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Cambridge Assessment International Education

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PHYSICS **9702/42**

Paper 4 A Level Structured Questions **May/June 2025**

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 (CJ/SG) 342383/3

Data

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

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	$f_o = \dfrac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

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

1 **(a)** Define the radian.

....

.... [1]

(b) The rear wheel and the pedals of a bicycle are connected by a chain that passes around two cogs (toothed wheels), as shown in Fig. 1.1.

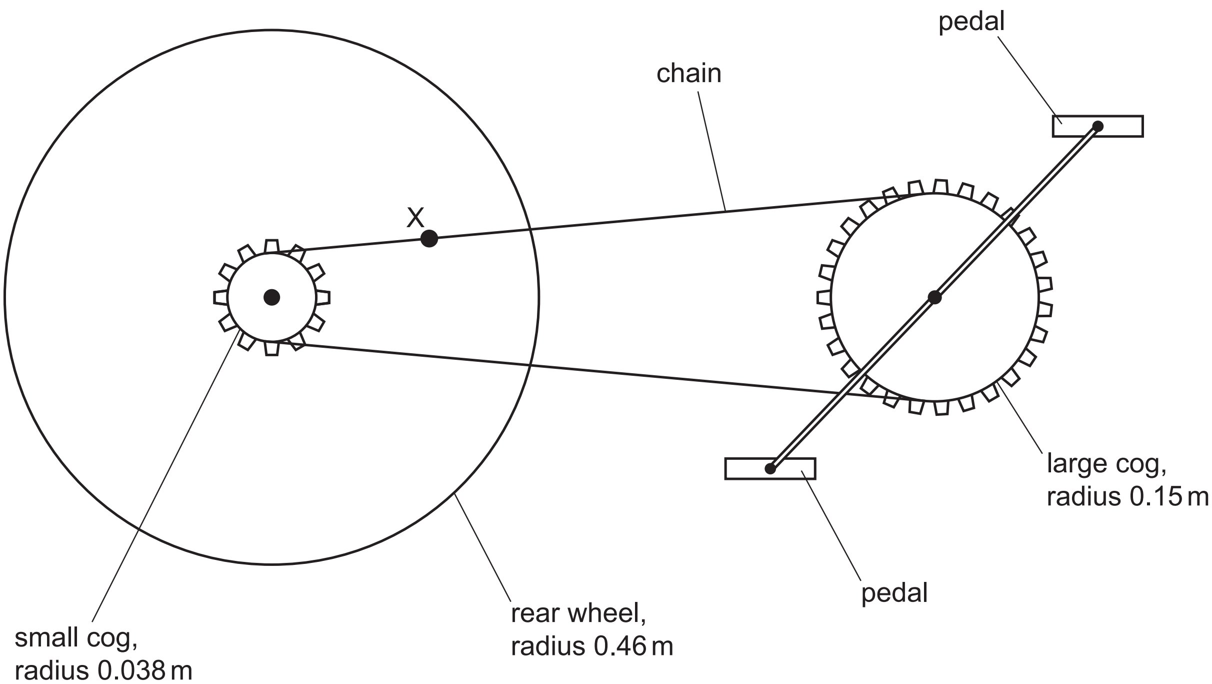

Fig. 1.1 (not to scale)

The small cog has a radius of 0.038 m and is fixed to the rear wheel so that it rotates with it.
The large cog has a radius of 0.15 m and is fixed to the pedals so that it rotates with them.
The rear wheel has a radius of 0.46 m.

The bicycle is being pedalled so that it moves in a straight line at a constant speed of $17\,\text{m}\,\text{s}^{-1}$.

(i) Calculate the angular speed of the rear wheel.

angular speed = ... $\text{rad}\,\text{s}^{-1}$ [2]

(ii) Calculate the period of rotation of the small cog.

period = ... s [2]

(iii) Show that the distance moved by point X on the chain during one full rotation of the small cog is 0.24 m.

[1]

(iv) Use the information in **(b)(iii)** to determine the angle through which the large cog rotates during one full rotation of the small cog.

angle = ... rad [2]

(c) The chain of the bicycle in **(b)** is moved onto a smaller cog fixed to the rear wheel. The speed of the bicycle does not change.

