



CANDIDATE
NAME

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CIVICS
GROUP

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REGISTRATION
NUMBER

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PHYSICS

9478/03

Paper 3 Longer Structured Questions

16th September 2026

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

Section A

Answer **all** questions.

Section B

Answer **one** question only.

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 paper clips, highlighters, glue or correction fluid.
The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
Section A	
Q1	10
Q2	10
Q3	5
Q4	8
Q5	6
Q6	8
Q7	8
Section B	
Q8	20
Q9	20
s.f.	
P3 Total	75

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

$$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$$

$$\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1}\right)$$

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

$$W = p\Delta V$$

pressure

$$p = \frac{F}{A}$$

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.

$$v = v_0 \cos \omega t = \pm \omega \sqrt{(x_0^2 - x^2)}$$

electric current

$$I = nAvq$$

resistors in series

$$R = R_1 + R_2 + \dots$$

resistors in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

capacitors in series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

capacitors in parallel

$$C = C_1 + C_2 + \dots$$

energy in a capacitor

$$U = \frac{1}{2} QV = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} CV^2$$

charging a capacitor

$$Q = Q_0 \left[1 - e^{-\frac{t}{\tau}} \right]$$

discharging a capacitor

$$Q = Q_0 e^{-\frac{t}{\tau}}$$

RC time constant

$$\tau = RC$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

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

$$B = \mu_0 nI$$

energy states for quantum particle in a box

$$E_n = \frac{h^2}{8mL^2} n^2$$

radioactive decay

$$x = x_0 e^{-\lambda t}$$

radioactive decay constant

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

Section A

Answer all the questions in this section in the spaces provided.

- 1 (a) Define moment of a force.

.....
 [1]

- (b) Fig. 1.1 shows a uniform metal beam pivoted at one end O and held in equilibrium in a horizontal plane by a spring attached to its other end P.

The spring has an unstretched length of 7.0 m and obeys Hooke's law.

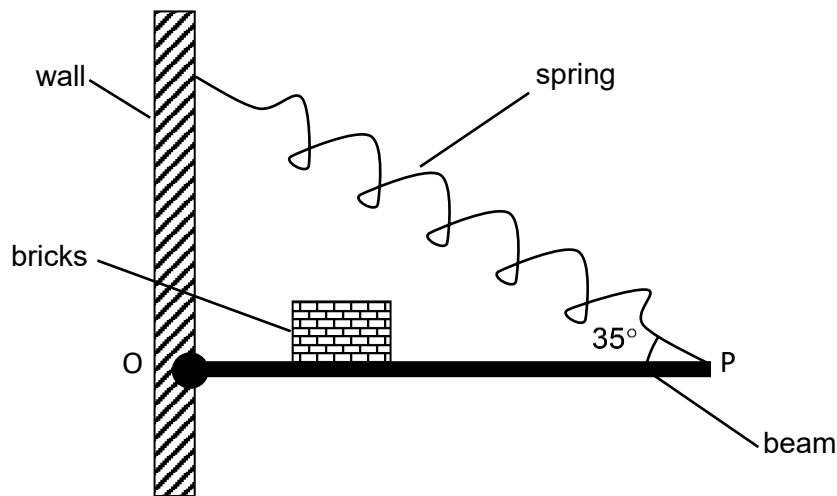


Fig. 1.1 (not to scale)

The beam has mass 190 kg and length 6.8 m. The spring makes an angle of 35° to the beam. A pile of bricks of total mass 120 kg is placed on the beam.

- (i) Show that the extension of the spring is 1.3 m. [1]

- (ii) On Fig. 1.1, draw labelled arrows to show all the forces acting on the beam. [2]

- (iii) Right now, the centre of the pile of bricks is 5.0 m away from end P. Calculate the spring constant k of the spring.

$$k = \dots\dots\dots \text{N m}^{-1} \text{ [2]}$$

- (iv) Calculate the elastic potential energy E_P of the spring.

$$E_P = \dots\dots\dots \text{J [2]}$$

- (v) The spring in Fig. 1.1 is now replaced with an inextensible string such that the beam remains in the original horizontal position.

