Name: ______________________________ Class: _____________

JURONG PIONEER JUNIOR COLLEGE

JC2 Preliminary Examination 2024

PHYSICS **9749/03**

Higher 2 **11 September 2024**

Paper 3 Longer Structured Questions **2 hours**

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

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

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

Section A
Answer **all** questions.

Section B
Answer any **one** question only.

You are advised to spend about 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	
1	/ 6
2	/ 8
3	/ 9
4	/ 11
5	/ 8
6	/ 11
7	/ 7
8	/ 20
9	/ 20
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	$\varphi = -\frac{GM}{r}$
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	$I = Anvq$
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 A small parcel is released from a helicopter which is ascending steadily at 2.5 m s^{-1}.

(a) Neglecting air resistance, determine the speed of the parcel after 2.0 s.

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

(b) Sketch, on the same axes in Fig. 1.1, two graphs to show the variation with time of the velocities of the helicopter (label H) and the parcel (label P) during the first 2.0 s. [2]

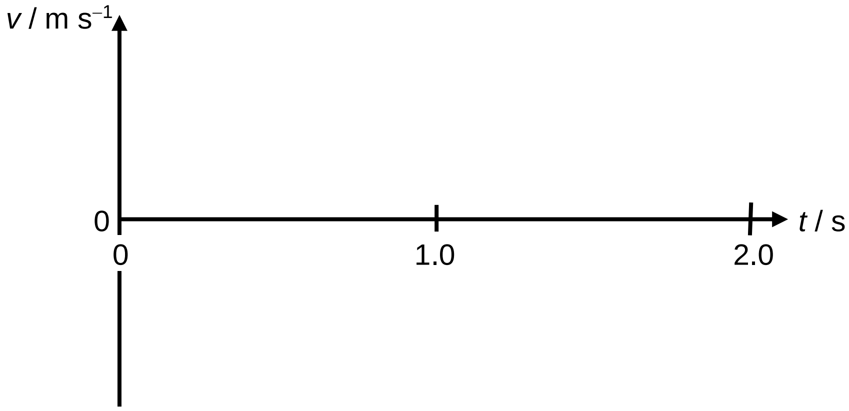

Fig. 1.1

(c) Using the sketched graphs, or otherwise, determine the distance between the helicopter and the parcel after 2.0 s.

distance = ……………….............. m [2]

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2 **(a)** Explain why the gravitational field strength near the surface of a planet is approximately constant for small changes in height.

....

....

.... [1]

(b) An isolated planet of uniform density has mass M and radius R.

Point P lies on a straight line passing through the centre of the planet, at a displacement x from the centre, as shown in Fig. 2.1.

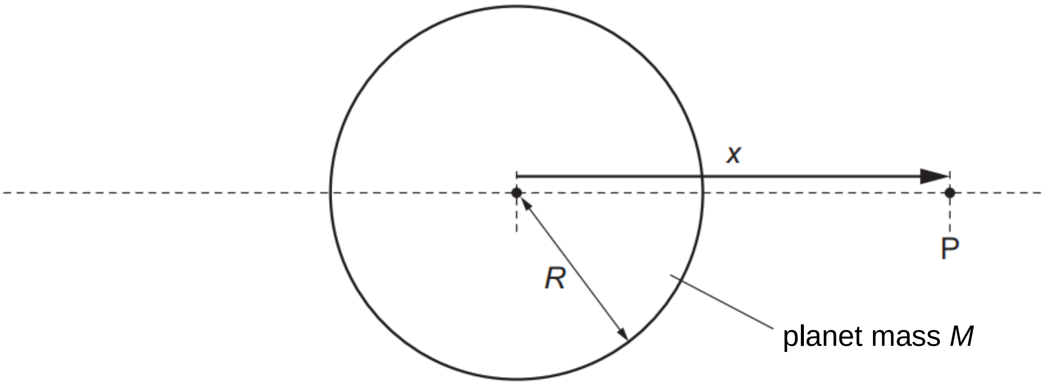


Fig. 2.1

Fig. 2.2 shows the variation with x of the gravitational field strength g at point P due to the planet for the values of x for which P is inside the planet.