Explain, without calculation, the effect of this change on the angular speed of the pedals.

....

....

.... [2]

[Total: 10]

2 **(a)** **(i)** State what is represented by a gravitational field line.

....

....

.... [2]

(ii) The Earth may be considered as a uniform sphere, as shown in Fig. 2.1.

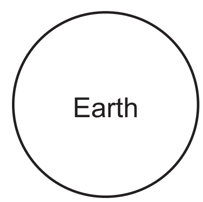

Fig. 2.1

On Fig. 2.1, draw field lines to represent the Earth's gravitational field outside the Earth. [2]

(b) The Earth's magnetic field may be considered as being due to the Earth acting as a long solenoid, as shown in Fig. 2.2.

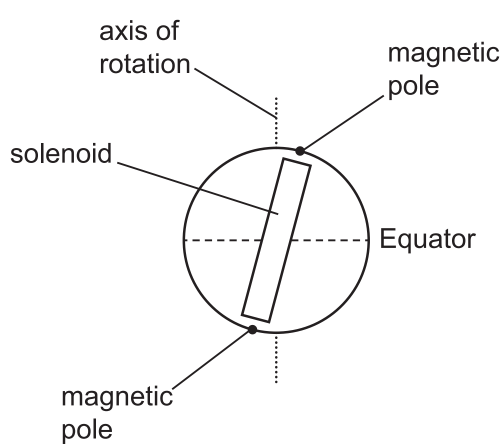

Fig. 2.2

The magnetic poles do not align with the geographic poles, which are on the axis of rotation.

Fig. 2.3 is a copy of Fig. 2.2 without the labels but with two magnetic field lines shown.

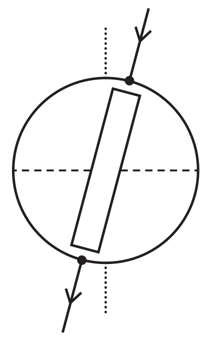

Fig. 2.3

(i) On Fig. 2.3, label the magnetic poles with the letters N and S to indicate which one is the magnetic N pole and which one is the magnetic S pole. [1]

(ii) On Fig. 2.3, draw field lines to represent the Earth's magnetic field outside the Earth. [2]

(c) An observer moves around the surface of the Earth.

(i) Use your answer in **(a)(ii)** to explain why the observed gravitational field of the Earth does not vary around the surface.

....

....

.... [2]

(ii) With reference to your answer in **(b)(ii)**, describe how the observed magnetic field of the Earth varies around the surface.

....

....

....

....

.... [3]

[Total: 12]

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

....

....

.... [2]

(b) A block of aluminium has a volume of $3.612 \times 10^{-3}\,\text{m}^3$ at a temperature of 0 °C.

Aluminium has a density of $2.700 \times 10^3\,\text{kg}\,\text{m}^{-3}$ at 0 °C.
It has a density of $2.620 \times 10^3\,\text{kg}\,\text{m}^{-3}$ at 500 °C.

The block is heated so that its temperature increases from 0 °C to 500 °C at an atmospheric pressure of $1.01 \times 10^5\,\text{Pa}$.
The increase in internal energy of the block is 4.38 MJ.

(i) Calculate the mass of the block.

mass = ... kg [2]

(ii) Show that the volume of the block at a temperature of 500 °C is $3.722 \times 10^{-3}\,\text{m}^3$.

[1]

(iii) Use the information in **(b)(ii)** to determine the magnitude of the work done on the block when its temperature is raised from 0 °C to 500 °C.

work done = ... J [2]

(iv) Explain whether the work done on the block is positive or negative.

....

....

.... [2]

(v) Use the first law of thermodynamics to determine, to three significant figures, a value for the specific heat capacity of aluminium. Explain your reasoning. Give a unit with your answer.

specific heat capacity = ... unit .... [3]

(c) Without further calculation, suggest with a reason how doubling the pressure in **(b)** is likely to affect the answer in **(b)(v)**.

....

....

