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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

1873242876

PHYSICS **9702/43**

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 (KN/FC) 336257/3

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)** State Newton's law of gravitation.

....

....

.... [2]

(b) A planet may be considered as a uniform sphere.

A satellite is in circular orbit of period T around the planet at a height h above the surface. The height of the orbit can be adjusted by use of the satellite's rocket engines.

Fig. 1.1 shows the variation with h of $T^{\frac{2}{3}}$.

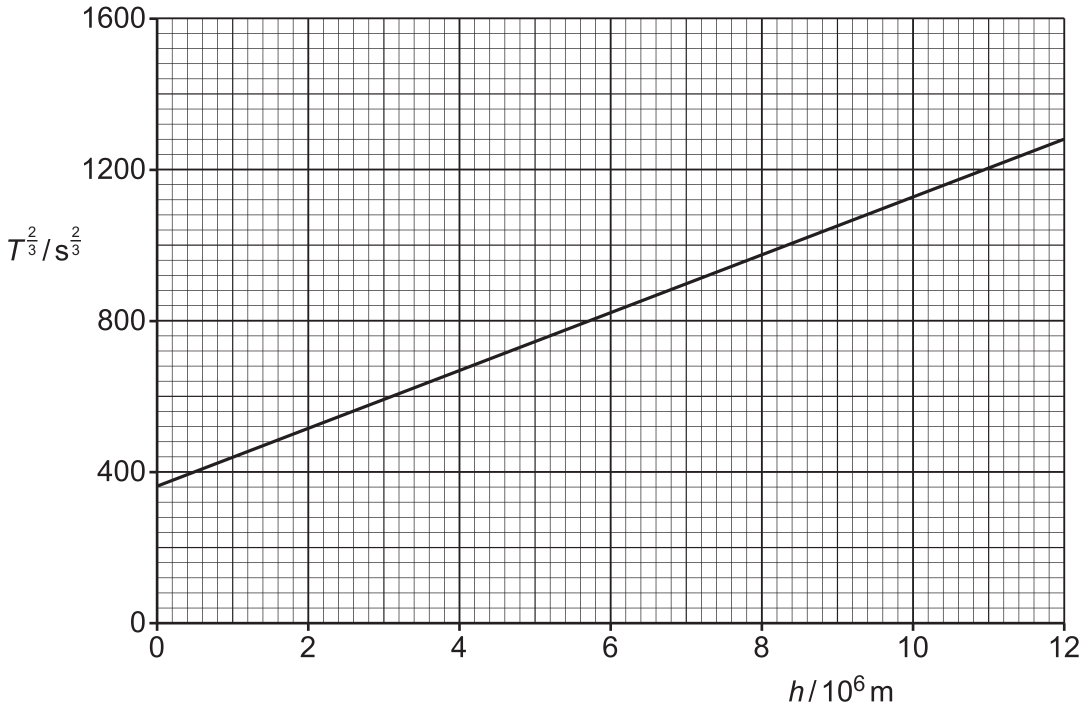

Fig. 1.1

(i) By reference to forces, explain why the orbit of the satellite is circular.

....

....

.... [2]

(ii) Use Newton's law of gravitation to show that h and T are related by

$$(h + B)^3 = \frac{GA}{4\pi^2} T^2$$

where G is the gravitational constant and A and B are constants that depend on the properties of the planet.

[3]

(iii) Use the gradient and intercept of the line in Fig. 1.1 to determine values for A and B. Give units with your answers.

A = ... unit ....

B = ... unit ....
[5]

[Total: 12]

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

....

....

.... [2]

(b) Two solid blocks X and Y are made from different metals. The blocks have different initial temperatures. Block Y is initially at room temperature.

The blocks are placed in direct thermal contact with each other at time t = 0. Fig. 2.1 shows the variation with t of the temperatures of the two blocks.

