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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

5273357103

PHYSICS **9702/44**

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

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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	$m_\text{p} = 1.67 \times 10^{-27}\ \text{kg}$
rest mass of electron	$m_\text{e} = 9.11 \times 10^{-31}\ \text{kg}$
Avogadro constant	$N_\text{A} = 6.02 \times 10^{23}\ \text{mol}^{-1}$
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	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$ $\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{m F}^{-1}\right)$
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	$f_\text{o} = \frac{f_\text{s} v}{v \pm v_\text{s}}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

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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	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + ...$
capacitors in parallel	$C = C_1 + C_2 + ...$
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	$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$

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1 **(a)** State Newton's law of gravitation.

.....

.....

..... [2]

(b) A binary star consists of star A, of mass 4.0×10^{30} kg, and star B, of mass 2.0×10^{30} kg, separated by a distance of 3.3×10^{12} m. The stars are both in circular orbit around their common centre of gravity X, as shown in Fig. 1.1.

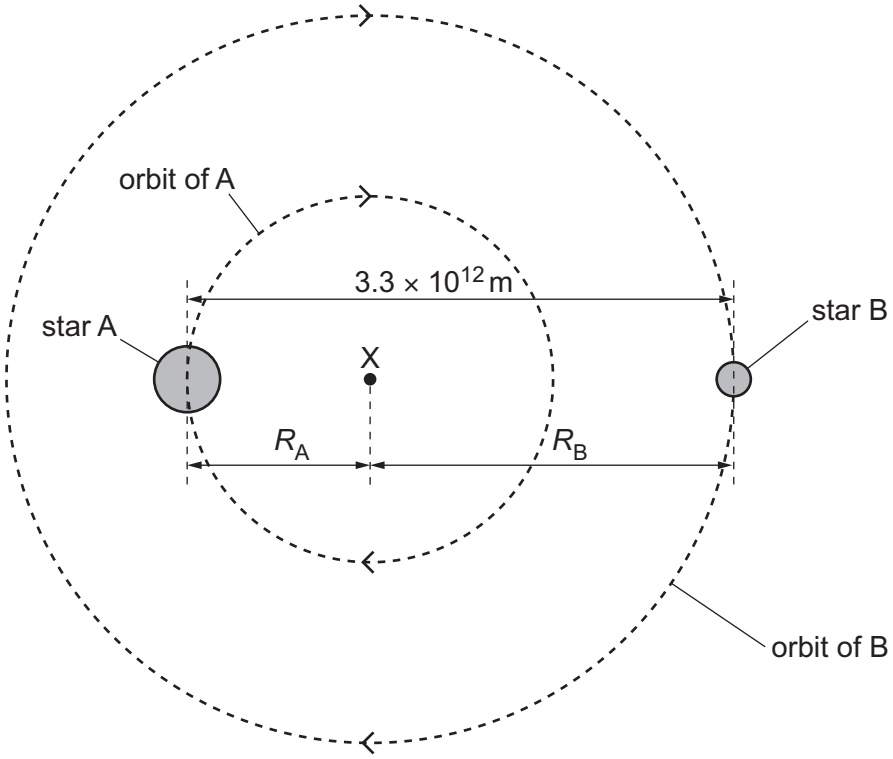


Fig. 1.1

The radius R_B of the orbit of star B is double the radius R_A of the orbit of star A.

(i) Use Newton's law of gravitation to calculate the magnitude of the gravitational force exerted by each star on the other.

force = ... N [2]

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(ii) Calculate the centripetal acceleration of star A.

acceleration = ... $m\,s^{-2}$ [1]

(iii) Use your answer in **(b)(ii)** to determine the period of the orbit of star A.

period = ... s [3]

(iv) By placing a tick (✓) in each row, complete Table 1.1 to show how the quantities indicated for star B compare with the same quantities for star A.

Table 1.1

	B less than A	B equal to A	B greater than A
centripetal acceleration			
linear speed			
period			

[3]

[Total: 11]

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2 **(a)** The equation of state for an ideal gas may be expressed as

$$pV = NkT.$$

(i) State the meaning of each of the symbols in this equation.

p: .....

V: .....

N: .....

k: .....

