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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

5924230129

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **October/November 2024**

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **24** pages. Any blank pages are indicated.

DC (PB/FC) 336256/3

Data

acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19}\ \text{C}$
unified atomic mass unit	$1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
molar gas constant	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$ $(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

gravitational potential	$\phi = -\frac{GM}{r}$
gravitational potential energy	$E_P = -\frac{GMm}{r}$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm\omega\sqrt{(x_0^{\,2} - x^2)}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
electrical potential energy	$E_P = \frac{Qq}{4\pi\varepsilon_0 r}$
capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
discharge of a capacitor	$x = x_0 e^{-\frac{t}{RC}}$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 e^{-\lambda t}$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$
intensity reflection coefficient	$\frac{I_R}{I_0} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$
Stefan–Boltzmann law	$L = 4\pi\sigma r^2 T^4$
Doppler redshift	$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$

1 A metal wheel consists of an axle A, eight spokes and a rim, as shown in Fig. 1.1.

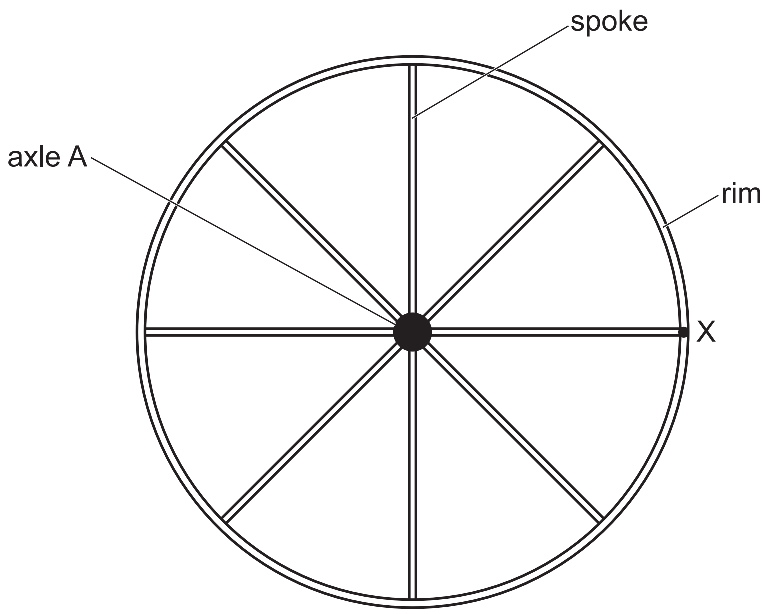

Fig. 1.1

Point X is on the rim at the end of one of the spokes.

The rim has a radius of 0.85 m.
The wheel is rotating clockwise with an angular speed of 140 rad s^{-1}.

(a) For point X, determine:

(i) the speed

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

(ii) the centripetal acceleration.

acceleration = ... $m s^{-2}$ [2]

(b) There is a uniform magnetic field of flux density 0.18 T into the plane of the page.

(i) State Lenz's law of electromagnetic induction.

....

....

.... [2]

(ii) Show that the time taken for point X to complete one revolution is 45 ms.

[1]

(iii) Calculate the magnetic flux cut by spoke AX during one revolution of the wheel.
Give a unit with your answer.

magnetic flux = ... unit .... [3]

(iv) Determine the magnitude of the electromotive force (e.m.f.) induced across spoke AX.

induced e.m.f. = ... V [2]

(v) Use Lenz's law to explain whether the potential is higher at end A or end X of the spoke.

....

....

.... [1]

[Total: 13]

2 The Sun may be considered as a uniform sphere with a mass of 1.99×10^{30} kg and a surface temperature of 5780 K.

A probe with a mass of 2.63 kg moves in a straight line towards the Sun.
When it is at a distance x from the centre of the Sun, the probe measures the gravitational field strength g due to the Sun and the radiant flux intensity F of radiation from the Sun.

(a) Define gravitational field.

....

.... [1]

(b) For the position of the probe where $x = 1.47 \times 10^{11}$ m:

(i) calculate g

g = ... N kg^{-1} [2]

(ii) determine the gravitational potential energy E_P of the probe.

E_P = ... J [2]

(c) **(i)** Show that, for any particular value of x, the numerical values of g and F are related by

$$g = \frac{4\pi GM}{L} F$$

where M is the mass of the Sun, L is the luminosity of the Sun and G is the gravitational constant.