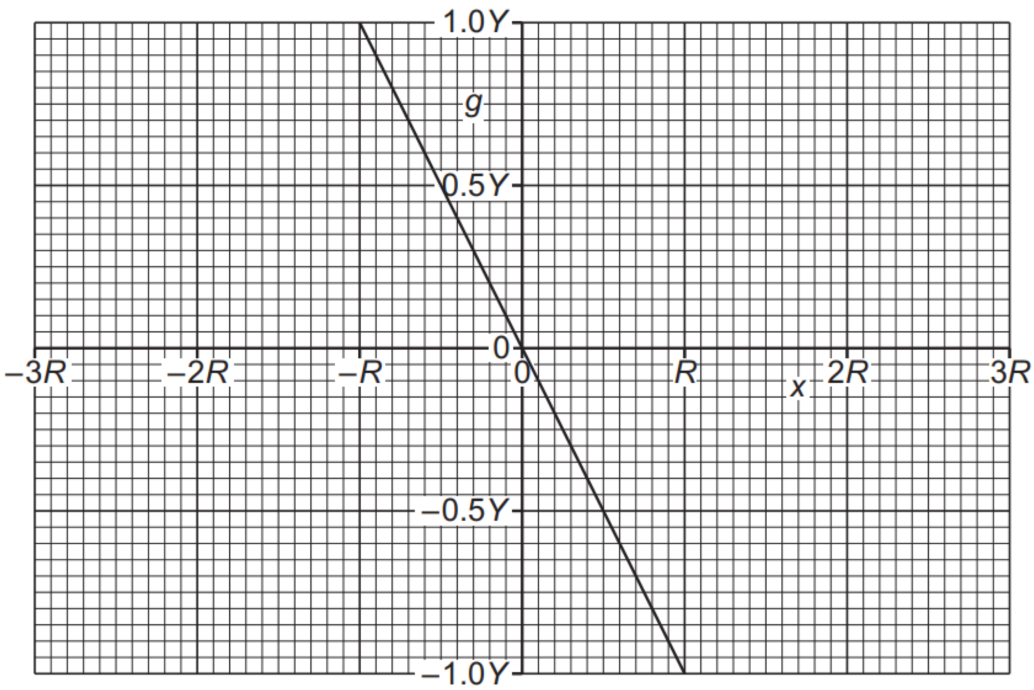


Fig. 2.2

The magnitude of the gravitational field strength at the surface of the planet is *Y*.

(i) State an expression for *Y* in terms of *M* and *R*. Identify any other symbols that you use.

[1]

(ii) Complete Fig. 2.2 to show the variation of *g* with *x* for values of *x*, up to $\pm 3R$, for which point P is outside the planet. [3]

(iii) A rock is projected vertically upwards from the surface of the planet with a speed of 4.7×10^3 m s^{-1}. The mass *M* of the planet is 6.4×10^{23} kg and the radius *R* of the planet is 3.4×10^6 m.

Calculate the distance travelled by the rock for it to lose half of its kinetic energy.

distance = ... m [3]

3 Two 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. 3.1.

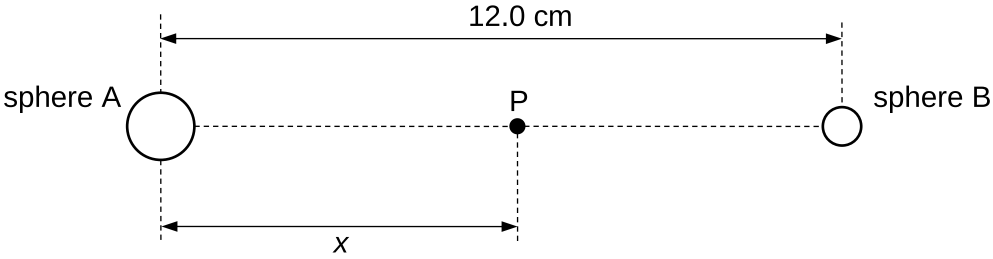


Fig. 3.1

The charge on each sphere may be assumed to be a point charge at the centre of the sphere. Point P is a variable point that lies on the line joining the centres of the spheres and is 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. 3.2.