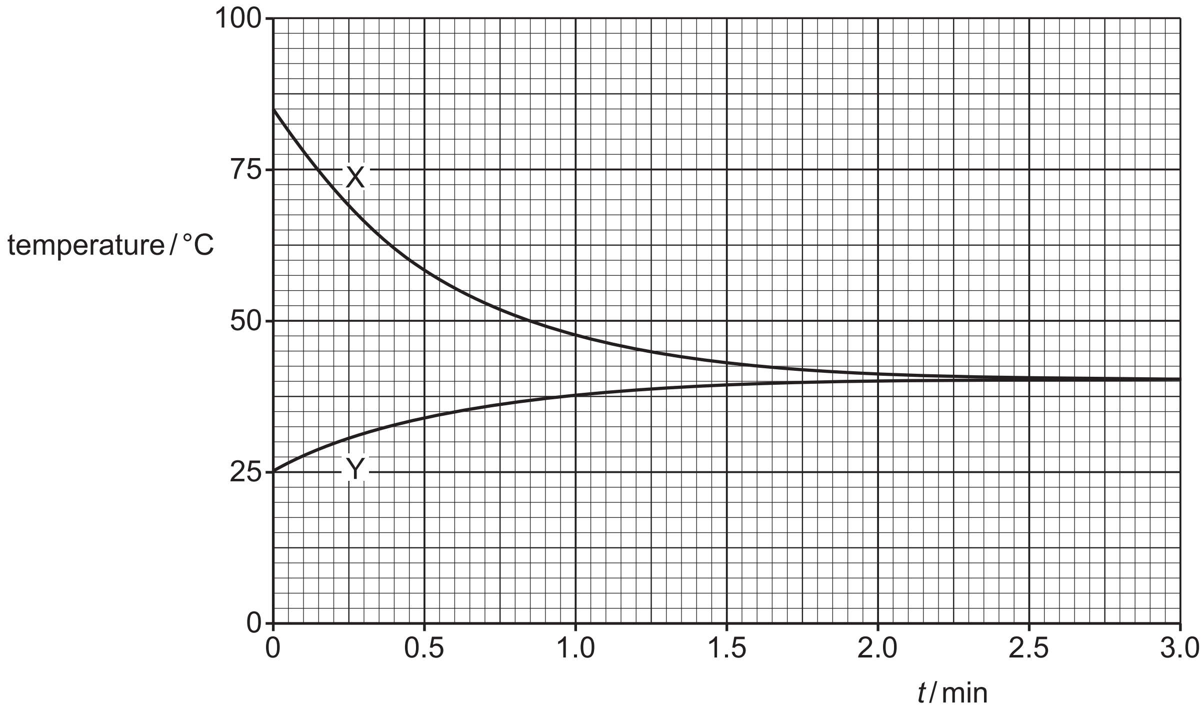

Fig. 2.1

(i) State **three** conclusions that may be drawn from Fig. 2.1. The conclusions may be qualitative or quantitative.

1 ....

....

2 ....

....

3 ....

....
[3]

(ii) The ratio $\dfrac{\text{mass of block Y}}{\text{mass of block X}}$ is equal to 1.3.

The metal in block Y has a specific heat capacity of $901\,\mathrm{J\,kg^{-1}\,K^{-1}}$.

Determine the specific heat capacity of the metal in block X.

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

[Total: 8]

3 **(a)** **(i)** State what is meant by the Avogadro constant.

....

....

.... [1]

(ii) State the relationship between the Avogadro constant N_A, the molar gas constant R and the Boltzmann constant k.

[1]

(b) Two samples X and Y of ideal gases are both at thermodynamic temperature T.

Sample X has volume V and consists of N molecules, each of mass m.
Sample Y has volume $2V$ and consists of $2N$ molecules, each of mass $2m$.

(i) Complete Table 3.1 by giving expressions, in terms of some or all of N, m, T, V and the constants in **(a)(ii)**, for the quantities indicated.