[3]

(ii) Fig. 2.1 shows the variation of g with F.

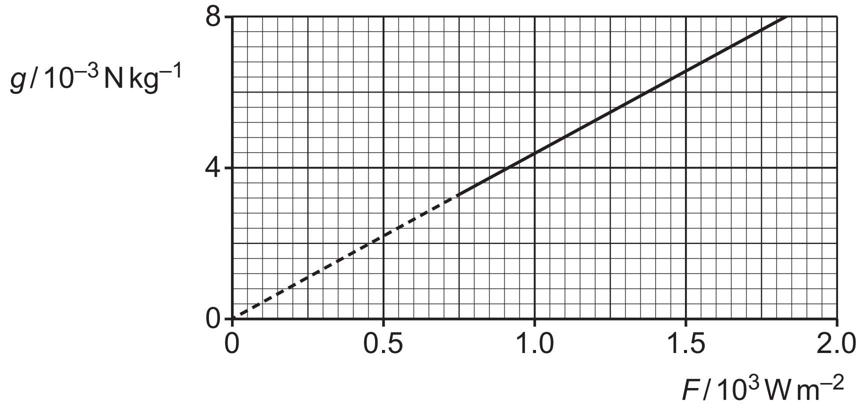

Fig. 2.1

Determine a value for the luminosity L of the Sun. Give a unit with your answer.

L = ... unit .... [2]

(iii) Use your answer in **(c)(ii)** to determine the radius r of the Sun.

r = ... m [2]

[Total: 12]

3 **(a)** Define specific latent heat.

....

....

.... [2]

(b) A dish containing $7.2 \times 10^{-5}\,m^3$ of a substance rests on a laboratory bench. The substance is initially a liquid of density $710\,kg\,m^{-3}$. Atmospheric pressure is $1.0 \times 10^5\,Pa$.

The liquid is heated at its boiling point so that it completely vaporises. The increase in the internal energy of the substance during this process is 17.6 kJ. The final volume of the vapour is $0.017\,m^3$.

(i) Show that the magnitude of the work done on the substance when it vaporises is 1.7 kJ.

[2]

(ii) Use the information in **(b)(i)** to calculate the thermal energy Q, in kJ, supplied to the substance to cause it to vaporise.

Q = ... kJ [2]

(iii) Use your answer in **(b)(ii)** to determine a value for the specific latent heat of vaporisation L_V, in $kJ\,kg^{-1}$, of the substance.

L_V = ... $kJ\,kg^{-1}$ [2]

(c) The substance in **(b)** has a specific latent heat of fusion L_F.

Suggest and explain whether L_F is likely to be less than, the same as, or greater than the answer in **(b)(iii)**.

....

....

....

....

.... [3]

[Total: 11]

4 **(a)** State **three** of the basic assumptions of the kinetic theory of gases.

1 ....

....

2 ....

....

3 ....

.... [3]

(b) Explain how molecular movement causes the pressure exerted by a gas.

....

....

....

....

.... [3]

(c) Fig. 4.1 shows the variation with thermodynamic temperature T of the mean-square speeds $\langle c^2 \rangle$ for two gases X and Y.

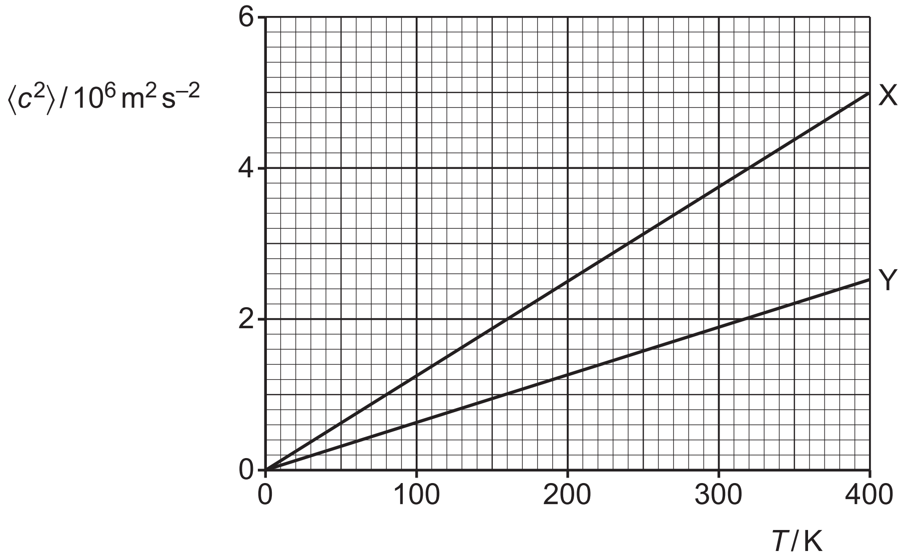

Fig. 4.1

Fig. 4.2 shows the variation with T of the product pV for samples of the two gases, where p is the pressure of the gas and V is the volume of the gas.