Describe and explain what would happen to the force exerted by the string on the beam as the pile of bricks is slowly moved towards the pivot O while maintaining equilibrium.

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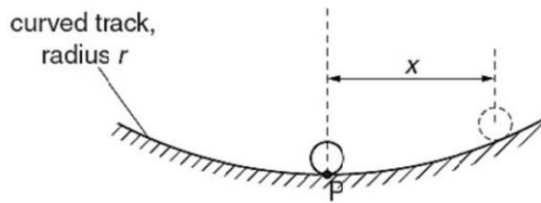
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.....

..... [2]

[Total: 10]

- 2 A small ball of mass 90 g rests at point P on a smooth curved track of radius r , as shown in Fig. 2.1.



The ball is moved a small distance to one side and is then released. The horizontal displacement x of the ball is related to its horizontal acceleration a towards P, by the expression

$$a = -\frac{gx}{r}$$

- (a) Explain why the horizontal oscillation undertaken by the ball can be taken as simple harmonic motion.

.....

[2]

- (b) The radius r of curvature of the track is 28 cm.

Determine the angular frequency of the oscillation.

angular frequency = ... rad s^{-1} [2]

- (c) After some time, the variation with time t of the displacement x of the ball is plotted as shown in Fig. 2.2. T is the period of oscillation.

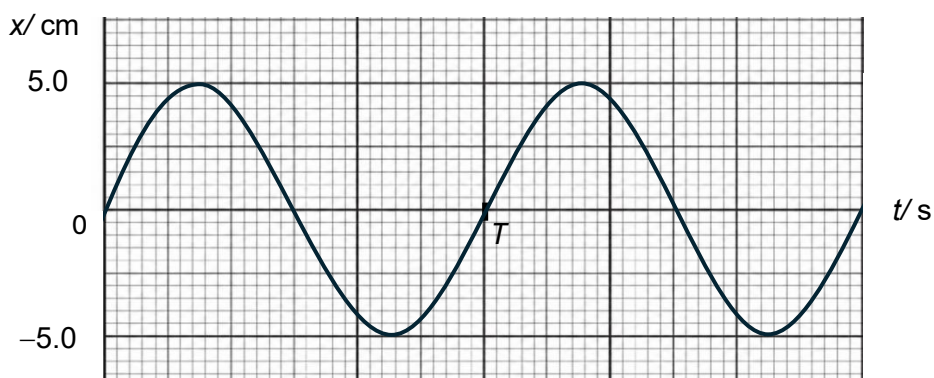


Fig. 2.2

- (i) On the axes of Fig. 2.3, sketch the variation with time t of the acceleration a of the ball. [2]

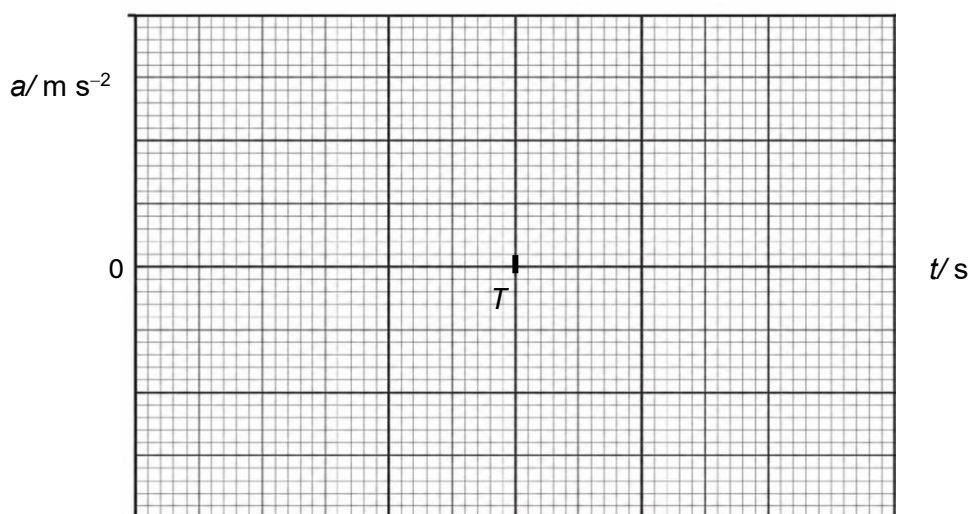


Fig. 2.3

- (ii) The track is subsequently brought to a room with high humidity and moisture is formed on the track such that the ball comes to a rest after 10 oscillations.