Table 3.1

	sample X	sample Y
pressure		
amount of substance		
mean-square speed of molecules		
internal energy		

[4]

(ii) The temperature of sample X is now varied.

On Fig. 3.1, sketch the variation with thermodynamic temperature of the root-mean-square (r.m.s.) speed of the molecules of the gas.

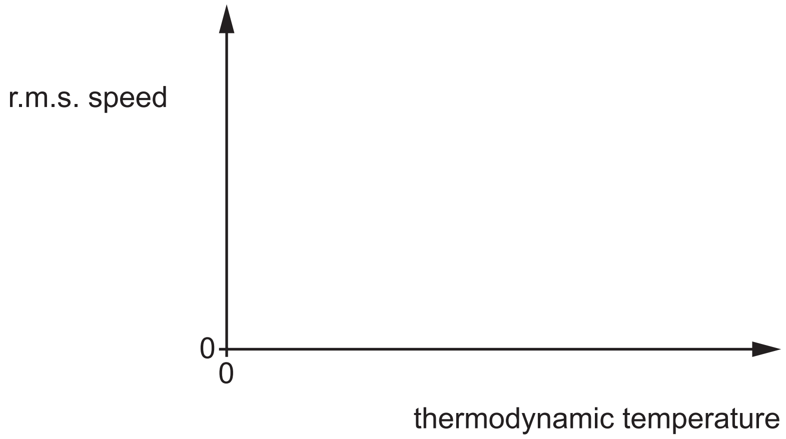

Fig. 3.1

[2]

[Total: 8]

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

....

....

.... [2]

(b) A block is suspended from a spring, as shown in Fig. 4.1.

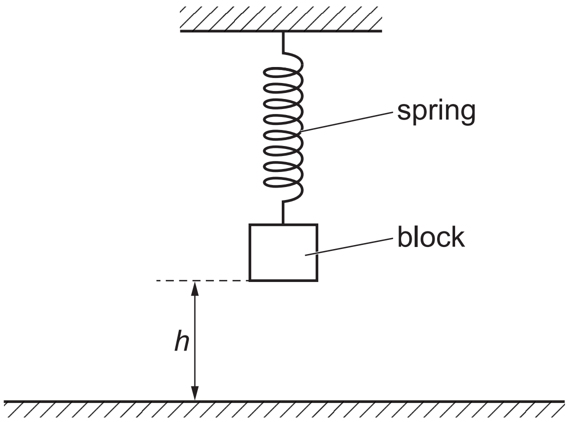

Fig. 4.1

The block is pulled down and released at time $t = 0$. It then oscillates vertically with simple harmonic motion.

Fig. 4.2 shows the variation of the velocity v of the block with height h of the base of the block above the floor.

