Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

5039556145

PHYSICS **9702/41**

Paper 4 A Level Structured Questions **May/June 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 (SL/CB) 329807/2

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	$f_o = \dfrac{f_s v}{v \pm v_s}$
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 gravitational potential at a point.

....

....

.... [2]

(b) A satellite X, of mass M, orbits a planet at a constant distance $4R$ from the centre of the planet, as shown in Fig. 1.1.

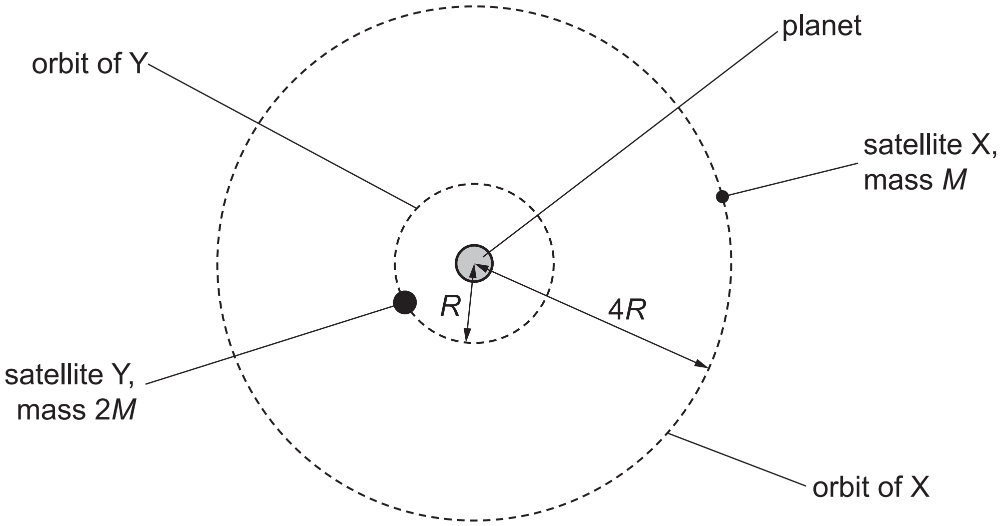

Fig. 1.1 (not to scale)

A second satellite Y, of mass $2M$, orbits the planet with orbital radius R.

The gravitational potential at X due to the planet is $-\Phi$. The planet is a uniform sphere.

(i) Explain why the gravitational potential at X is negative.

....

....

.... [2]

(ii) State an expression, in terms of Φ, for the gravitational potential at Y due to the planet.

gravitational potential = ... [2]

(iii) Complete Table 1.1 by giving expressions, in terms of some or all of *M*, *R* and *Φ*, for the quantities indicated for each of the satellites X and Y.

Table 1.1

	satellite X	satellite Y
gravitational field strength at satellite due to planet		
gravitational potential energy of satellite		

[4]

[Total: 10]

2 **(a)** **(i)** State the magnitude and unit of absolute zero on the thermodynamic temperature scale.

.... [1]

(ii) Explain why temperature measured using a laboratory liquid-in-glass thermometer does **not** give a measurement of thermodynamic temperature.

....

.... [1]

(b) Fig. 2.1 shows a simplified diagram of a type of thermometer called a platinum resistance thermometer.