On the axes of Fig. 2.2, sketch the variation with time t of the displacement x of the ball, for the first two periods after moisture has formed. [2]

- (iii) After many oscillations, the amplitude of oscillation decreased from 5.0 cm to 2.5 cm.

Calculate the loss in energy of the oscillation.

loss in energy = ... J [2]

[Total: 10]

- 3** A cup contains 0.22 kg of water at a temperature 5.0 °C.

A bucket contains 0.50 kg of ice at a temperature of –8.0 °C.

Data:

specific heat capacity of water: $c_{\text{water}} = 4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$

specific heat capacity of ice: $c_{\text{ice}} = 2.09 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$

latent heat of fusion of ice: $L_f = 334 \text{ J g}^{-1}$

- (a)** Determine, for the water in the cup,

- (i)** the heat released if its temperature decreases to 0 °C;

heat released = ... J [1]

- (ii)** the heat released by the 0 °C water if it freezes to 0 °C ice;

heat released = ... J [1]

- (b)** Determine, for the ice in the bucket, the heat absorbed by the ice if its temperature increases to 0 °C.

heat absorbed = ... J [1]

- (c) A cup of water, of mass 0.22 kg and temperature 5.0 °C, is poured into a bucket containing ice, of mass 0.50 kg and temperature –8.0 °C.

State and explain the final temperature of the system.

Ignore any heat loss to the surroundings.

final temperature = ... °C

Explanation:

.....

.....

..... [2]

[Total: 5]

- 4 (a) A radio mast transmits a signal using a transmitter with output power 15.0 W. The signal is received at a research station 3.5 km away.

(i) Calculate the power received by a receiving antenna of effective area 450 cm².

power received = ...W [2]

(ii) State the assumption made in your calculation of part (a)(i).

.....[1]

(iii) The amplitude of the signal at a distance of 2.5 km from the transmitter is A_0 .
Determine, in terms of A_0 , the amplitude of the signal received at the antenna at a distance of 3.5 km.

amplitude = ... A_0 [2]

- (b) (i) State what is meant by a polarised wave.

.....
[1]

- (ii) A vertically polarised light of intensity I_0 is incident on a polariser P with its transmission axis at an angle of 40° from the vertical as shown in Fig. 4.1. The wave then passes through another polariser Q with its transmission axis at an angle of 40° from the vertical in the other direction.

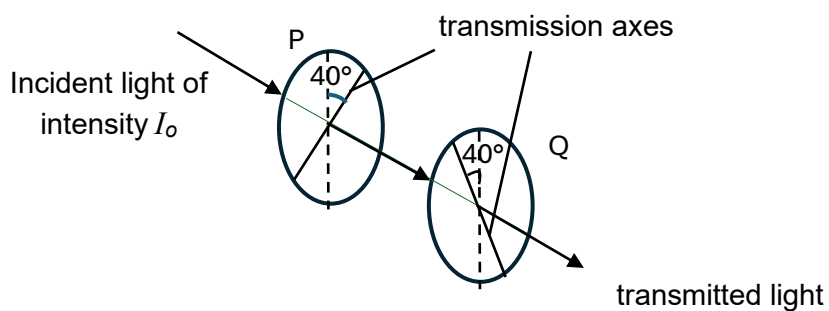


Fig. 4.1

Determine the intensity of the transmitted light in terms of I_0 .

intensity = ... I_0 [2]

[Total: 8]

- 5 (a) Explain why the gravitational field strength is equal to the acceleration of free fall.

.....

.....

.....

..... [2]

- (b) The mean radius of the Earth is 6370 km.