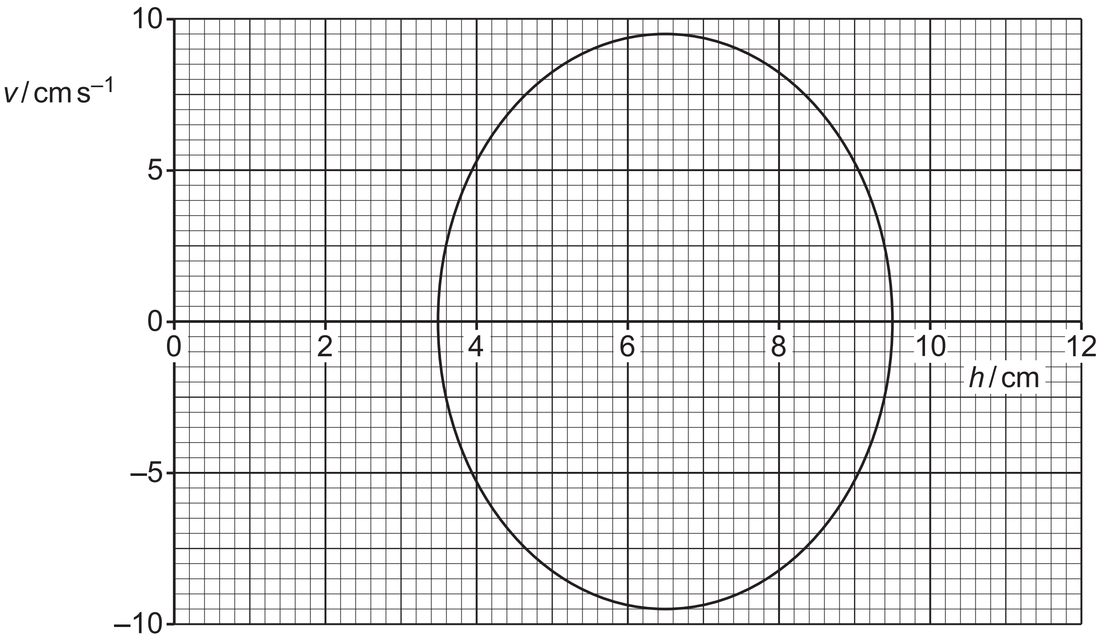

Fig. 4.2

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(i) Determine the amplitude, in cm, of the oscillations.

amplitude = ... cm [1]

(ii) Show that the angular frequency of the oscillations is 3.2 rad s^{-1}.

[2]

(iii) Calculate the period T of the oscillations.

T = ... s [2]

(iv) On Fig. 4.3, sketch the variation of h with time t from t = 0 to t = 6.0 s.

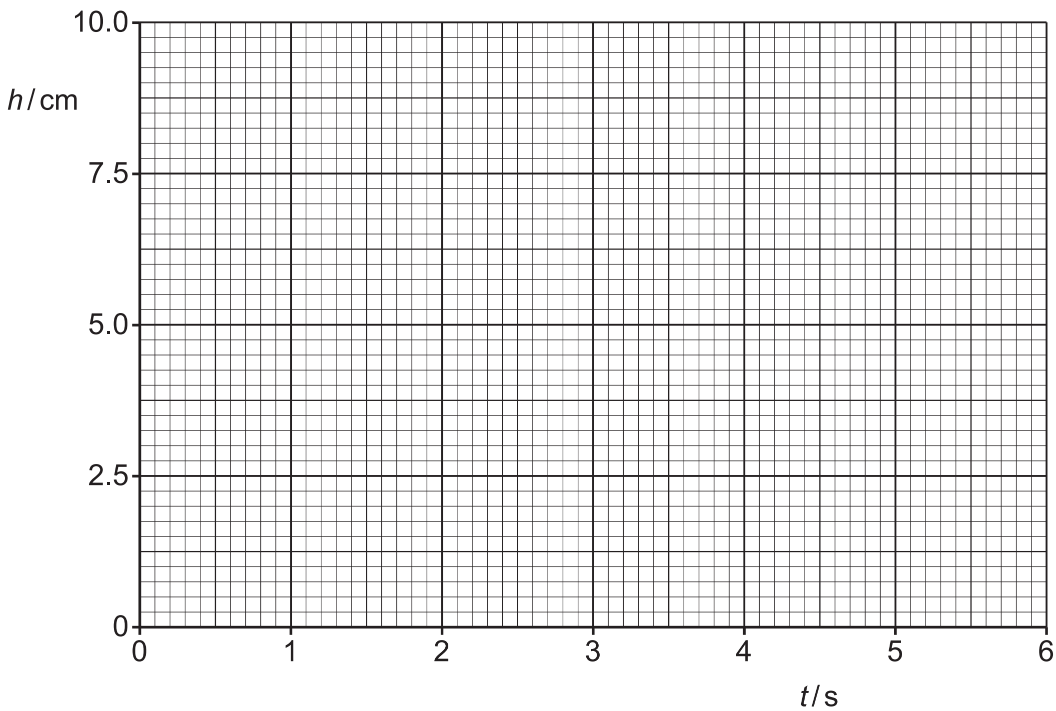

Fig. 4.3

[4]

[Total: 11]

5 **(a)** State the relationship between electric field and electric potential.