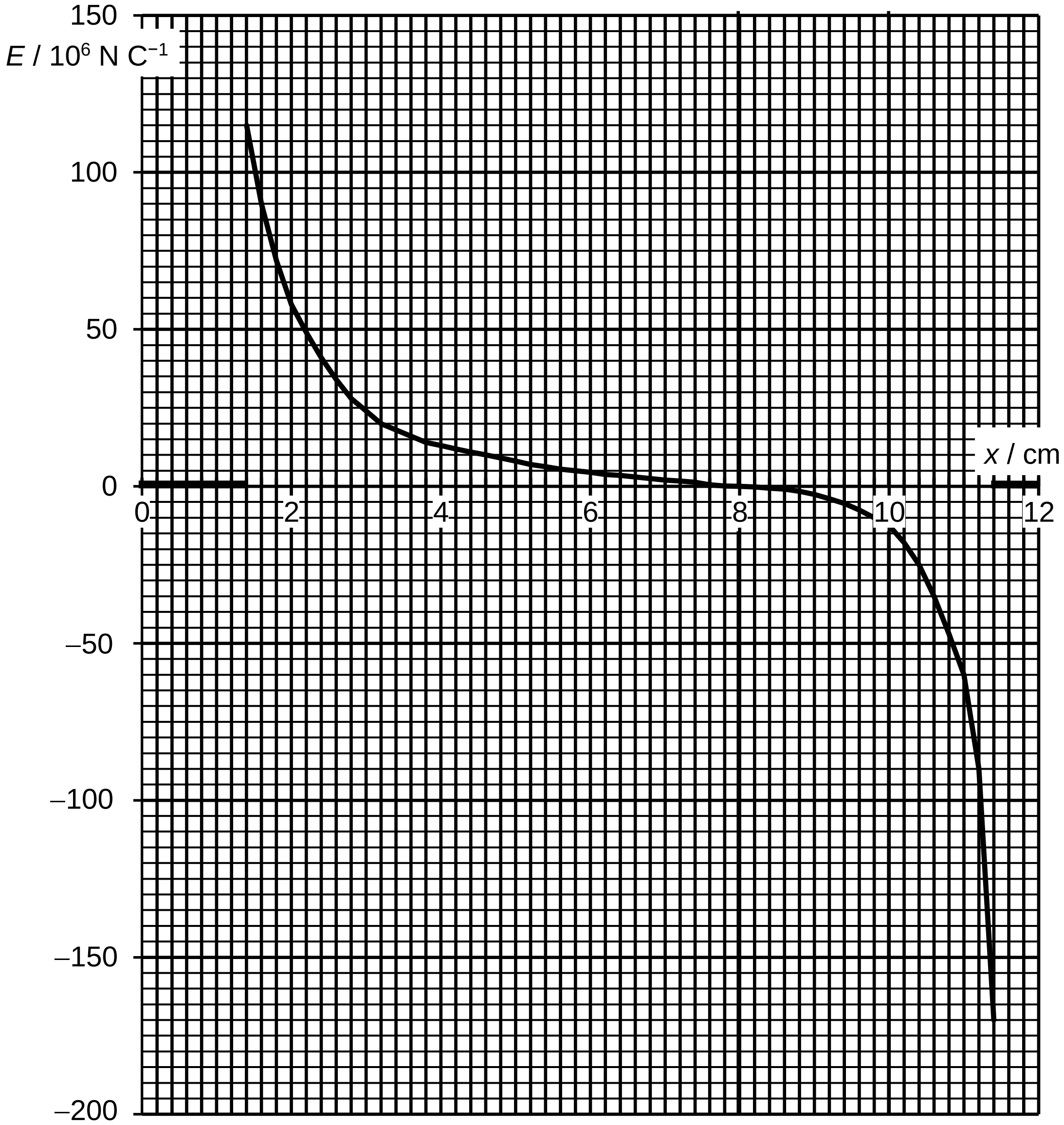


Fig. 3.2

(a) State the evidence provided by Fig. 3.2 that the spheres are conductors.

....

.... [1]

(b) The sphere A is positively charged.

(i) State and explain the polarity of sphere B.

....

....

....

.... [2]

(ii) Use Fig. 3.2 to determine the ratio $\dfrac{\text{charge on sphere A}}{\text{charge on sphere B}}$.

ratio = ... [2]

(c) **(i)** State, in words, the relation between electric field strength and electric potential.

.... [1]

(ii) A point charge of -2.0 μC is moved by an external force from x = 2.0 cm to x = 8.0 cm, along the line joining the centres of the spheres.

Use Fig. 3.2 to estimate the work done by the external force.

work done = ... J [3]

4 **(a)** State what is meant by *magnetic flux linkage*.

....

....

.... [2]

(b) Two coils, P and Q are wound onto an iron core, as shown in Fig. 4.1.

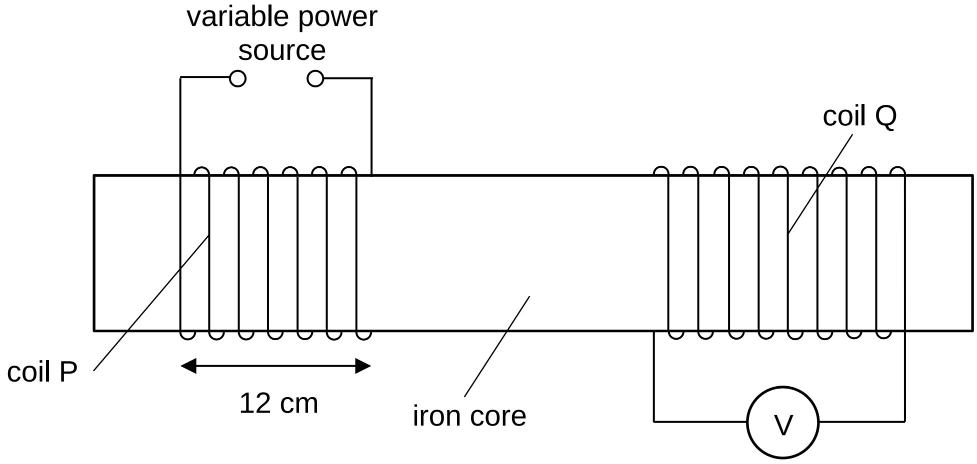


Fig. 4.1

Coil P contains 1800 turns of wire, has a length of 12 cm, and is connected to a variable power supply. Coil Q contains 2400 turns of wire and is connected to a voltmeter. The diameter of each turn of wire for both coils is 3.6 cm.

The variation with t of the current I in coil P is shown in Fig. 4.2.