Show that the mass of the Earth is 5.97×10^{24} kg.

[1]

- (c) Determine the gravitational potential at the surface of the Earth.

gravitational potential = ... J kg⁻¹ [1]

- (d) Explain why the gravitational potential is negative.

.....

.....

.....

..... [2]

[Total: 6]

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- 6 (a) State the principle of superposition.

.....
 [1]

- (b) A 15.0 m long glass tube has a loudspeaker, connected to a signal generator, placed at one end.

A microphone connected to a cathode-ray oscilloscope (CRO) can be moved through the tube as shown in Fig. 6.1.

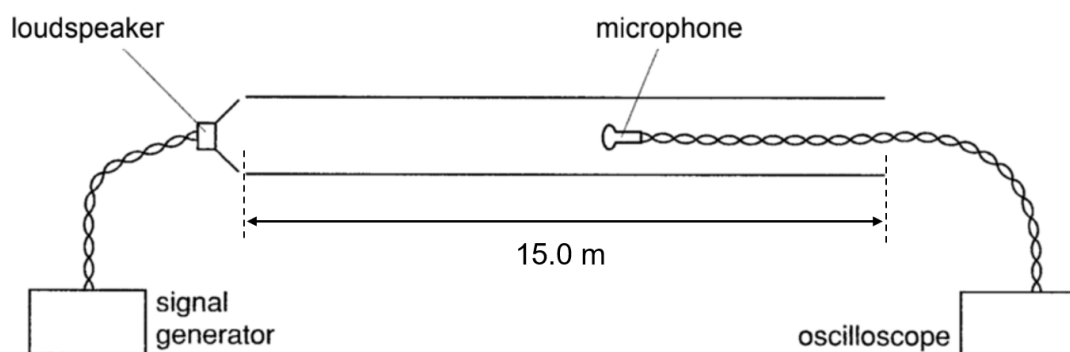


Fig. 6.1

State the conditions for the formation of a stationary wave and explain how an observable stationary wave is formed in the long glass tube.

.....

 [3]

- (c) The speaker produces sound waves with speed 320 m s^{-1} and an amplitude of 0.060 mm .
The frequency of the wave is adjusted until a loud sound is heard.

- (i) State the maximum amplitude of the stationary wave

maximum amplitude = ... mm [1]

- (ii) The microphone is moved from one end to the other within the 15.0 m long glass tube and detects a total of three pressure antinodes.

Complete Fig. 6.2 to represent the stationary wave in the glass tube.

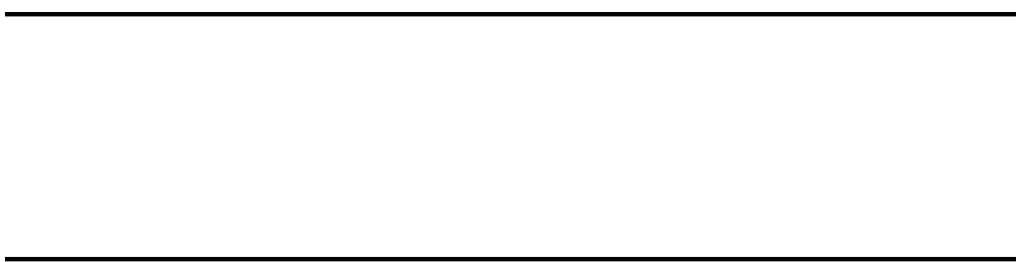


Fig. 6.2

[2]

- (iii) Using your answer in (c)(ii), determine the frequency of the stationary wave.

frequency = ... Hz [1]

[Total: 8]

- 7 The radioactive isotope of Bismuth $^{210}_{83}\text{Bi}$ decays into Polonium Po with the emission of a beta particle.

(a) (i) Write down the equation representing the beta decay of $^{210}_{83}\text{Bi}$.

.....[2]

(ii) State two quantities that are conserved in any radioactive decay process.

.....

.....[2]

(b) (i) The mass of a $^{210}_{83}\text{Bi}$ nucleus is 209.939u.