T: .....

[3]

(ii) Using the equation of state, derive an expression for the average translational kinetic energy E_K of a particle in the gas in terms of some or all of *N*, *k* and *T*.

E_K = ... [2]

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(b) A molecule of hydrogen gas consists of two hydrogen atoms, each of nucleon number 1.
A molecule of oxygen gas consists of two oxygen atoms, each of nucleon number 16.

Assume that hydrogen and oxygen both behave as ideal gases.

A sample of hydrogen gas is at the same temperature as a sample of oxygen gas.

For the two samples, determine the ratio

$$\frac{\text{root-mean-square (r.m.s.) speed of hydrogen molecules}}{\text{root-mean-square (r.m.s.) speed of oxygen molecules}}.$$

ratio = ... [2]

[Total: 7]

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3 **(a)** With reference to molecular kinetic energy and molecular potential energy, explain what is meant by the internal energy of an ideal gas.

.....

.....

..... [2]

(b) A sample of an ideal gas is initially in state A, at a pressure of 2.0×10^5 Pa and with a volume of $0.016\,m^3$, as shown in Fig. 3.1.

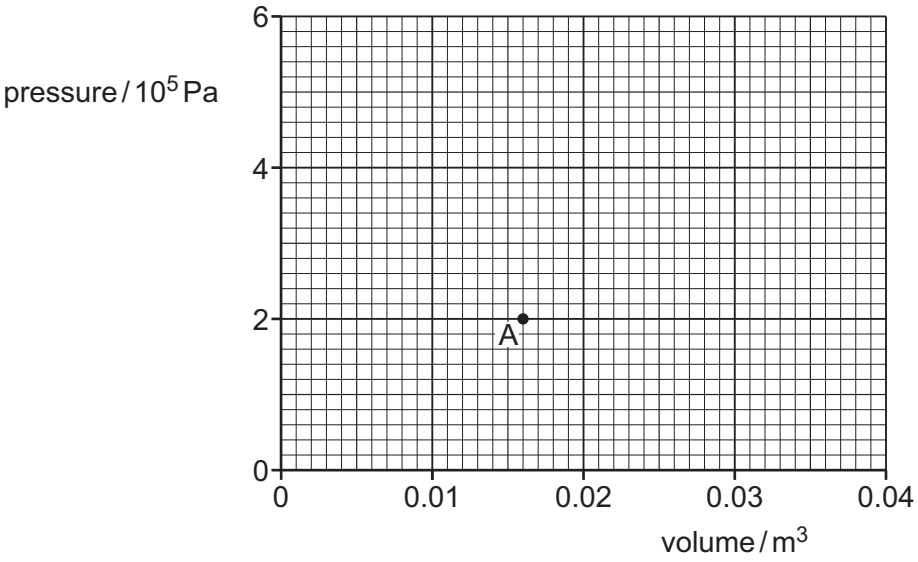


Fig. 3.1

In state A, the temperature of the gas is 400 K.

The gas undergoes two successive changes X and Y.

In change X, it is heated at constant volume to a pressure of 4.0×10^5 Pa. At the end of change X, the gas is in state B.

In change Y, it is then allowed to expand at constant temperature back to its original pressure. At the end of change Y, the gas is in state C.

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(i) Determine the internal energy of the gas in state A.

internal energy = ... J [2]

(ii) Determine the temperature of the gas in state B.

temperature = ... K [1]

(iii) Determine the volume of the gas in state C.

volume = ... m^3 [1]

(iv) On Fig. 3.1, draw two lines, one to represent change X and one to represent change Y. Label your lines X and Y respectively. [3]

[Total: 9]

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4 **(a)** State what is meant by the frequency of the oscillations of an oscillating object.

.....

..... [1]

(b) An object is oscillating.

Fig. 4.1 shows the variation of the acceleration a of the object with its displacement x from the equilibrium position.

Fig. 4.2 shows the variation of the kinetic energy E_K of the object with time t.