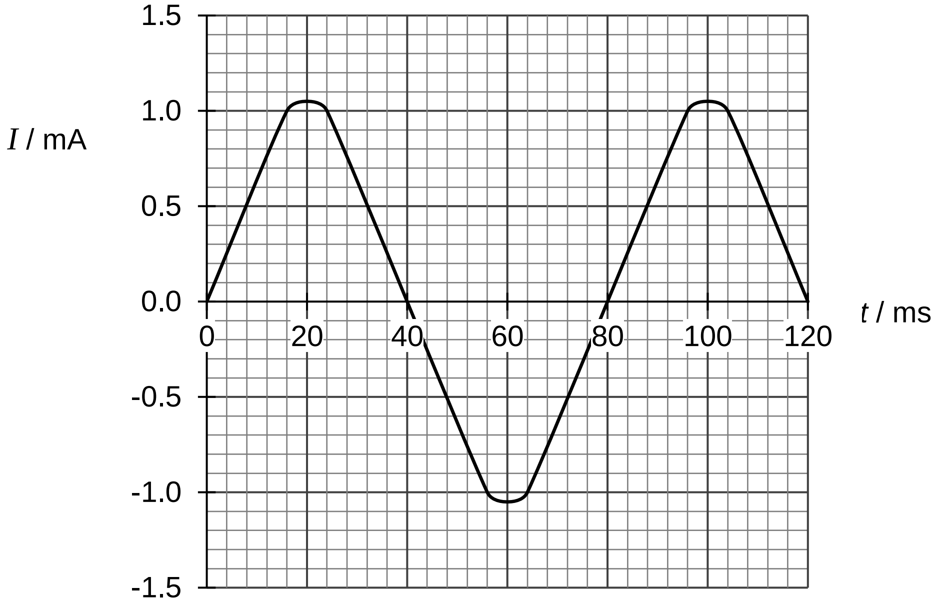


Fig. 4.2

(i) The permeability of the iron core is $1.0 \times 10^3\ \mu_0$.

Show that the maximum magnetic flux ϕ in the iron core is 2.0×10^{-5} Wb.

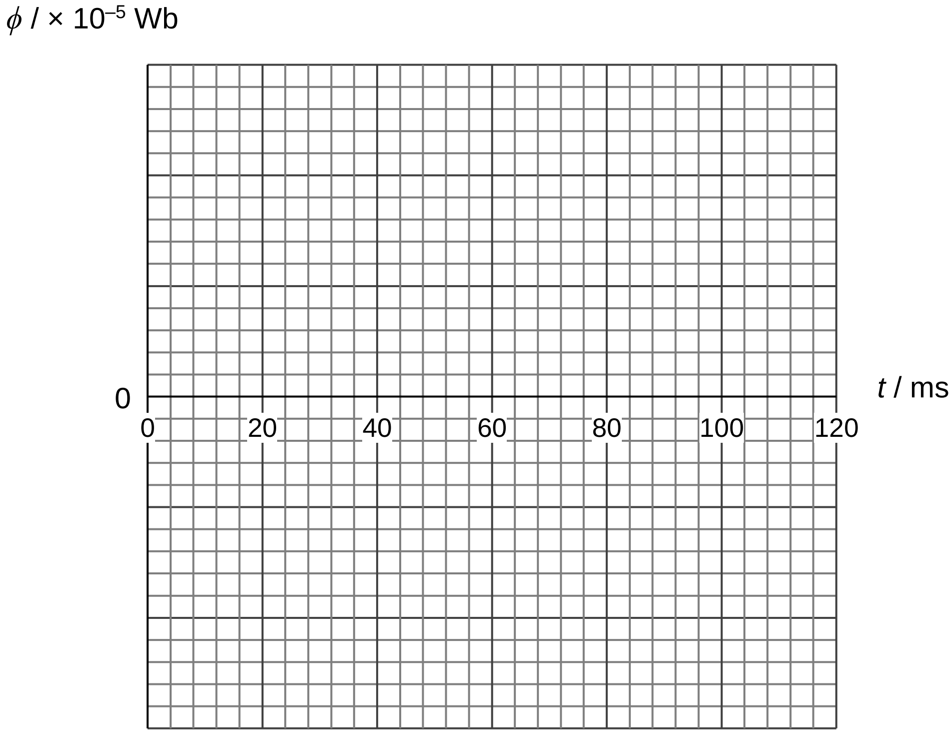
[2]

(ii) Determine the maximum reading recorded in the voltmeter.

reading = ... V [4]

(iii) Using your answers in **(i)** and **(ii)**, draw in Fig. 4.3 the variations with time t of the flux ϕ in the iron core and the reading V in the voltmeter.

Add a suitable scale to the vertical axis.



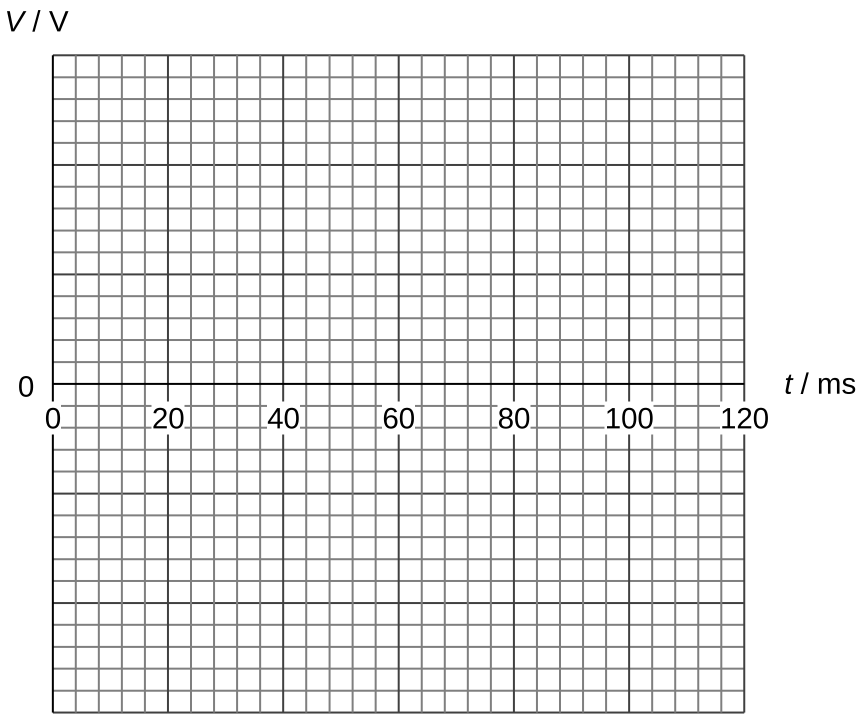


Fig. 4.3

[3]

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5 Fig. 5.1 shows an ideal transformer, where the primary coil is connected to an alternating voltage supply of 20 V. The secondary coil is connected to an ideal ammeter and a fixed resistor R of resistance 50 Ω. The number of turns in the primary coil N_P is 25.