....

....

.... [2]

(b) Two charged isolated insulating spheres X and Y are near to each other, as shown in Fig. 5.1.

Fig. 5.1

P is a point on the line joining the centres of the spheres.

Explain why it is **not** possible for the total electric potential and the resultant electric field to simultaneously be zero at point P.

....

....

....

....

.... [3]

(c) The magnitudes of the charges on spheres X and Y in Fig. 5.1 are Q and $2Q$ respectively. The spheres may be considered as point charges at their centres.

Point P is a distance x from the centre of sphere X.

The electric potential at point P is zero.

(i) Show that the distance y of point P from the centre of sphere Y is equal to $2x$.

[2]

(ii) State an expression, in terms of Q, x and the permittivity of free space ε_0, for the electric field strength E_X at P due to sphere X.

E_X = ... [1]

(iii) Determine an expression, in terms of Q, x and ε_0, for the resultant electric field strength E at point P due to the two spheres.

E = ... [2]

[Total: 10]

6 **(a)** **(i)** State what is meant by rectification of an alternating voltage.

....

.... [1]

(ii) State the difference between half-wave rectification and full-wave rectification.

....

....

.... [2]

(b) **(i)** Complete Fig. 6.1 to show a circuit that produces half-wave rectification of an alternating input voltage V_{IN} to produce output voltage V_{OUT} across the resistor R.

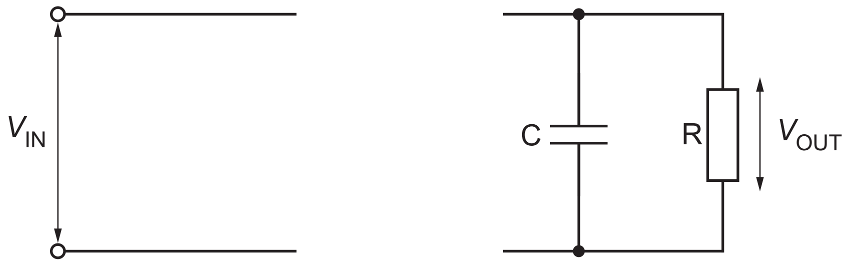

Fig. 6.1

[2]

(ii) State the purpose of the capacitor C in the circuit of Fig. 6.1.

....

.... [1]

(c) The input voltage V_{IN} in Fig. 6.1 is a square wave. Fig. 6.2 shows the variation of V_{IN} with time t.

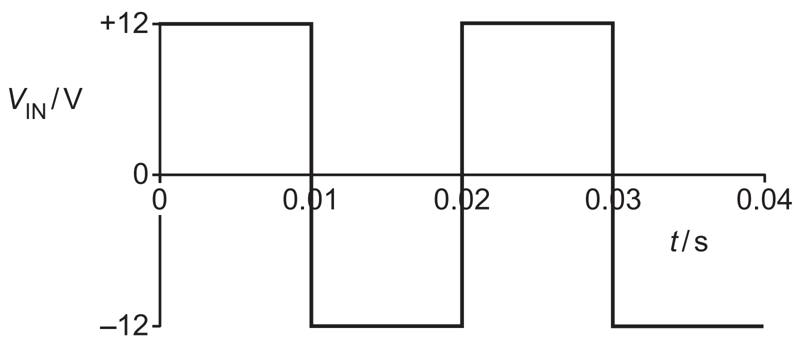

Fig. 6.2

Fig. 6.3 shows the variation of V_{OUT} with t.