Show that its mass defect is 1.767u.

(mass of proton, $m_p = 1.00729\text{u}$; mass of neutron, $m_n = 1.00867\text{u}$)

[2]

(ii) Calculate the binding energy per nucleon, in MeV, of $^{210}_{83}\text{Bi}$. Leave your answer to 3 significant figures.

binding energy per nucleon = ... MeV [2]

[Total: 8]

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SECTION B

Answer any ONE of the two questions

- 8 A particle of mass m and charge q , is initially at rest at the midpoint between two parallel plates. A potential difference V_0 is applied across the plates.

The particle accelerates towards the upper plate and enters into a region with a uniform magnetic flux density B , directed perpendicularly out of the page. There is no magnetic field anywhere else. A snippet of the particle's path is shown in Fig. 8.1.

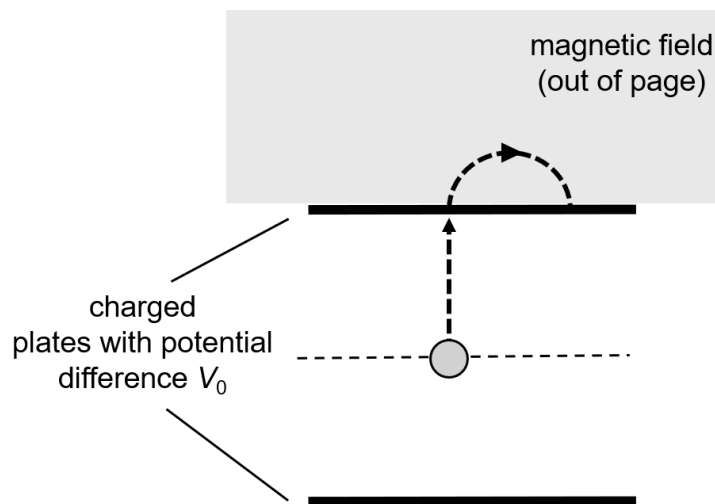


Fig. 8.1

(a) Explain

1. why the charged particle in Fig. 8.1 is positively charged,

.....

 [2]

2. and which plate has a higher electric potential.

.....

 [2]

- (b) (i) Show that the magnitude of the potential difference between the top plate and the midpoint between the plates is:

$$\Delta V = \frac{V_0}{2}$$

[1]

- (ii) Using your answer in (b)(i), show that the velocity of the particle when it first enters the magnetic field is:

$$v = \sqrt{\frac{qV_0}{m}}$$

[1]

- (c) Explain whether the speed of the particle increases while it is in the magnetic field.

.....

 [2]

- (d) Show that the time travelled in the magnetic field can be expressed as

$$t = \frac{m\pi}{Bq}$$

[4]

- (e) The mechanism shown in Fig. 8.1 forms the basis of a classical cyclotron.

Instead of two parallel plates, the cyclotron consists of two hollow, D-shaped metal electrodes (known as dees) separated by a narrow central gap. The dees are housed in a vacuum chamber within the uniform magnetic field of flux density B directed perpendicularly out of the page.

An alternating high-voltage source produces an electric field across the gap.

When the charged particle is released at the centre, it is accelerated across the gap into the upper dee. Shielded from the electric field inside the hollow metal dee, the magnetic field bends the particle into a semicircular path.

Upon exiting back into the gap, the electric field reverses polarity, accelerating the particle into the lower dee at a higher speed. This process repeats, producing an expanding spiral path until the particle exits the cyclotron.

This is shown in Fig. 8.2.