.... [1]

[Total: 13]

4 **(a)** The equation of state for an ideal gas may be written as

$$pVA = NBT$$

where p is the pressure of the gas, V is the volume of the gas, A is the Avogadro constant, B is another constant and N is the number of molecules of the gas.

(i) State the meaning, in the equation, of the symbol T.

.... [1]

(ii) Identify the constant B.

.... [1]

(b) The product pV for an ideal gas is also given by

$$pV = \frac{1}{3}Nm\langle c^2\rangle.$$

(i) State the meanings, in this equation, of the symbols m and $\langle c^2\rangle$.

m: ....

$\langle c^2\rangle$: ....
[2]

(ii) Use the equations in **(a)** and **(b)** to derive an expression, in terms of A, B and T, for the mean kinetic energy E_K of a molecule of the gas.

E_K = ... [2]

(c) On Fig. 4.1, sketch the variation with *T* of the root-mean-square (r.m.s.) speed of the molecules of an ideal gas.

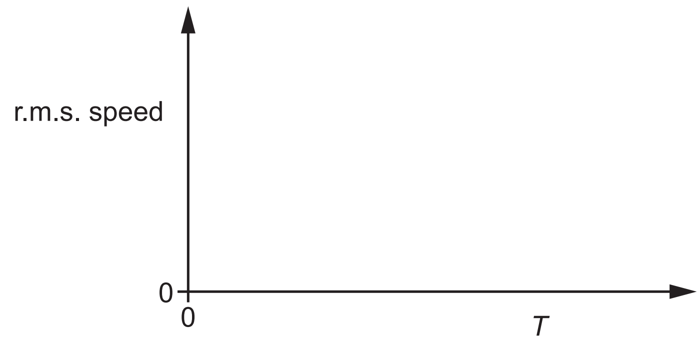

Fig. 4.1

[2]

[Total: 8]

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

....

....

.... [2]

(b) A block is suspended by a spring. The block oscillates vertically with simple harmonic motion.

The velocity v of the block varies with time t according to

$$v = 0.56 \cos 16t$$

where v is in $m\,s^{-1}$ and t is in s.

(i) Calculate the period of the oscillation.

period = ... s [1]

(ii) Determine the amplitude x_0 of the oscillation.

x_0 = ... m [2]

(iii) Use your answer in **(b)(ii)** to determine the equation for v in terms of the displacement x of the block, where v is in $m\,s^{-1}$ and x is in m.

v = ... [1]

(iv) On Fig. 5.1, sketch the variation of *v* with *x*.

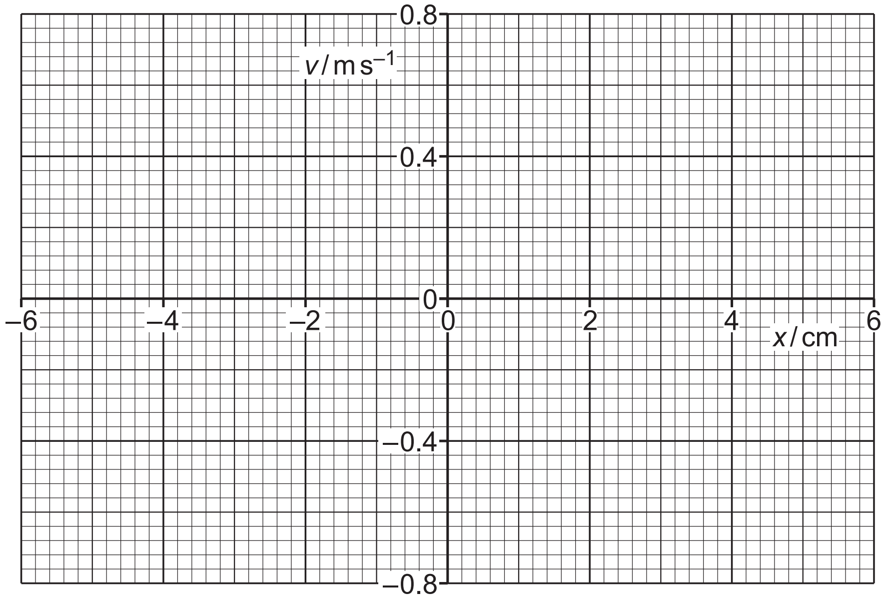

Fig. 5.1

[3]