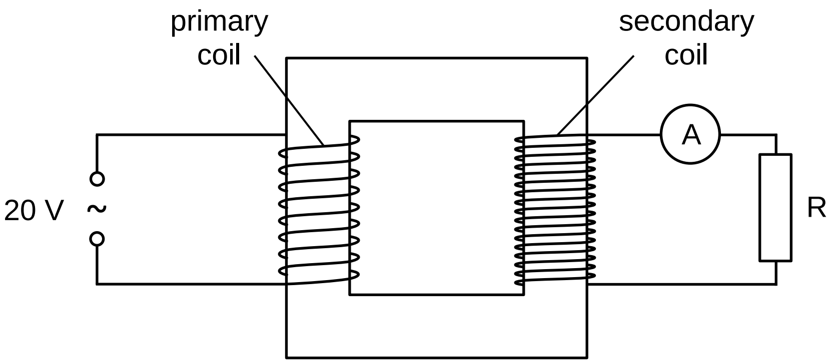

Fig. 5.1

Fig. 5.2 shows the variation with time t of the current I recorded from the ammeter.

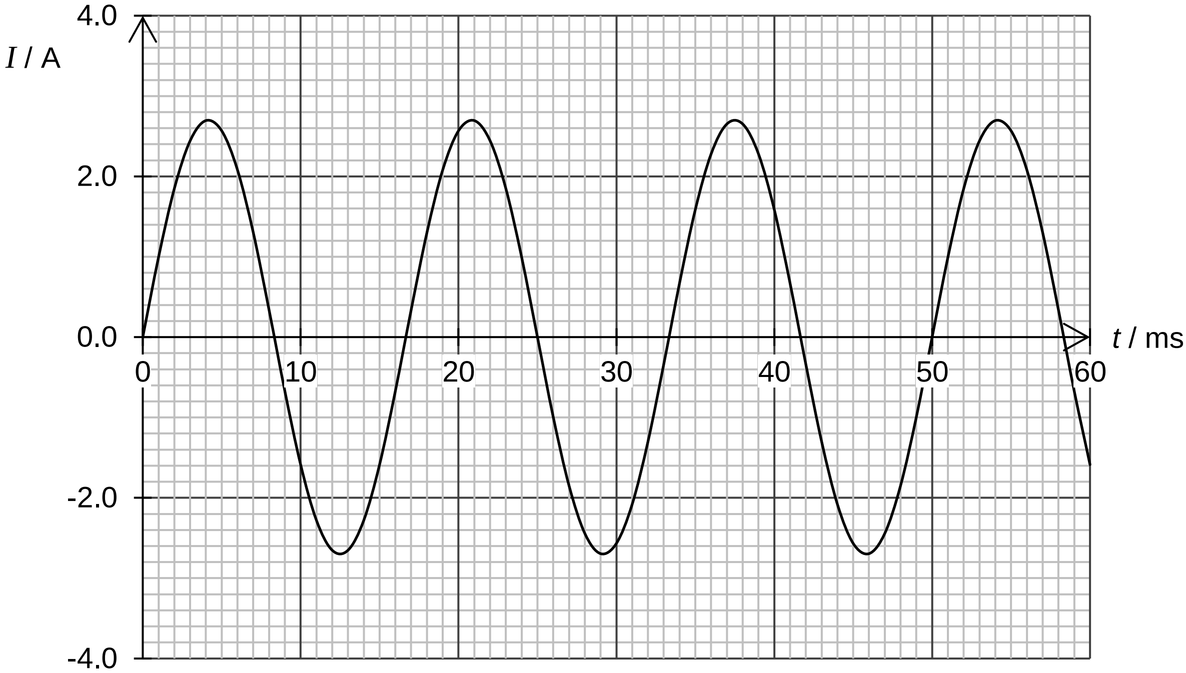

Fig. 5.2

(a) Determine the mean power dissipated across the resistor R.

mean power = ... W [2]

(b) Determine the number of turns in the secondary coil N_S.

N_S = ... [2]

(c) Determine the frequency of the alternating voltage supply. Explain your working.

frequency = ... Hz [2]

(d) Explain how your answer in **(a)** will be affected if the frequency of the alternating voltage supply is doubled, while the peak voltage of the supply remains the same.

....

....

.... [2]

6 **(a)** State what is meant by the term *threshold frequency* as applied to the photoelectric effect.

....

.... [1]

(b) In a typical set-up of the photoelectric experiment, a metal surface is illuminated with radiation of wavelength 450 nm, causing the emission of photoelectrons which are collected at an adjacent electrode.