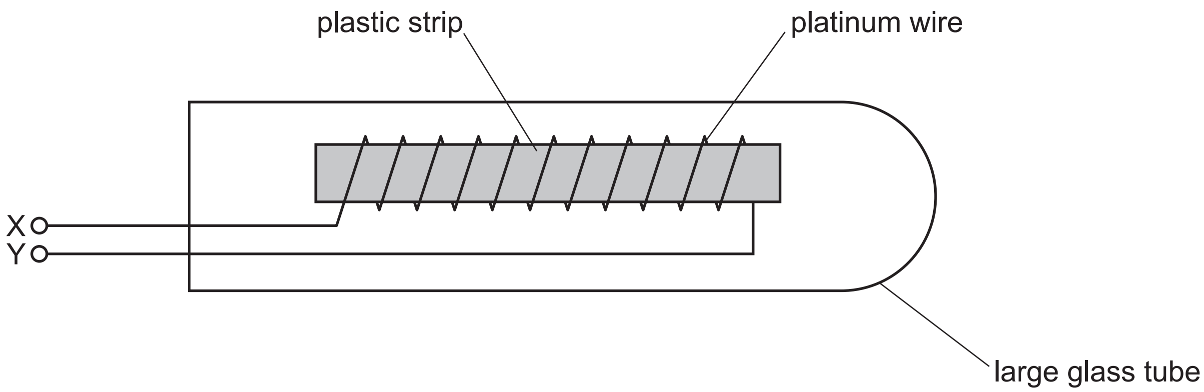

Fig. 2.1

The glass tube is immersed in the environment for which the temperature is to be determined. The resistance between the terminals X and Y is measured.

Fig. 2.2 shows the variation of the resistivity ρ of platinum with thermodynamic temperature T.

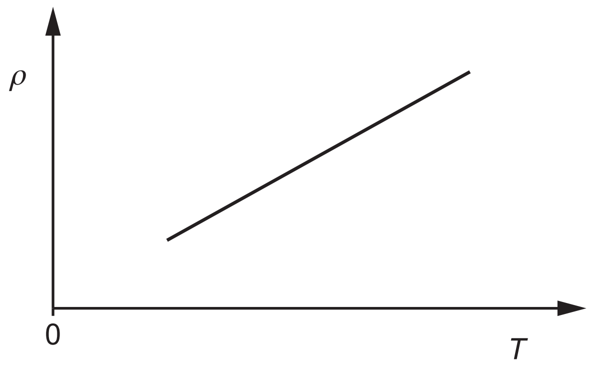

Fig. 2.2

(i) Explain how Fig. 2.2 shows that platinum is a suitable metal for use in a resistance thermometer.

....

....

.... [2]

(ii) Suggest a reason why a platinum resistance thermometer is **not** suitable for measuring a rapidly changing temperature.

....

....

.... [1]

(iii) Suggest a type of thermometer that is suitable for measuring a rapidly changing temperature.

.... [1]

(c) A negative temperature coefficient thermistor may be used as a type of resistance thermometer.

State **one** way in which the variation with temperature of the resistance of a thermistor differs from that of a platinum wire.

....

.... [1]

[Total: 7]

3 **(a)** **(i)** State what is meant by an ideal gas.

....

....

.... [2]

(ii) Use one of the basic assumptions of the kinetic theory to explain what can be deduced about the potential energy associated with the random motion of molecules in an ideal gas.

....

....

.... [2]

(b) A sample of $0.26\,\text{m}^3$ of an ideal gas is at pressure $2.0 \times 10^5\,\text{Pa}$ and temperature 290 K.

Determine:

(i) the number N of molecules of the gas

N = ... [2]

(ii) the average translational kinetic energy E_K of one molecule of the gas

E_K = ... J [2]

(iii) the internal energy of the gas. Explain your reasoning.

internal energy = ... J [2]

(c) The volume V of the gas in **(b)** is now varied, keeping its pressure constant.

On Fig. 3.1, sketch the variation with V of the internal energy U of the gas.

Fig. 3.1

[2]

[Total: 12]

4 **(a)** State what is meant by resonance.

....

....

.... [2]

(b) A small ball is held in place using a stretched string. One end of the string is fixed to a wall and the other end is attached to a vibration generator, as shown in Fig. 4.1.