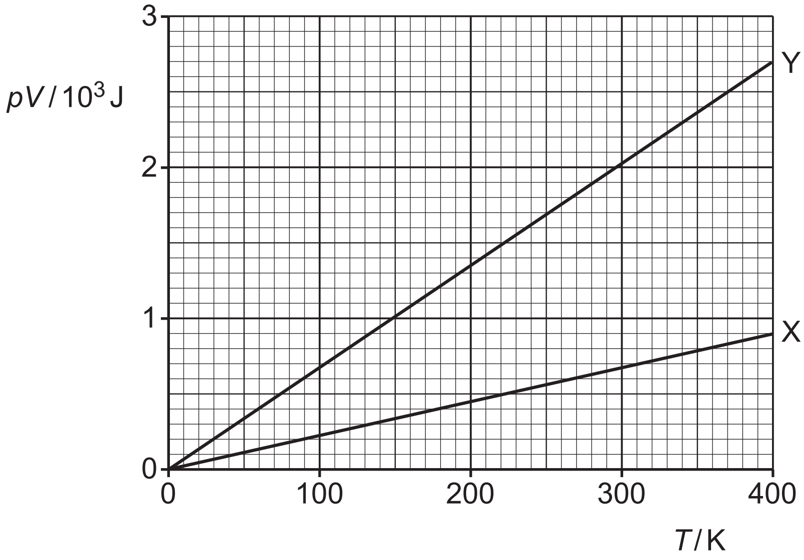

Fig. 4.2

State **three** conclusions about the gases and their samples that may be drawn from Fig. 4.1 and Fig. 4.2. The conclusions may be qualitative or quantitative. Use the space below for any working that you need.

1 ....

....

2 ....

....

3 ....

....
[3]

[Total: 9]

5 Fig. 5.1 shows a pendulum consisting of a metal sphere suspended by a thin string.

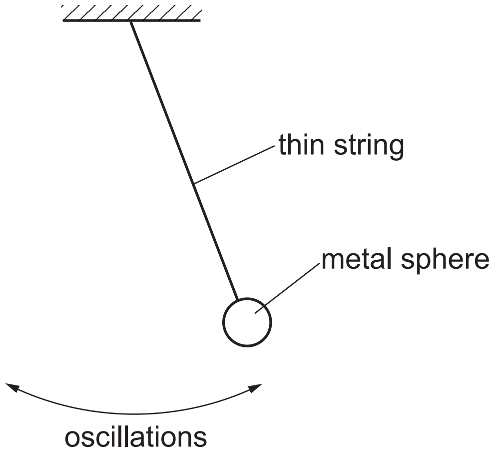

Fig. 5.1 (not to scale)

The sphere undergoes small oscillations about its equilibrium position. The oscillations may be considered to be simple harmonic.

Fig. 5.2 shows the variation with time t of the displacement x of the sphere from its equilibrium position.