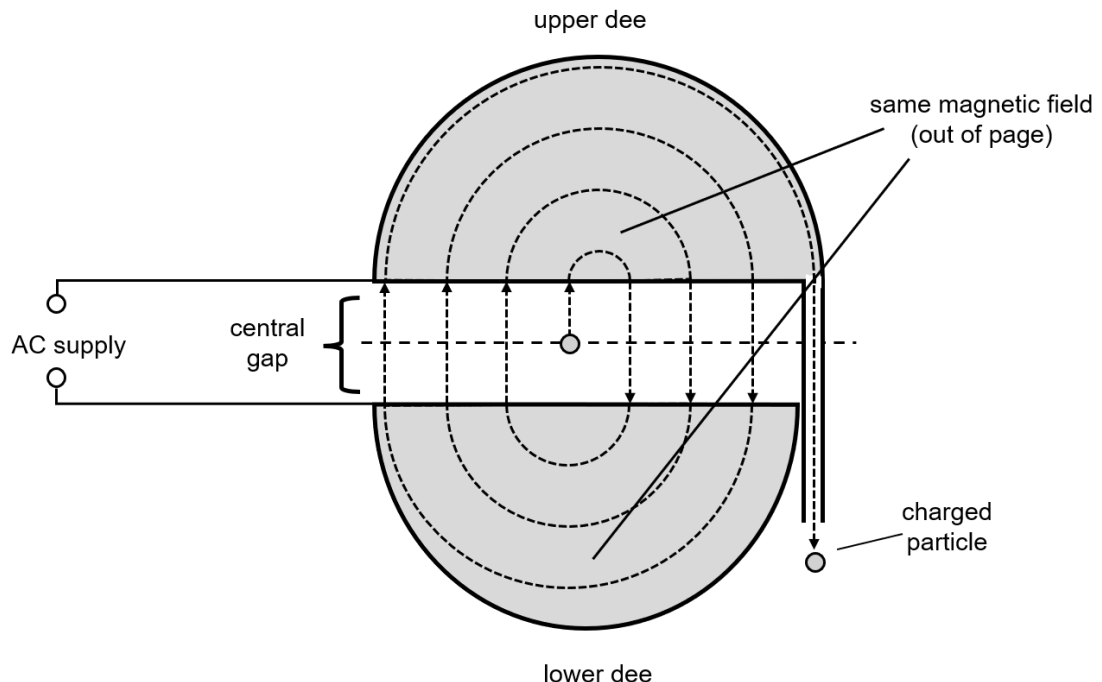


Fig. 8.2

A man claims that the time travelled in each dee is the same as that found in (d).

State and explain if his claim is true.

.....

.....

.....

..... [2]

- (f) The alternating voltage supply is a square wave that switches its polarity at constant time intervals equal to the time taken for the particle to complete a semicircle inside each dee.

This is shown in Fig. 8.3.

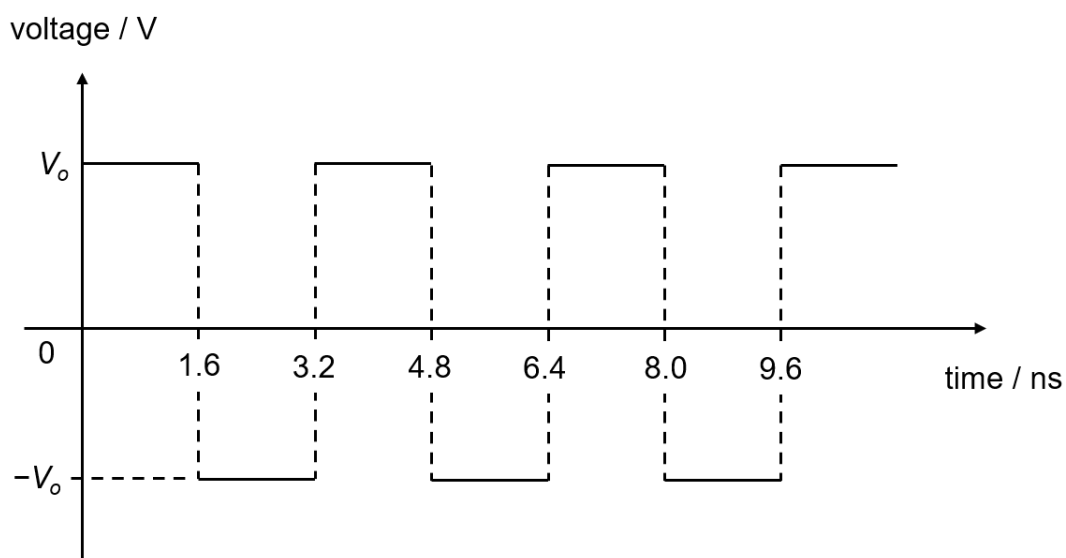


Fig. 8.3

Given that the charge to mass ratio of the particle is $1.0 \times 10^8 \text{ C kg}^{-1}$, using the equation in (d), determine the magnetic flux density in the dees.