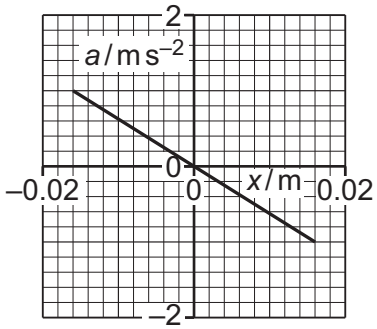


Fig. 4.1

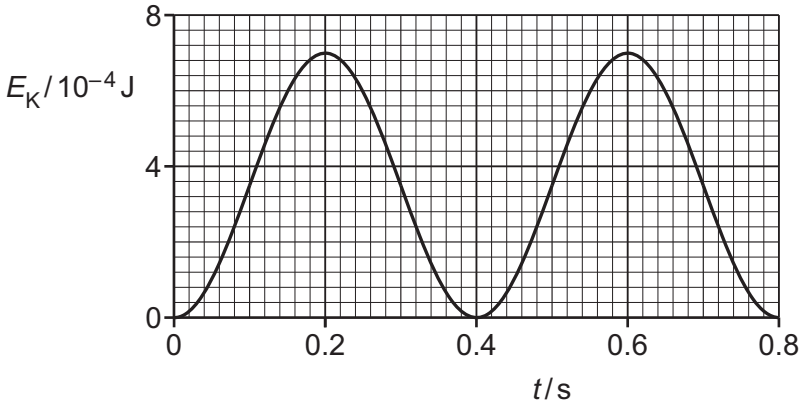


Fig. 4.2

(i) Explain how Fig. 4.2 shows that the period of the oscillations is 0.80 s.

.....

.....

..... [1]

(ii) Calculate the angular frequency ω of the oscillations.

ω = ... rad s^{-1} [2]

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(iii) Apart from the period, frequency and angular frequency of the oscillations, determine **three** other conclusions about the object and its oscillations 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.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(iv) Describe the interchange between kinetic energy and potential energy during the oscillations. Numerical values are **not** required.

.....

.....

.....

.....

..... [3]

[Total: 10]

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5 **(a)** Explain why the electric potential near an isolated proton is positive.

.....

.....

.....

.....

..... [3]

(b) An isolated metal sphere is positively charged and has radius R, as shown in Fig. 5.1.

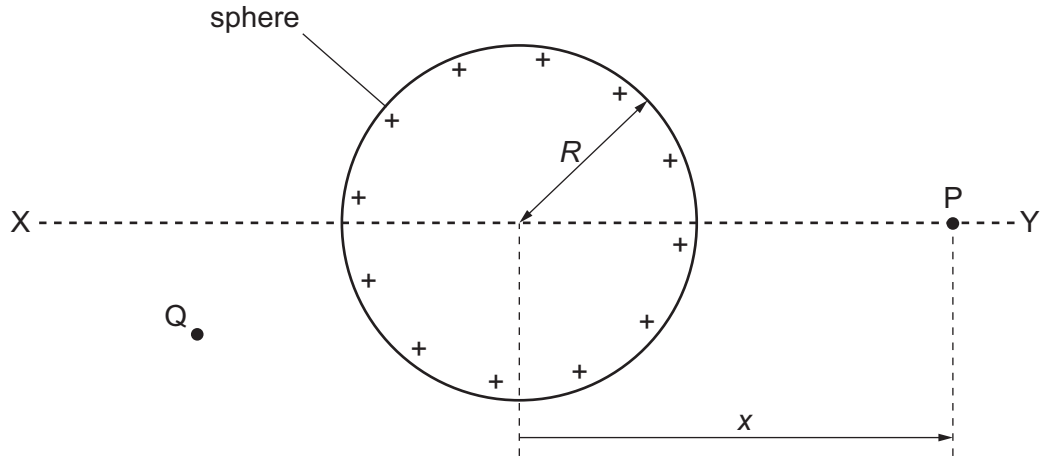


Fig. 5.1

Line XY passes through the centre of the sphere.
Point P lies on line XY at a variable displacement x from the centre of the sphere.
Point Q is at a fixed position that is not on line XY.

The electric field strength at the surface of the sphere is E_0.

(i) On Fig. 5.1, draw an arrow at point Q to show the direction of the electric field at that point. [1]

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(ii) On Fig. 5.2, sketch the variation of the electric field E at point P with x for values of x between $x = -3R$ and $x = 3R$. Do **not** include the region inside the sphere between $x = -R$ and $x = R$.