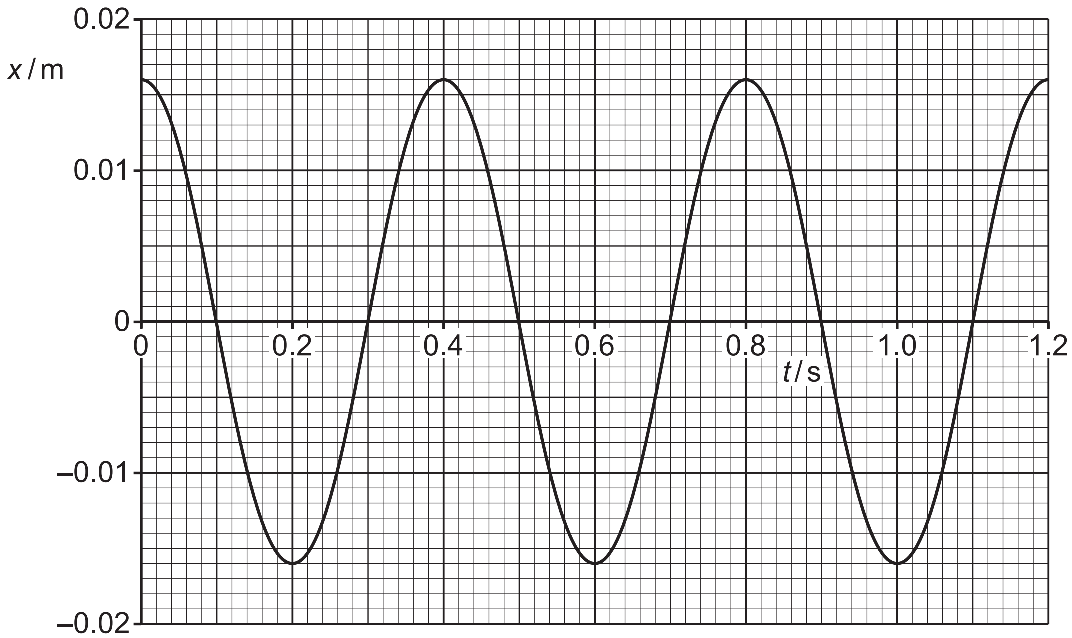

Fig. 5.2

(a) On Fig. 5.1, draw an arrow, from the centre of the sphere, to represent the direction of the resultant force acting on the sphere when it is in the position shown. [1]

DO NOT WRITE IN THIS MARGIN

(b) The mass of the sphere is 0.15 kg.

(i) State the amplitude of the oscillations.

amplitude = ... m [1]

(ii) Determine the angular frequency of the oscillations.

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

(iii) Calculate the total energy of the oscillations.

total energy = ... J [2]

(c) On Fig. 5.3, sketch the variation with x of the kinetic energy E_K of the sphere.

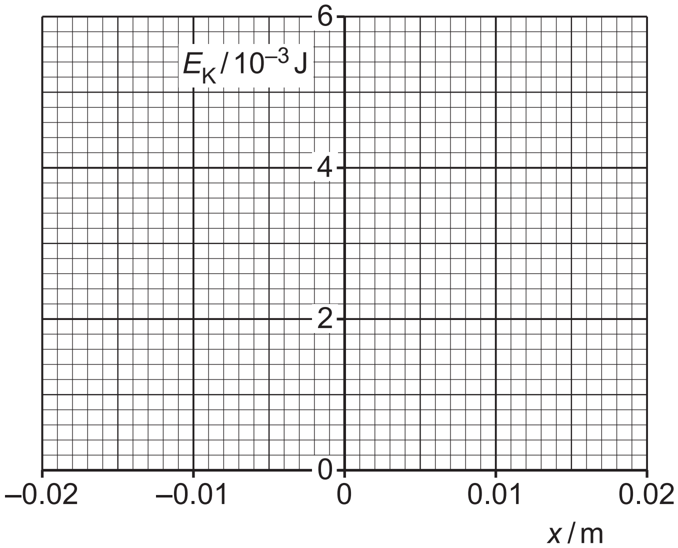

Fig. 5.3

[3]

[Total: 9]

6 (a) State Coulomb's law.

....

....

.... [2]

(b) Fig. 6.1 shows an isolated hollow conducting sphere that is positively charged.

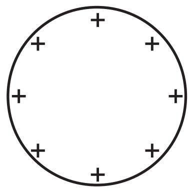

Fig. 6.1

On Fig. 6.1, draw field lines to represent the electric field outside the sphere. [3]

(c) Fig. 6.2 shows the variation of the electric field strength E with distance x from the centre of the sphere in **(b)**.