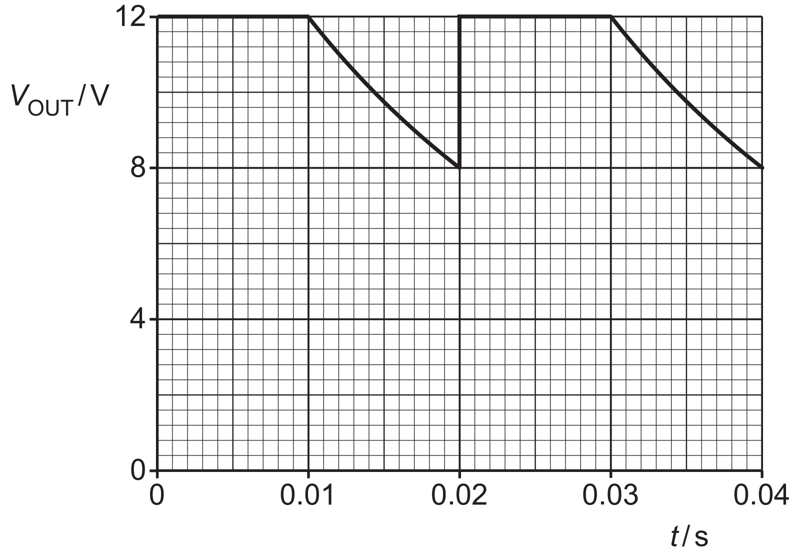

Fig. 6.3

The maximum energy stored in the capacitor is 0.041 J.

(i) Show that the capacitance of C is 570 μF.

[2]

(ii) Determine the resistance of R.

resistance = ... Ω [3]

[Total: 11]

7 **(a)** Define magnetic flux density.

....

....

.... [2]

(b) A long, straight wire carries a current into the page, as shown in Fig. 7.1.

Fig. 7.1

On Fig. 7.1, draw four field lines to represent the magnetic field around the wire due to the current in it. [3]

(c) Two identical wires X and Y are placed parallel to each other. The wires both carry current into the page, as shown in Fig. 7.2.

Fig. 7.2

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(i) Explain why the two wires exert a magnetic force on each other.

....

....

....

.... [2]

(ii) On Fig. 7.2, draw an arrow to show the direction of the magnetic force exerted on wire X. Label your arrow F. [1]

(iii) The current in X is double the current in Y.

State how the magnetic force exerted on wire Y compares with the magnetic force exerted on wire X.

....

....

.... [2]

(iv) The direction of the current in both wires is now reversed.

State, with a reason, the effect of this change on the direction of the force on wire X.

....

.... [1]

[Total: 11]

8 A polished sheet of magnesium in a vacuum emits electrons when it is illuminated by ultraviolet radiation.

(a) State the name of this phenomenon.

.... [1]

(b) For emission of electrons to occur, the frequency of the ultraviolet radiation must be at least 8.8×10^{14} Hz.

(i) Calculate the work function energy of magnesium.

work function energy = ... J [2]

(ii) For ultraviolet radiation with a frequency of 11×10^{14} Hz, calculate the maximum speed of the emitted electrons.

maximum speed = ... $m\,s^{-1}$ [3]

(c) The frequency f of the ultraviolet radiation incident on the magnesium sheet is varied between 8.0×10^{14} Hz and 11×10^{14} Hz.

On Fig. 8.1, sketch the variation with f of the maximum kinetic energy E_{MAX} of the emitted electrons. Use the space below for any working that you need.