[Total: 9]

6 Two parallel metal plates X and Y are separated by a distance of 0.041 m, as shown in Fig. 6.1.

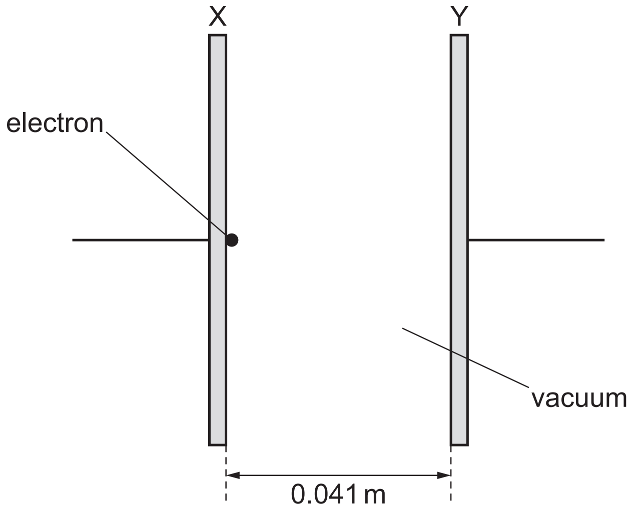

Fig. 6.1

There is a vacuum between the plates. An electron is at rest at the centre of plate X.

A potential difference (p.d.) of 58 kV is applied across the plates. This causes the electron to accelerate towards plate Y.

(a) On Fig. 6.1, use the symbols + and – to indicate which of plates X and Y is the positive plate and which is the negative plate. [1]

(b) (i) Calculate the electric field strength *E* between the plates. Give a unit with your answer.

E = ... unit .... [2]

(ii) Determine the acceleration of the electron.

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

(c) Many electrons are now accelerated from rest from plate X to plate Y in Fig. 6.1. When the electrons hit plate Y, the absorption of their kinetic energies results in the emission of electromagnetic waves.

(i) Show that the minimum wavelength of these electromagnetic waves is 21 pm.

[3]

(ii) State the region of the electromagnetic spectrum that contains these waves.

.... [1]

(iii) Explain how these electromagnetic waves may be used to form images of internal body structures.

....

....

....

.... [2]

[Total: 11]

7 Fig. 7.1 shows a circuit containing a capacitor of capacitance C and a resistor of resistance R.

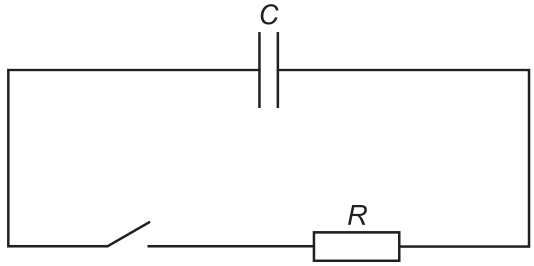

Fig. 7.1

Initially, the switch is open and the potential difference (p.d.) across the capacitor is 12 V.

The switch is closed at time $t = 0$ and the capacitor discharges through the resistor.

Fig. 7.2 shows the variation of the charge Q on the capacitor with the p.d. V_C across the capacitor as the capacitor discharges. Fig. 7.3 shows the variation of the current I in the resistor with the p.d. V_R across the resistor as the capacitor discharges.