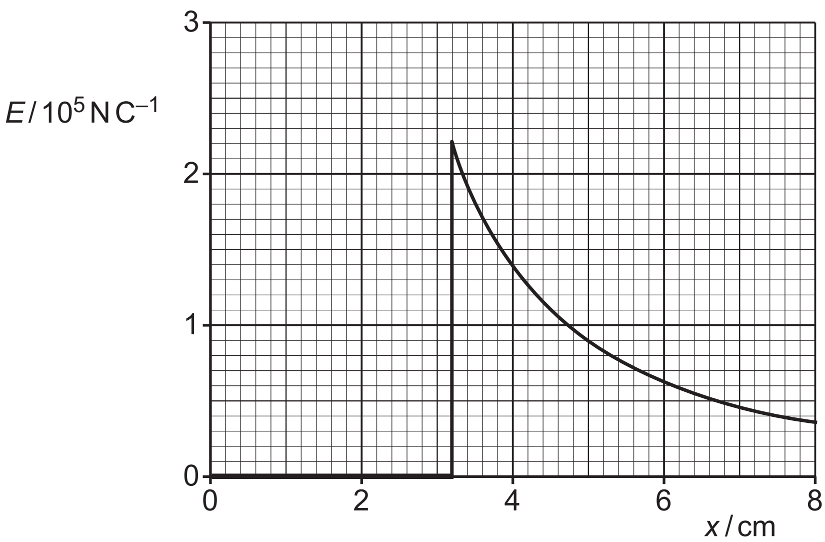

Fig. 6.2

(i) Determine the radius, in cm, of the sphere.

radius = ... cm [1]

(ii) Calculate the charge on the sphere.

charge = ... C [3]

(iii) Suggest an explanation for the fact that the electric field inside the sphere is zero.

....

....

.... [1]

[Total: 10]

7 **(a)** Define the capacitance of a parallel-plate capacitor.

....

....

.... [2]

(b) An initially uncharged capacitor X, of capacitance *C*, is gradually charged so that the final potential difference (p.d.) between its plates is *V* and the final charge is *Q*.

(i) On Fig. 7.1, sketch the variation of charge with p.d. for capacitor X as the p.d. increases from 0 to *V*.

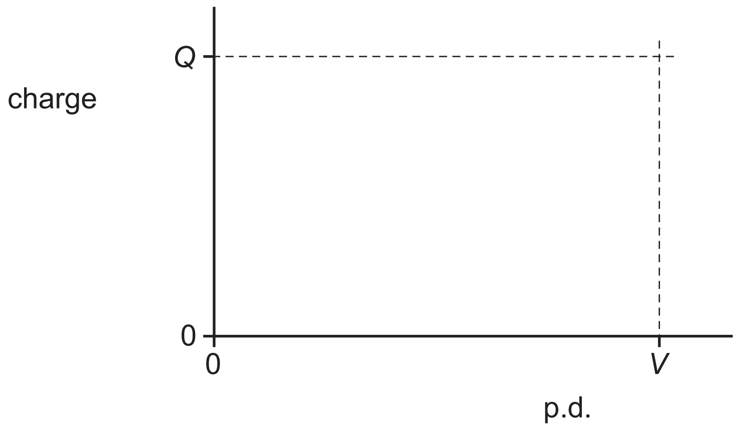

Fig. 7.1

[2]

(ii) Determine an expression, in terms of *Q* and *V*, for the work *W* done on capacitor X during the charging process. Explain your reasoning.

W = ... [2]

(c) Another capacitor Y is initially uncharged. The fully charged capacitor X in **(b)** is now connected to capacitor Y, as shown in Fig. 7.2.

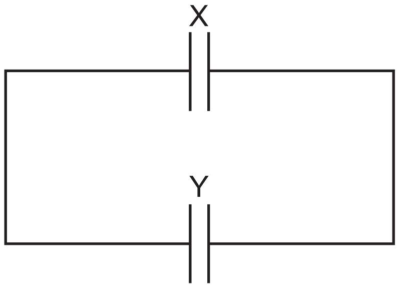

Fig. 7.2

The capacitance of capacitor Y is 3*C*.

(i) Complete Table 7.1 to show expressions, in terms of *Q* and *V*, for the final p.d.s across, and the final charges on, the two capacitors.
Use the space below for any working that you need.

Table 7.1

	X	Y
final p.d.		
final charge		

[3]

(ii) State whether the total energy stored in the two capacitors is less than, the same as, or greater than the energy initially stored in capacitor X.

.... [1]

[Total: 10]

8 **(a)** State what is meant by the frequency of an alternating current.

....

.... [1]

(b) An alternating current I in a resistor of resistance 680 Ω varies with time t according to

$$I = 3.5 \sin(40\pi t)$$

where I is in A and t is in s.

(i) Show that the period of the alternating current is 50 ms.