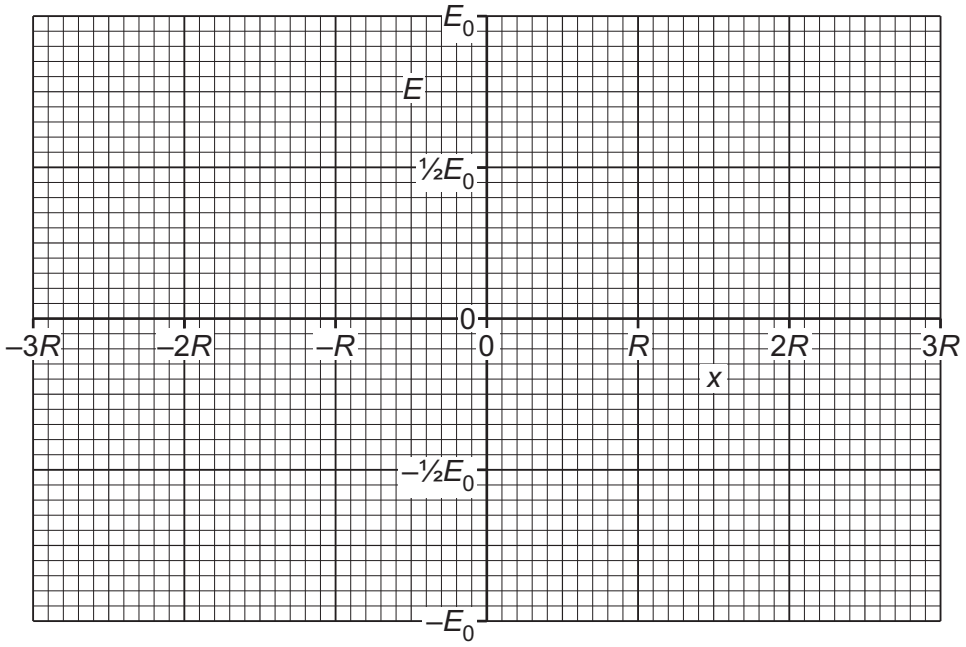


Fig. 5.2

[3]

(c) The proton and the electron in a hydrogen atom are separated by a distance of 5.3×10^{-11} m.

Calculate the electric potential energy of the proton and the electron.

electric potential energy = ... J [2]

[Total: 9]

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6 Fig. 6.1 shows part of a bridge rectifier circuit that can be used for rectification of an alternating input voltage V_{IN}.

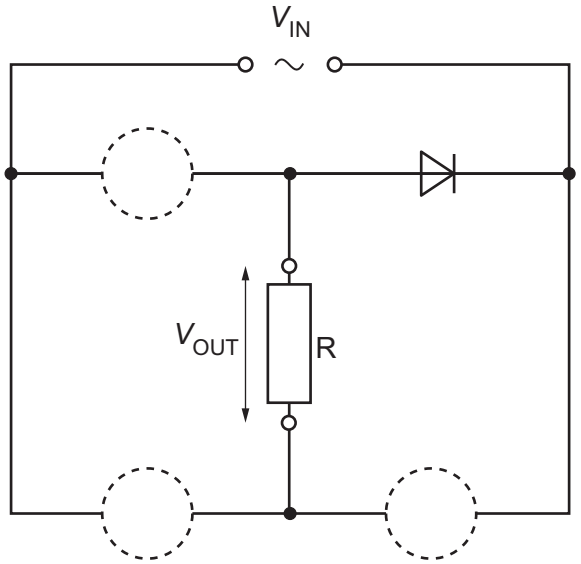


Fig. 6.1

The circuit contains four diodes, one of which is shown.
The rectified output voltage V_{OUT} is applied across load resistor R.

(a) (i) State what is meant by rectification.

.....

..... [1]

(ii) State the name of the type of rectification produced by a bridge rectifier circuit.

..... [1]

(iii) Complete the circuit in Fig. 6.1 by drawing the three missing diodes inside the dashed circles. [2]

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(b) The input voltage varies with time t according to the equation

$$V_{IN} = 34 \sin 18t$$

where V_{IN} is in V and t is in s.