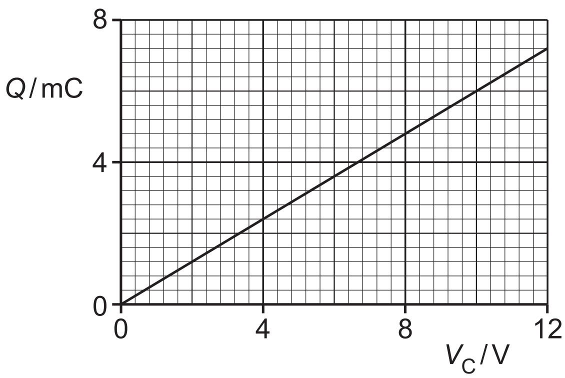

Fig. 7.2

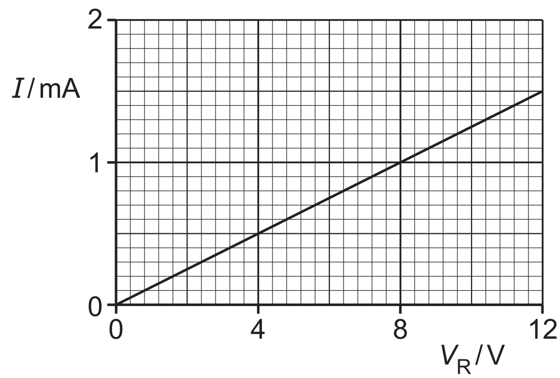

Fig. 7.3

(a) State the relationship between V_C and V_R.

.... [1]

(b) Determine:

(i) the capacitance C, in μF

C = ... μF [2]

(ii) the resistance R, in kΩ

R = ... kΩ [2]

(iii) the time constant τ of the circuit.

τ = ... s [2]

(c) Use Fig. 7.2, Fig. 7.3 and your answer in **(a)** to explain why the variation of Q with t is exponential in nature.

....

....

....

....

.... [3]

[Total: 10]

8 Fig. 8.1 shows a circuit that produces rectification of an alternating input voltage.

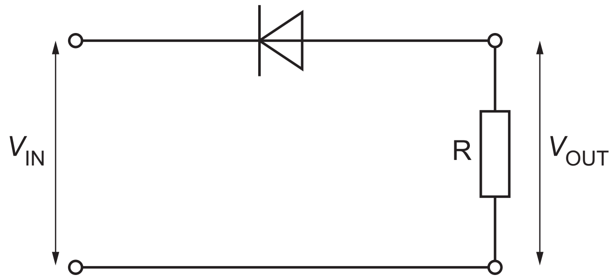

Fig. 8.1

The input voltage V_{IN} is sinusoidal. The rectified output voltage V_{OUT} is applied across resistor R.

The variation of V_{IN} with time t has amplitude V_0 and period T, as shown in Fig. 8.2.

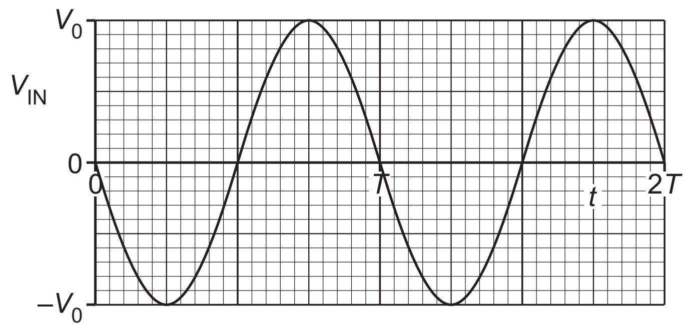

Fig. 8.2

The root-mean-square (r.m.s.) value of V_{IN} is 6.0 V.

(a) **(i)** State the type of rectification produced by the circuit of Fig. 8.1.

.... [1]

(ii) Calculate V_0.

V_0 = ... V [1]

(b) Resistor R has resistance 45 Ω.

Assume that there is no p.d. across the diode when it is conducting.

(i) Determine the peak power P_0 in the resistor.

P_0 = ... W [2]

(ii) On Fig. 8.3, sketch the variation of the power P in the resistor with t between $t = 0$ and $t = 2T$.