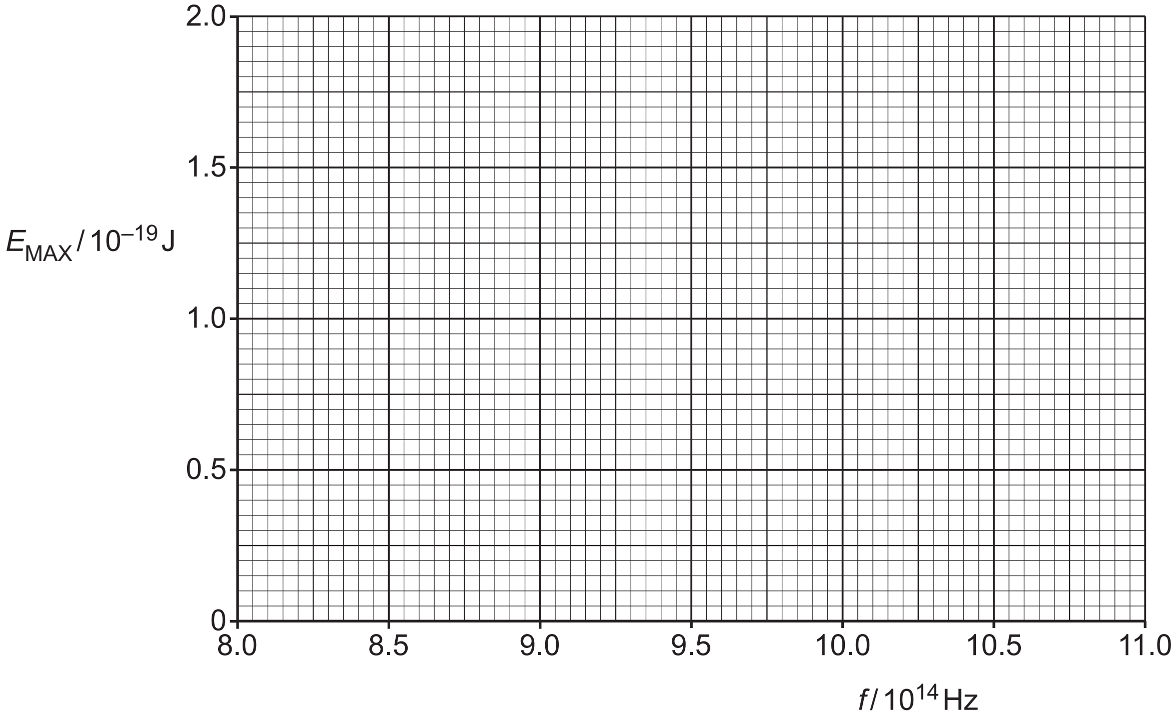

Fig. 8.1

[3]

[Total: 9]

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9 Fluorine-18 ($^{18}_{9}F$) decays by beta-plus (β^+) emission with a half-life of 110 minutes.

(a) **(i)** State the name of the beta-plus particle.

.... [1]

(ii) Show that the decay constant of fluorine-18 is $1.05 \times 10^{-4}\,s^{-1}$.

[1]

(iii) Determine the activity of 2.1×10^{-12} kg of fluorine-18.

activity = ... Bq [3]

(b) A small sample of fluorine-18 injected into the body acts as a tracer for use in medical imaging.

(i) Describe how the interaction of a β^+ particle with an electron in the body enables the formation of an image.

....

....

....

....

.... [3]

(ii) Suggest why 110 minutes is a suitable half-life for a nuclide used as a tracer in medical diagnosis.

....

....

.... [2]

[Total: 10]

10 (a) Explain how redshift leads to the idea that the Universe is expanding.

....

....

....

....

.... [3]

(b) Stars in a distant galaxy emit radiation. The total luminosity of the stars in the galaxy is 1.90×10^{36} W.
The emission spectrum of the radiation contains a line X at a wavelength of 658 nm.

Radiation from the galaxy is observed on the Earth. The observed radiation has a radiant flux intensity of 8.42×10^{-16} W m^{-2}. In the observed emission spectrum, line X is at a wavelength of 726 nm.

Determine:

(i) the distance *d* of the galaxy from the Earth

d = ... m [2]

(ii) the speed *v* of the galaxy relative to the Earth.

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

(c) Observations of many galaxies, such as the one in **(b)**, lead to many pairs of values of *d* and *v*. Plotting these values reveals a trend.

(i) On Fig. 10.1, sketch the variation of *v* with *d*.

Fig. 10.1

[2]

(ii) State the name of the quantity represented by the gradient of the line in Fig. 10.1.

.... [1]

[Total: 10]

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