(i) Calculate the energy of a photon incident on the surface.

energy = ... J [2]

(ii) The intensity of the incident radiation is 2.7×10^{3} W m^{-2} and the area of the metal surface is 3.0 cm^{2}.

Calculate the number of photons incident per second on the surface.

number per second = ... [2]

(iii) Fig. 6.1 shows a graph of how the photoelectric current I varies with the potential difference V between the electrodes.

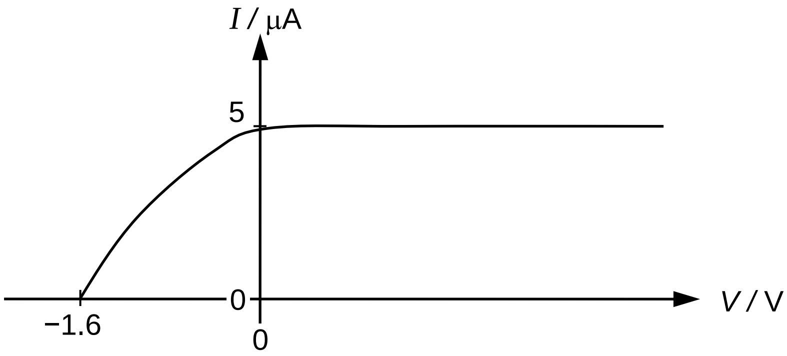

Fig. 6.1

Calculate the threshold wavelength of the metal.

wavelength = ... m [3]

(c) The X-ray spectrum is first produced by an X-ray tube with tungsten (atomic number, Z = 74). Another X-ray spectrum is produced using barium (atomic number, Z = 56) and both spectrums are as shown in Fig. 6.2.

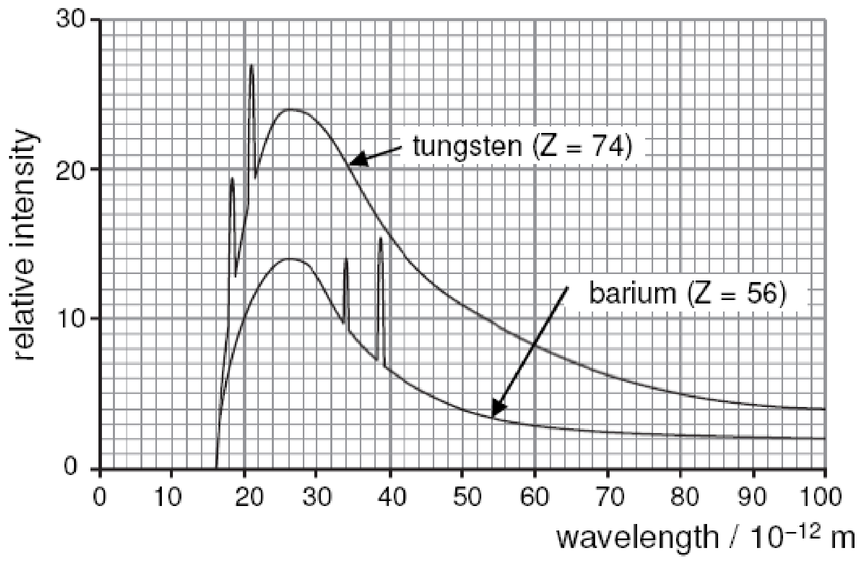

Fig. 6.2

(i) The accelerating potential used to produce the X-ray spectra using tungsten and barium are the same.

State a feature in Fig. 6.2 that shows how this can be deduced.

....

.... [1]

(ii) Determine the accelerating potential.

accelerating potential = ... V [2]

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7 **(a)** Define

(i) half-life,

....

.... [1]

(ii) decay constant.

....

.... [1]

(b) The presence of radioactive carbon-14 ($^{14}_{6}C$) is caused by the collision of neutrons with nitrogen-14 ($^{14}_{7}N$) in the upper atmosphere. The equation for the reaction is:

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + X$$

Data for some masses are given in Fig. 7.1.

nucleus	mass / *u*
carbon-14	14.003242
nitrogen-14	14.003158
neutron	1.008665

Fig. 7.1

(i) Use the data from Fig. 7.1 to determine the mass of the particle X in *u*, given that the amount of energy released in one such reaction is 0.7060 MeV.

mass = ... *u* [3]

(ii) The mass of carbon-14 produced by this reaction in one year is 7.5 kg. The molar mass of carbon-14 is 14 g. The half-life of carbon-14 is 5.7×10^3 years.

1. Determine the number of carbon-14 atoms produced each year.

number of atoms = ……………….............. [1]

2. Determine the probability of decay of a carbon-14 nucleus in a time of 1.0 year.

probability = ……………….............. [1]

Section B

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

8 **(a)** State what is meant by *simple harmonic motion*.

....

....

....

.... [2]

(b) An electric toothbrush has a circular brush head of diameter 12 mm as shown in Fig. 8.1.

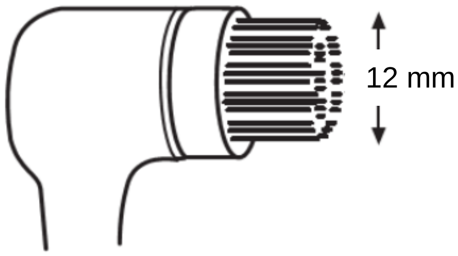


Fig. 8.1

The toothbrush has two settings.