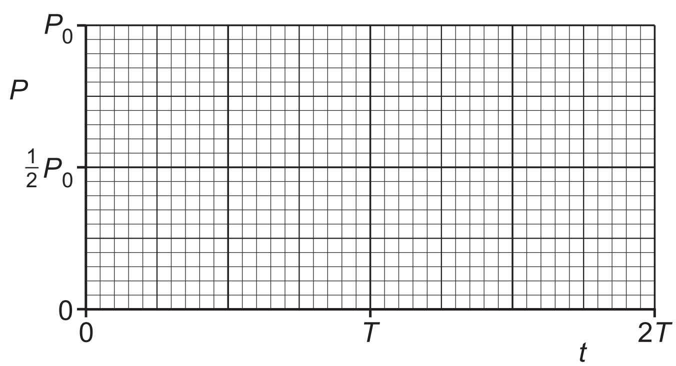

Fig. 8.3

[3]

(iii) Use the answer in **(b)(ii)** to explain why the mean power in the resistor is $\frac{1}{4}P_0$.

....

....

.... [2]

(iv) Use the information in **(b)(iii)** to determine the r.m.s. value of V_{OUT}.

r.m.s. voltage = ... V [1]

[Total: 10]

9 **(a)** State what is meant by the photoelectric effect.

....

....

.... [2]

(b) The photoelectric effect is investigated in two stages using the circuit shown in Fig. 9.1.

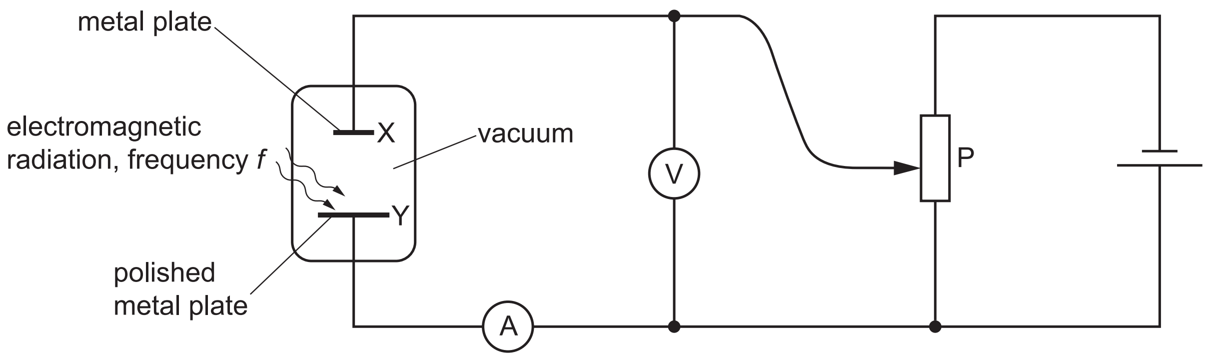

Fig. 9.1

The polished metal plate Y is illuminated with electromagnetic radiation of frequency f and constant power.

In stage 1 of the investigation, frequency f is set to a constant value of 2.5×10^{15} Hz. The current I in the ammeter is varied by adjusting the potentiometer P. Fig. 9.2 shows the variation of I with the voltmeter reading V. There is a value V_S of V at which the current just falls to zero.

In stage 2 of the investigation, stage 1 is repeated for different values of frequency. As frequency f is varied, the voltmeter reading V_S at which the current just falls to zero is measured. Fig. 9.3 shows the variation of V_S with f.

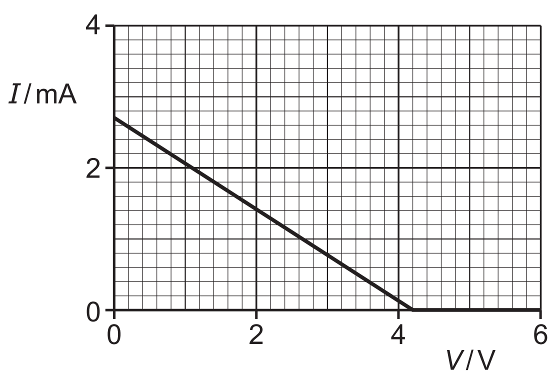

Fig. 9.2

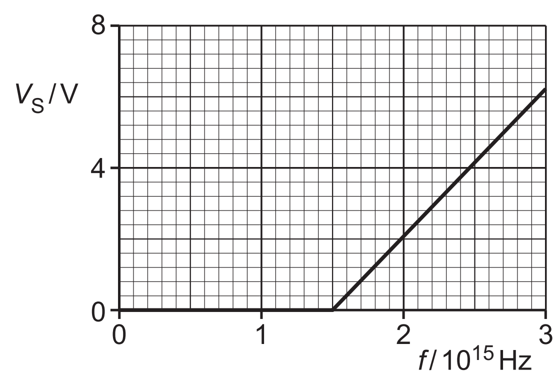

Fig. 9.3

(i) Explain, with reference to photons, why V_S depends on the frequency of the incident electromagnetic radiation.