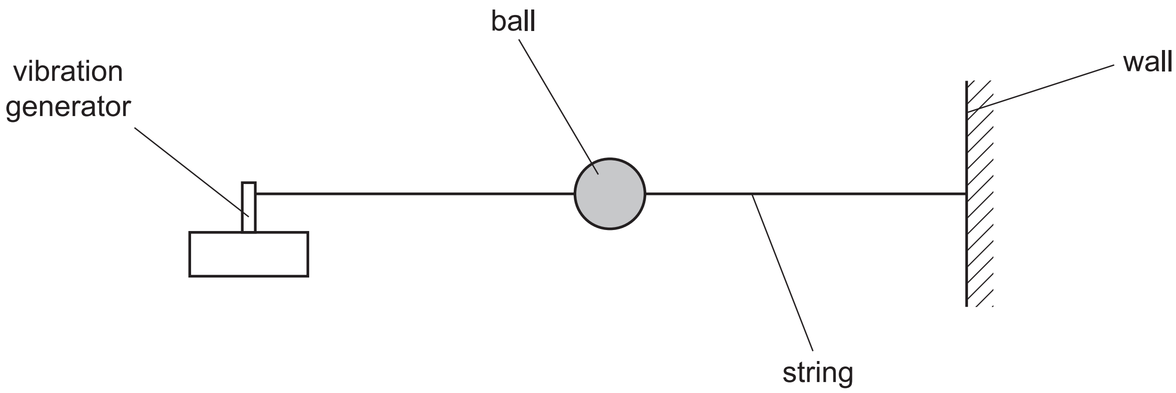

Fig. 4.1

Initially, the vibration generator is switched off.

A student displaces the ball vertically and then releases it. Fig. 4.2 shows the variation of the displacement of the ball with time after it is released.

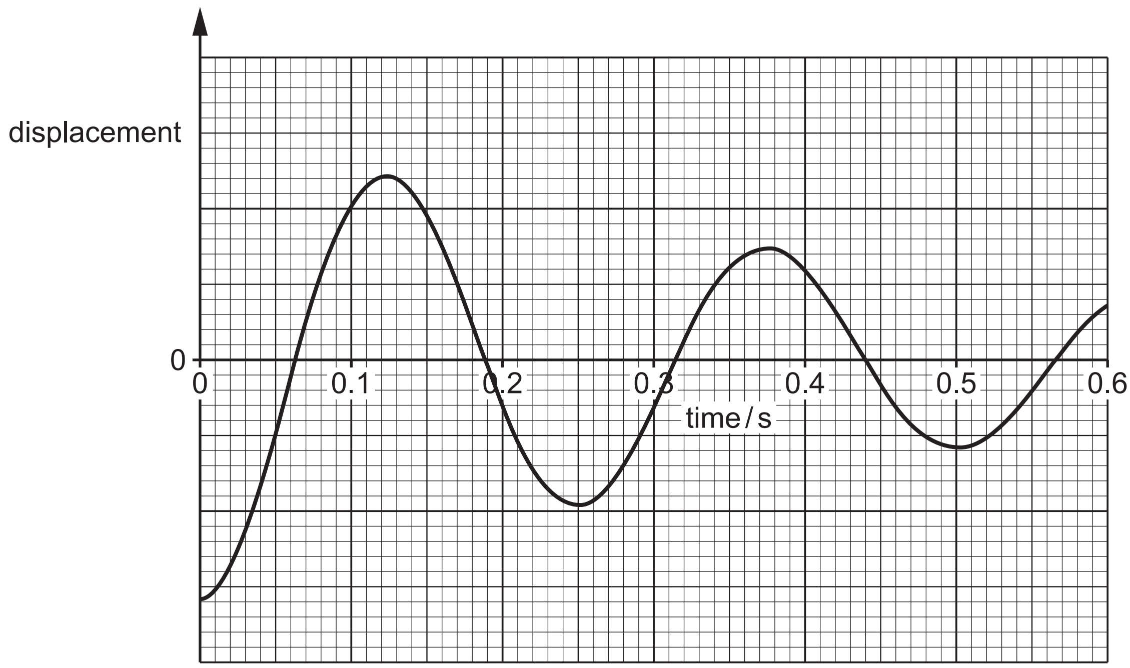

Fig. 4.2

(i) State the name of the phenomenon illustrated by the decrease in the amplitude of the oscillations in Fig. 4.2.