On setting 1, the brush head vibrates with simple harmonic motion with a frequency of 33 Hz. From its leftmost position, it moves a maximum horizontal distance of 4.2 mm as shown in Fig. 8.2.

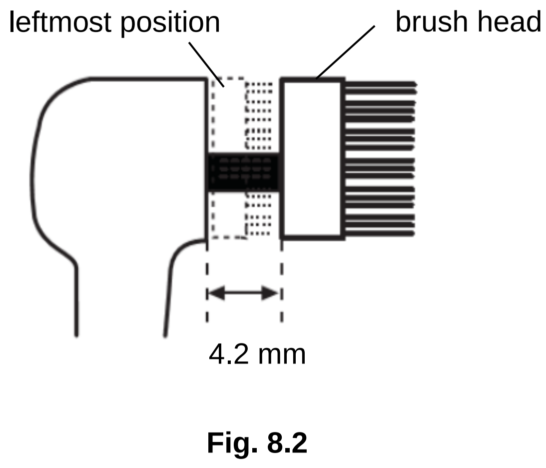


Fig. 8.2

(i) Using the information provided, write an expression for the variation with time t of displacement x, in metres, of the brush head from its equilibrium position.

x = ... [2]

(ii) Determine the speed of the brush head when it has moved a horizontal distance of 0.8 mm to the right from its leftmost position.

Explain your working.

speed = ... m s^{-1} [3]

(c) On setting 2, the brush head can be considered to oscillate with simple harmonic motion with amplitude *A* as shown in Fig. 8.3.

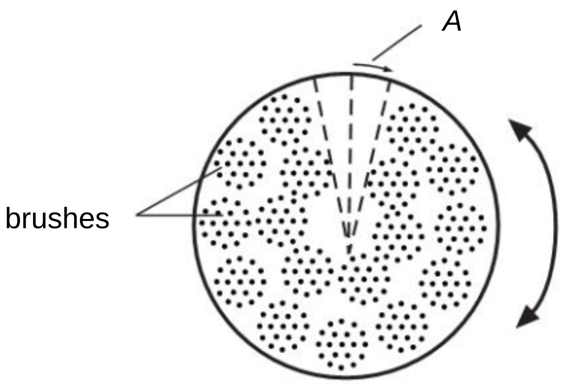


Fig. 8.3

The velocity, in m s^{-1}, of a point on the circumference of the head can be given by the expression

$$v = 9.2 \times 10^{-2} \cos 77t$$

Determine *A*.

A = ... m [2]

(d) Fig. 8.4 shows a particle of toothpaste of mass 2.5×10^{-6} kg on the edge of the brush head.

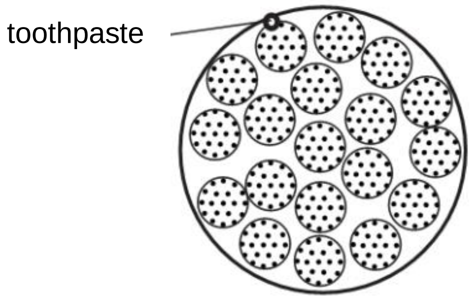


Fig. 8.4

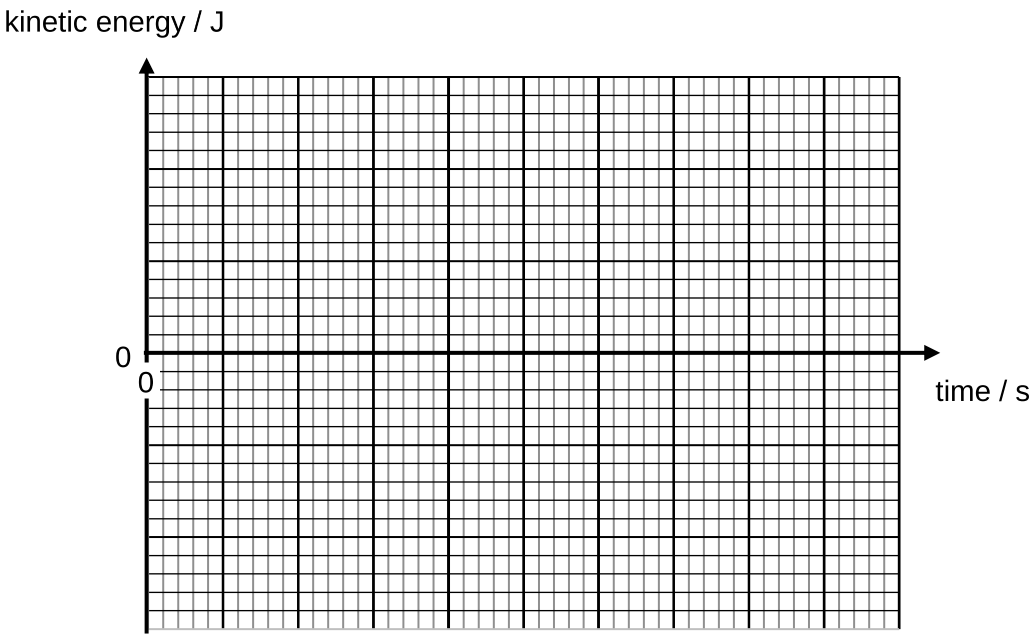
The switch is on setting 2.