(i) Show that the period of the input voltage is 0.35 s.

[2]

(ii) Calculate the root-mean-square (r.m.s.) input voltage.

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

(iii) On Fig. 6.2, sketch the variation of V_{OUT} with t from $t = 0$ to $t = 0.35$ s.

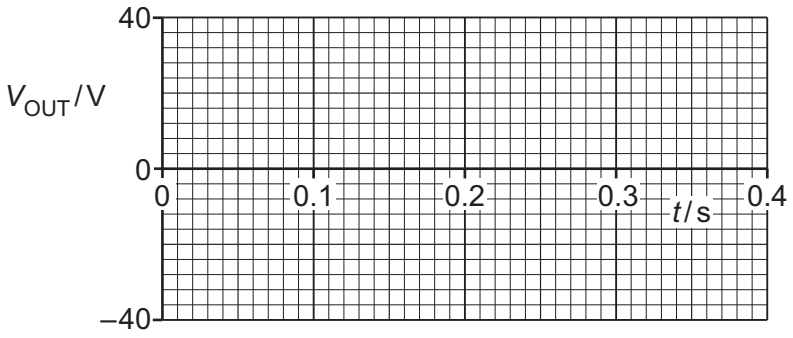


Fig. 6.2

[3]

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(c) Resistor R has a resistance of 56 kΩ. A capacitor of capacitance 12 μF is connected into the circuit of Fig. 6.1 in order to smooth the output voltage.

(i) On Fig. 6.1, draw the capacitor correctly connected into the circuit. [1]

(ii) Calculate the time constant of the smoothing circuit.

time constant = ... s [2]

(iii) During each discharge cycle, the time for which the capacitor is discharging is 0.14 s.

Determine the minimum value of the smoothed output voltage.

minimum voltage = ... V [2]

[Total: 15]

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

.....

.....

..... [2]

(b) A helicopter hovering in stationary equilibrium has four rotors, each of length 12 m, as shown in the view from above in Fig. 7.1.

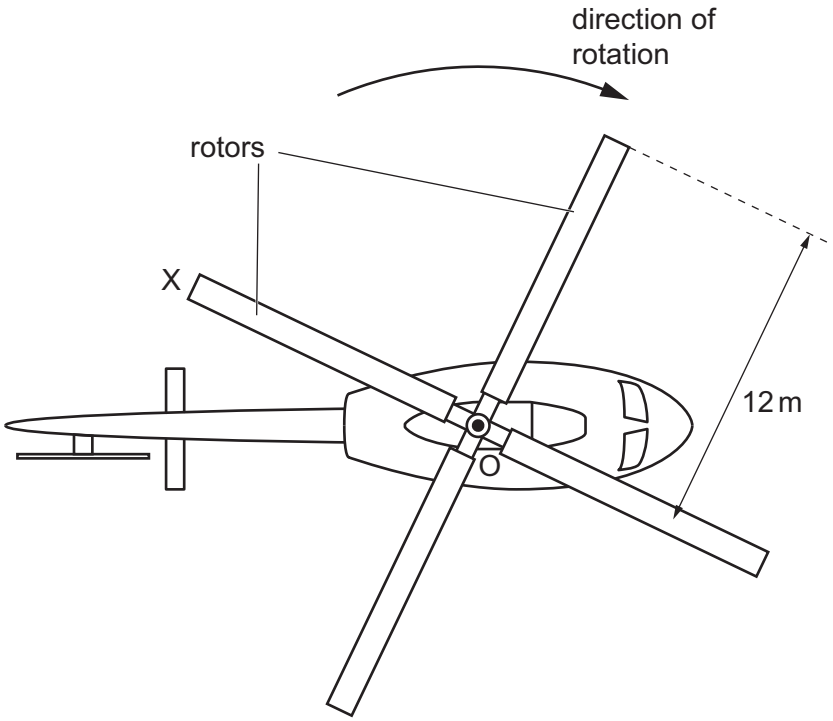


Fig. 7.1

The vertical component of the Earth's magnetic field at the helicopter is downwards with a flux density of 0.047 mT.