.... [1]

(ii) Explain the decrease with time of the amplitude of the oscillations of the ball.

....

....

.... [2]

(iii) Determine the frequency of the oscillations of the ball.

frequency = ... Hz [1]

(c) The vibration generator in **(b)** is switched on and its frequency *f* of vibration is gradually increased from 0 to 10 Hz.

On Fig. 4.3, sketch the variation with *f* of the amplitude of the oscillations of the ball.

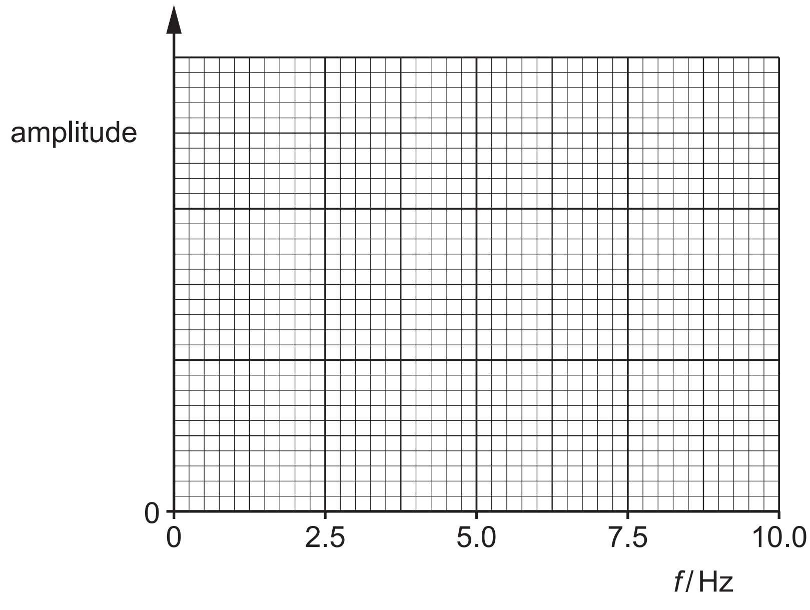

Fig. 4.3

[2]

[Total: 8]

5 **(a)** Define electric field.

....

....

.... [2]

(b) Fig. 5.1 shows two parallel conducting plates that are in a vacuum. The plates are separated by a distance of 6.7 cm and have a potential difference (p.d.) of 430 V between them.

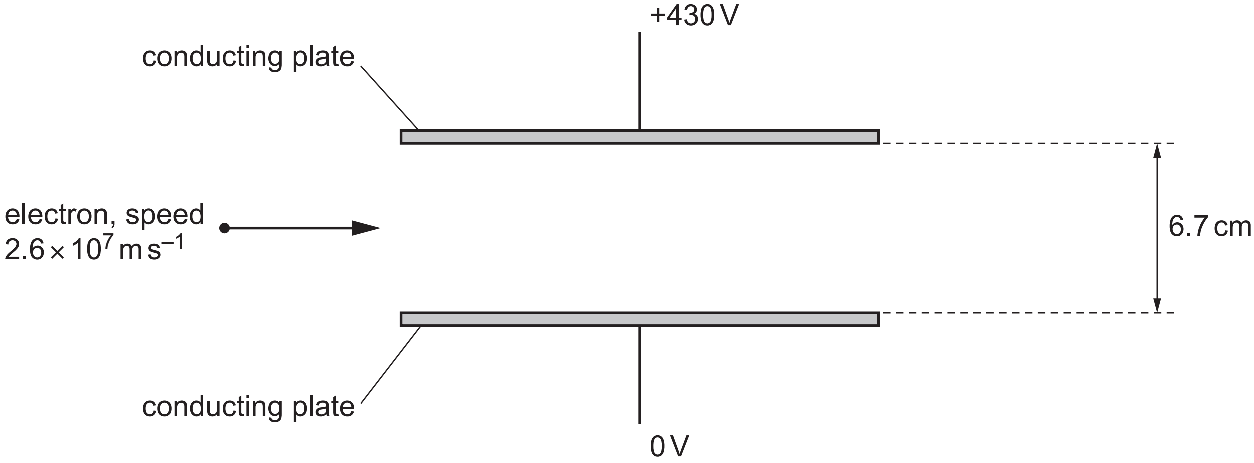

Fig. 5.1

(i) On Fig. 5.1, draw four field lines to represent the electric field between the plates. [2]

(ii) Determine the strength *E* of the electric field between the plates.