....

....

....

....

....

.... [3]

(ii) State **three** quantitative conclusions that can be drawn from the results in Fig. 9.2 and Fig. 9.3. Use the space for any working.

1 ....

....

2 ....

....

3 ....

....

[3]

[Total: 8]

10 **(a)** Radioactive decay is a spontaneous process.

State the meaning, in this context, of the term spontaneous.

....

.... [1]

(b) Two radioactive isotopes X and Y each decay to form a stable isotope.
A sample initially contains only atoms of isotope X. At this time, its activity is 4*A*.
Another sample initially contains only atoms of Y. At this time, its activity is *A*.

Fig. 10.1 shows the variation of the activity of each sample with time *t* between *t* = 0 and *t* = 6*T*.

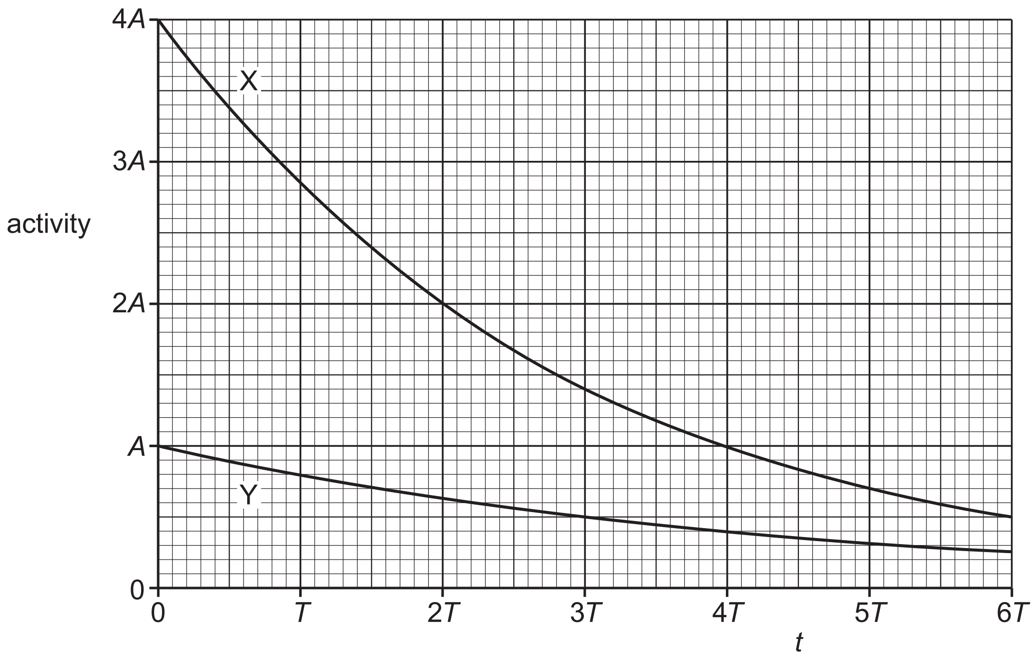

Fig. 10.1

(i) Complete Table 10.1 to give expressions, in terms of either or both of *A* and *T*, for the quantities indicated for each of the samples.

Table 10.1

sample	half-life	decay constant	initial activity	initial number of nuclei
X			4*A*	
Y			*A*	

[3]

DO NOT WRITE IN THIS MARGIN

(ii) Determine, in terms of T, the time at which the two samples will have equal activities.

time = ... T [3]

(c) A radiation detector is placed near to one of the samples in **(b)**.

Explain why the count rate measured by the detector is less than the activity of the sample.

....

....

.... [2]

[Total: 9]

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