is suddenly made to move at a constant speed of 2.3 m s^{-1} to the right.

(i) Calculate the e.m.f. induced in rod CD.

e.m.f. induced = ………………………. V [2
]

(ii) State which end of rod CD is at a higher potential.

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

(iii) Calculate the initial current in rod AB.

current = …………………………… A [2]

(iv) State and explain the direction of the initial force acting on rod AB.

…………………………………………………………………………………………….

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

(v) Determine the magnitude of the initial acceleration of rod AB.

acceleration = ……………………. m s^{-2} [2]

[Total: 20]

End of Paper