The rotors each rotate in a horizontal plane in the direction shown with a frequency of 85 Hz.

(i) Calculate the magnetic flux Φ cut by rotor OX during one complete rotation. Give a unit with your answer.

Φ = ... unit ..... [3]

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(ii) Determine the magnitude of the electromotive force (e.m.f.) induced across the length of rotor OX.

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

(iii) Use Lenz's law to explain whether end O or end X of the rotor is at the higher potential.

.....

.....

.....

..... [2]

[Total: 9]

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8 Oxygen-15 ($^{15}_{8}O$) is radioactive and has a half-life of 2.04 minutes.

The decay of oxygen-15 produces positrons. For this reason, oxygen-15 is sometimes used as a tracer in positron emission tomography (PET scanning).

(a) State what is meant by a tracer.

.....

.....

..... [2]

(b) The equation for the decay of oxygen-15 is

$$^{15}_{8}O \rightarrow {}^{P}_{Q}X + {}^{R}_{S}\beta^{+} + Z$$

where X is the nucleus formed during the decay and Z is another particle.

(i) State the values of the integers *P*, *Q*, *R* and *S*.

P = ... *R* = ...

Q = ... *S* = ...

[2]

(ii) State the name of particle Z.

..... [1]

(c) **(i)** Define the activity of a sample.

.....

..... [1]

(ii) Calculate the decay constant of oxygen-15. Give a unit with your answer.

decay constant = ... unit ..... [2]

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(iii) Determine the rate at which positrons are produced in a sample of oxygen-15 that has a mass of 2.85×10^{-6} kg.

rate = ... s^{-1} [4]

(d) The particles that are emitted from the body and detected outside it during PET scanning are not positrons but another type of particle.

(i) State the name of the particles that are detected.

..... [1]

(ii) Explain how these particles are formed inside the body.

.....

.....

.....

..... [2]

[Total: 15]

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

.....

.....

..... [2]

(b) The photoelectric effect is investigated using two clean metal plates. One plate is made from metal X and the other is made from metal Y.

Metal X has work function energy Φ. Metal Y has work function energy 2Φ.
Metal X has threshold frequency F.

State expressions, in terms of either or both of Φ and F, for

(i) the threshold frequency of metal Y

threshold frequency = ... [1]

(ii) the Planck constant.

Planck constant = ... [1]

(c) The maximum kinetic energy E_K of photoelectrons is determined for each of the plates in **(b)** for different frequencies f of incident radiation.

On Fig. 9.1, sketch the variation of E_K with f for each plate. Label your lines X and Y to identify which line relates to which plate.

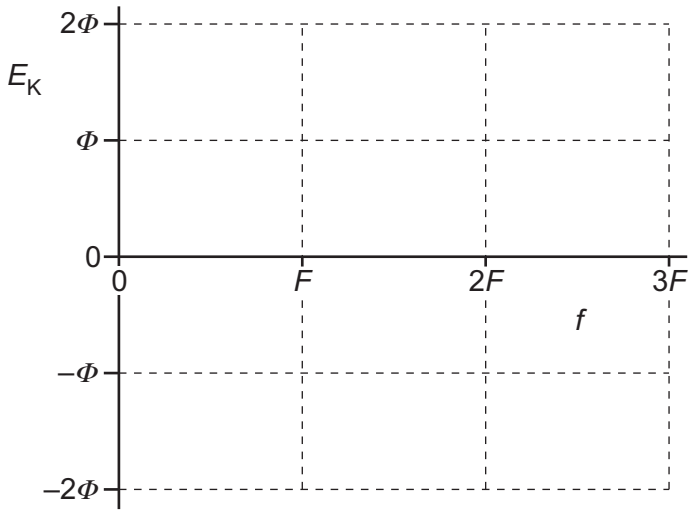


Fig. 9.1

[4]

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10 **(a)** State what is meant by redshift.

.....

.....

..... [2]

(b) Explain how observations of redshift lead to the idea that the universe is expanding.

.....

.....

..... [2]

(c) Explain how Hubble's law leads to the Big Bang theory of the origin of the universe.

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..... [3]

[Total: 7]

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