[1]

(ii) On Fig. 8.1, sketch the variation of I with t between t = 0 and t = 100 ms.

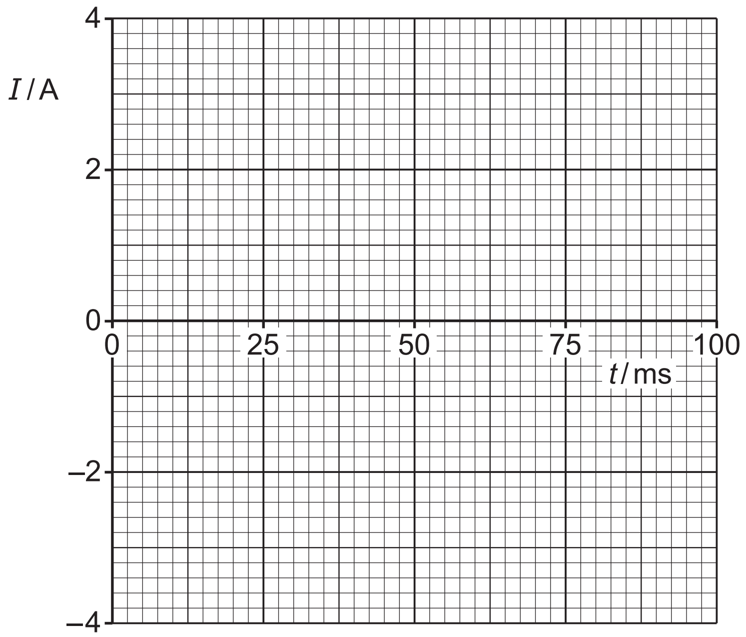

Fig. 8.1

[3]

(iii) Determine the root-mean-square (r.m.s.) current in the resistor.

r.m.s. current = ... A [1]

(c) Use data from **(b)**, including your answer in **(b)(iii)**, to show by calculation that the mean power in the 680 Ω resistor is half of the peak power.

[3]

[Total: 9]

9 Electrons in a vacuum are accelerated from rest through a potential difference (p.d.) V to form a beam. The electrons each have mass m and charge q.

The beam is incident on a graphite crystal that acts as a diffraction grating. After passing through the crystal, the beam reaches a fluorescent screen. An interference pattern is observed on this screen.

(a) Explain what this observation shows about the nature of electrons.

....

....

.... [1]

(b) Determine an expression, in terms of m, q and V, for the momentum p of an electron in the beam.

p = ... [3]

(c) The p.d. through which the electrons are accelerated is now increased to a greater value.

Describe and explain the effect of this change on the interference pattern observed.

....

....

.... [2]

(d) The electrons are now accelerated through different values of V, resulting in pairs of corresponding values for p and the de Broglie wavelength λ.

(i) On Fig. 9.1, sketch the variation of p with $\frac{1}{\lambda}$.

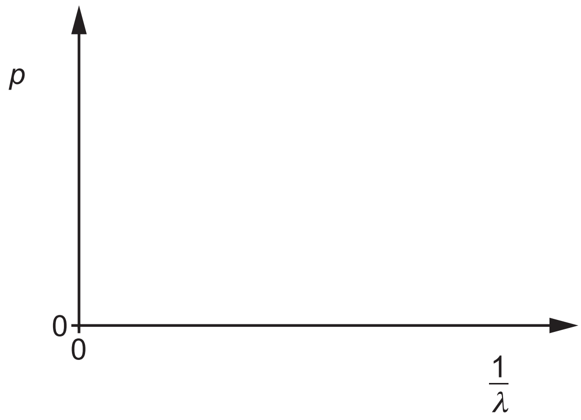

Fig. 9.1

[2]

(ii) State the name of the quantity represented by the gradient of the line in Fig. 9.1.

.... [1]

[Total: 9]

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10 **(a)** Radioactive decay is both random and spontaneous.

(i) State what is meant by random.

....

.... [1]

(ii) State what is meant by spontaneous.

....

.... [1]

(iii) State **one** piece of evidence for the random nature of decay.

....

.... [1]

(b) **(i)** Describe the differences between nuclear fission and nuclear fusion.

....

....

....

....

.... [3]

(ii) Explain, with reference to the variation of binding energy per nucleon with nucleon number, why the processes of nuclear fission and nuclear fusion both result in a release of energy.

....

....

.... [2]

[Total: 8]

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