E = ... $N\,C^{-1}$ [2]

(iii) An electron travels at a speed of $2.6 \times 10^7\,m\,s^{-1}$ towards the region between the plates, as shown in Fig. 5.1.

On Fig. 5.1, draw the path of the electron as it moves between and beyond the plates. [2]

(c) A uniform magnetic field is now applied in the region of the electric field in Fig. 5.1, so that the electron in **(b)(iii)** travels undeviated through the region.

(i) Determine the direction of the uniform magnetic field.

.... [1]

(ii) Explain, with reference to the forces exerted by the two fields on the electron, why the path of the electron is undeviated.

....

....

.... [2]

(iii) Determine the flux density B of the uniform magnetic field. Give a unit with your answer.

B = ... unit .... [2]

[Total: 13]

6 Fig. 6.1 shows a capacitor of capacitance C connected in series with a resistor of resistance R.

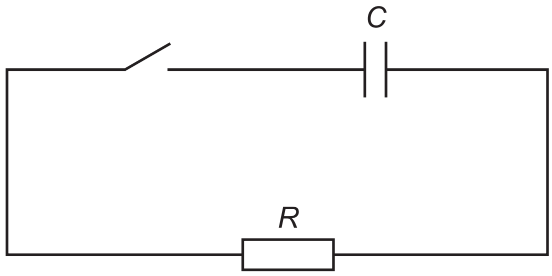

Fig. 6.1

Initially the switch is open and there is a p.d. of 12 V across the capacitor.

At time $t = 0$, the switch is closed so that there is a current I in the resistor.

Fig. 6.2 shows the variation of I with t.

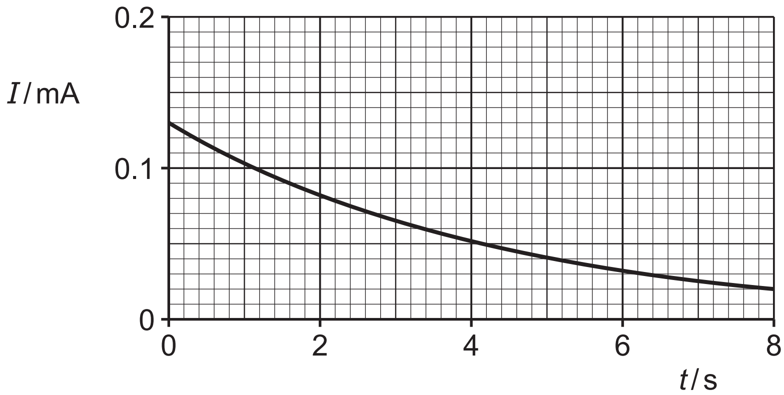

Fig. 6.2

(a) Explain the shape of the line in Fig. 6.2.

....

....

....

....

.... [3]

(b) Use Fig. 6.2 to determine:

(i) resistance *R*

R = ... Ω [2]

(ii) the time constant τ of the circuit in Fig. 6.1.

τ = ... s [3]

(c) Use your answers in **(b)** to determine capacitance *C*.

C = ... F [2]

[Total: 10]

7 A circuit contains a power supply that provides a sinusoidal alternating input voltage V_{IN}. There is an output voltage V_{OUT} across a load resistor R, as shown in Fig. 7.1.