(i) Calculate the maximum kinetic energy of the particle of toothpaste.

maximum kinetic energy = ... J [2]

(ii) On the axes of Fig. 8.5, sketch a graph of the variation of the kinetic energy of the particle with time over two periods. Appropriate numerical values are required on both axes.

Add suitable scales to both axes.



[3]

Fig. 8.5

(iii) Determine the time interval between the maximum linear velocity of the toothpaste and its subsequent maximum linear acceleration when both are in the same direction.

time = ... s [2]

(e) The brush head is rotated by a machine whose oscillations are simple harmonic. A component of mass 0.0460 kg in the toothbrush was forced into oscillations when the machine is in use. Fig. 8.6 shows how the amplitude of the oscillation varies with frequency.

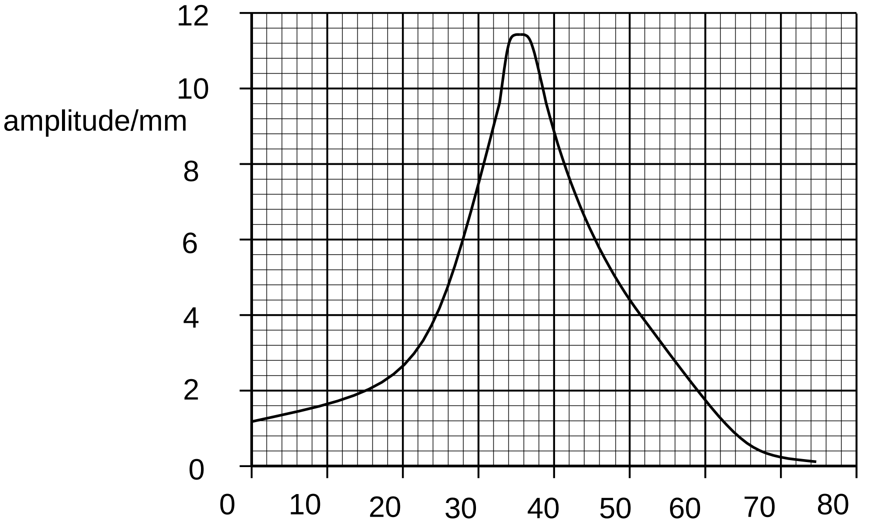


Fig. 8.6

(i) State

1. what is meant by a *forced* oscillation,

....

.... [1]

2. the name of the effect observed at a frequency of 35 Hz in Fig. 8.6.

....

.... [1]

(ii) Draw on Fig. 8.6 to show how the amplitude of the oscillation varies with frequency if the component is supported on a rubber mounting.

[2]

9 An ideal gas has a volume and mass of 500 cm^3 and 0.23 g respectively, at a pressure of 80 kPa and temperature of 250 K.

(a) The gas is first compressed at a constant pressure, such that the temperature of the gas changes to 180 K.

(i) Determine the work done on the gas.

work done = ... J [3]

(ii) Determine change in the internal energy of the gas.

change in internal energy = ... J [2]

(iii) Determine the heat loss by the gas in the process.

heat loss = ... J [1]

(b) The gas is then heated at constant volume, until the temperature reaches 250 K.

(i) Determine the pressure of the gas at 250 K.

pressure = ... kPa [2]

(ii) Determine the specific heat capacity of the gas at constant volume. Explain your working.

specific heat capacity = ... J kg^{-1} K^{-1} [3]

(iii) Determine the root-mean-square speed of the gas particles after it has been heated to 250 K.

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

(iv) State and explain how your answer in **(iii)** would vary if a greater amount of the same gas were to be heated to the same temperature.

....

....

.... [2]

(c) The gas now undergoes an expansion at constant temperature, until the volume of the gas reaches 500 cm^3 and the gas returns to its original state.

In Fig. 9.1, sketch the variation with volume of the pressure of the gas as it undergoes a cycle of the following processes:

(i) compression at constant pressure in **(a),**

(ii) heating at constant volume in **(b)**,

(iii) expansion at constant temperature in **(c)**.

Appropriate numerical values are required on both axes.

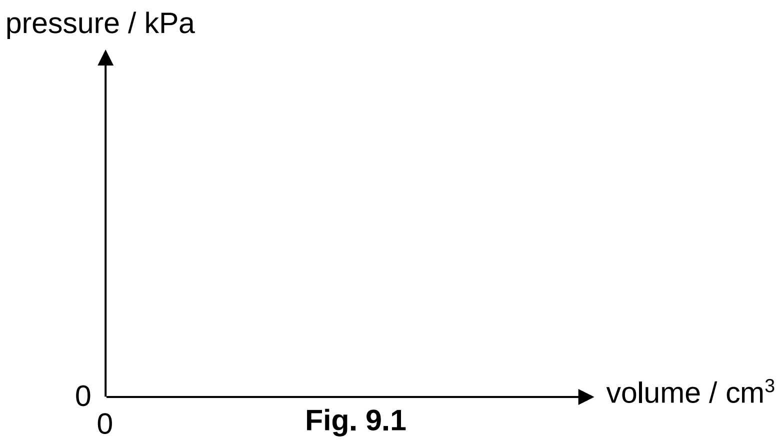


Fig. 9.1

[3]

(d) State and explain whether heat is gained or lost by the gas in one cycle of the processes in **(c)**.

....

....

....

.... [2]

End of paper