You may assume that the time taken for the charged particle to travel the central gap is negligible.

magnetic flux density = ... T [2]

- (g) Determine the kinetic energy of the charge when it first enters the lower dee, leaving your answer in q and V_0 .

kinetic energy = ... [2]

- (h) The particle leaves the cyclotron with a kinetic energy of $6.5 qV_0$.

Determine the number of times it travels in the lower dee before leaving the cyclotron.

number = ... [2]

[Total: 20]

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- 9 (a) The state of a sub-atomic particle is represented by a wavefunction $\psi(x)$.

Explain

- (i) the physical meaning of the square of the wavefunction amplitude $|\psi(x)|^2$;

.....
 [1]

- (ii) how the probability of the particle residing in the region between two positions, x_1 and x_2 , can be determined.

.....
 [1]

- (b) An electron is confined in a one-dimensional infinite potential well of width L . The wavefunction of the electron is

$$\psi(x) = \begin{cases} A \sin \frac{n\pi x}{L}, & 0 < x < L \\ 0, & x \leq 0 \text{ or } x \geq L \end{cases}$$

where n is a positive integer and A the normalization factor.

For a particular value of n , the wavefunction is shown in Fig. 9.1.

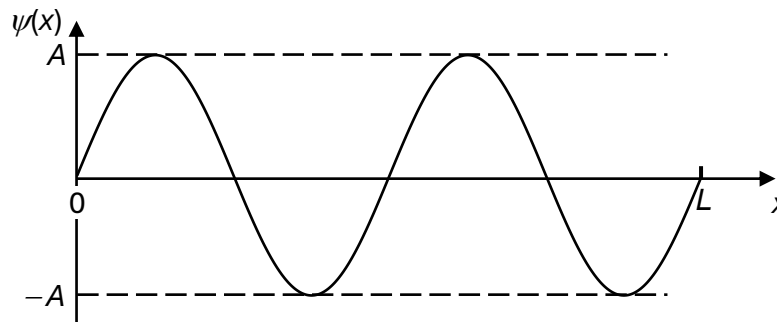


Fig. 9.1

- (i) State the value of n for the wavefunction plotted in Fig. 9.1.

$n = \dots\dots\dots$ [1]

- (ii) Determine an expression for A in terms of L .

$A = \dots\dots\dots$ [3]

- (iii) Determine the probability of finding the particle between $x = \frac{L}{8}$ and $x = \frac{L}{2}$.

probability = ... [2]

- (iv) The one-dimensional well is of length $L = 3.5 \times 10^{-10}$ m.

Determine the energy, in eV, of the quantum state shown in Fig. 9.1.

energy = ... eV [2]

- (c) (i) A beam of white light passes through a cool, low-pressure gas before it is diffracted by a diffraction grating that is placed perpendicular to the direction of the beam. The resulting beam of light is observed on a screen.

1. State the name of the spectrum observed on the screen.

Describe its appearance.

name:

appearance:

..... [2]

2. Explain the formation of the spectrum.

.....

.....

.....

.....

.....

.....

.....

..... [4]

- (ii) The white light source is removed, and the same gas is heated until it glows.

State the name of the spectrum observed on the screen.

Describe its appearance.

name:

appearance:

..... [1]

- (iii) The ground state energy of the atoms of the cold gas is -13.6 eV, and the first excited state energy is -3.4 eV.

Determine the wavelength of the photon corresponding to the transition between these two energy levels.

State which region of the electromagnetic spectrum this photon belongs to.

wavelength = ... nm

region of EM spectrum = ... [3]

[Total: 20]

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