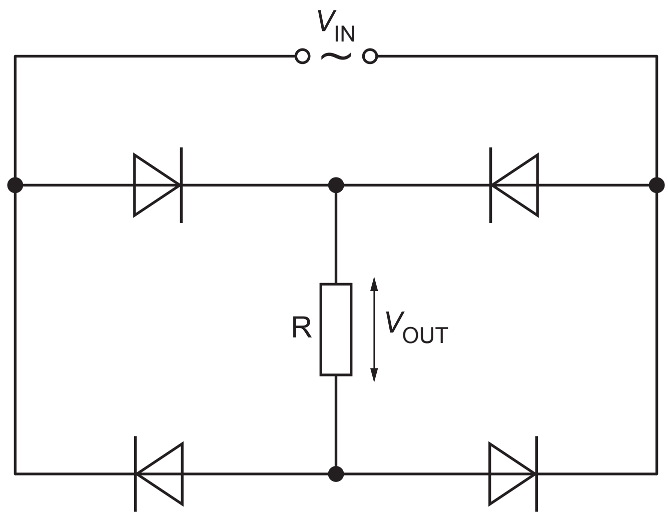

Fig. 7.1

(a) State the purpose of the circuit in Fig. 7.1.

....

....

.... [2]

(b) Fig. 7.2 shows the variation of V_{OUT} with time *t*.

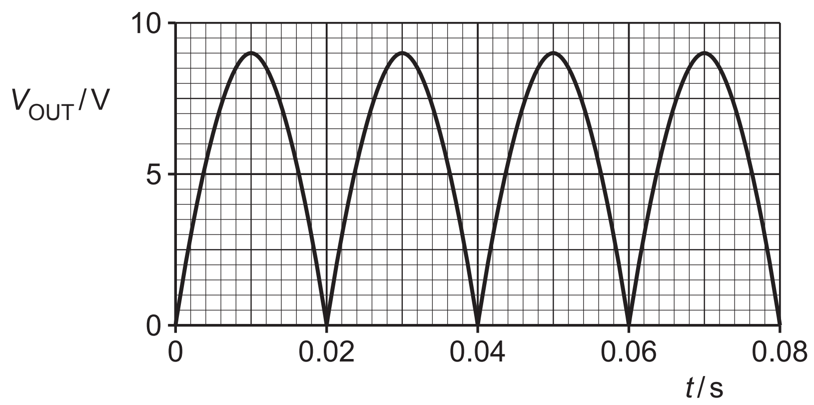

Fig. 7.2

(i) The load resistor R has a resistance of 370 Ω.

Show that the maximum power dissipated in R is 0.22 W.

[2]

(ii) On Fig. 7.3, sketch the variation with *t* of the power *P* dissipated in R.

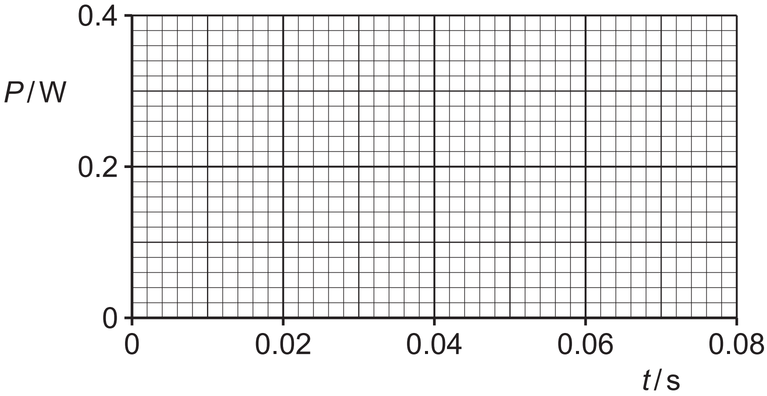

Fig. 7.3

[3]

(iii) Calculate the mean power dissipated in R.

mean power = ... W [1]

(c) The circuit of Fig. 7.1 is disconnected, and R is connected directly across the power supply.

Explain, without calculation, how the mean power now dissipated in R compares with the answer in **(b)(iii)**.

....

....

.... [2]

[Total: 10]

8 **(a)** State what is meant by a photon.

....

....

.... [2]

(b) Fig. 8.1 shows a tube in which X-rays are produced at a metal target.

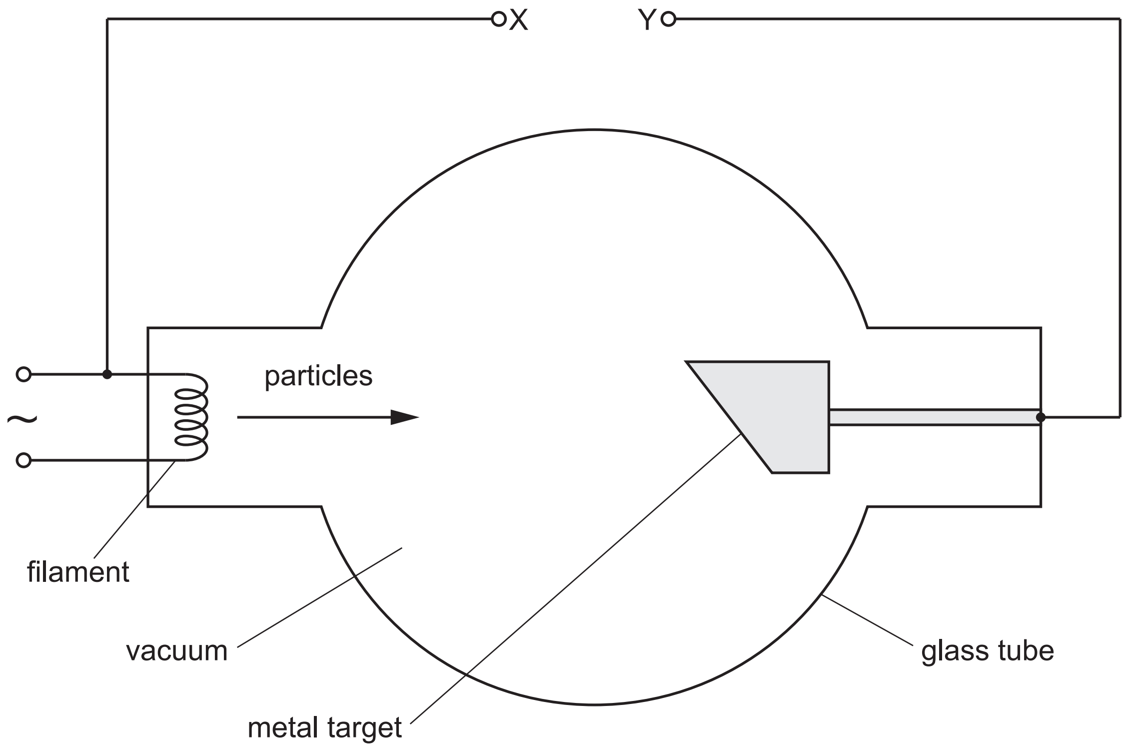

Fig. 8.1

Particles are accelerated from the filament to the target by a constant high voltage applied across the terminals X and Y.

(i) State the name of the particles.

.... [1]

(ii) On Fig. 8.1, use + and – signs to label terminals X and Y to indicate the polarity of the high voltage. [1]

(c) For an accelerating voltage of 32 kV in Fig. 8.1, determine:

(i) the maximum energy, in MeV, of an X-ray photon produced at the target

maximum photon energy = ... MeV [1]

(ii) the maximum momentum of an X-ray photon produced at the target

maximum photon momentum = ... N s [2]

(iii) the minimum wavelength of X-rays produced at the target.

minimum wavelength = ... m [3]

(d) Explain why X-rays can be used to produce images of internal body structures that have good contrast.

....

....

....

....

.... [3]

[Total: 13]

9 **(a)** Define half-life of a radioactive isotope.

....

....

.... [1]

(b) Radioactive isotope X decays to isotope Y.

A sample contains only nuclei of X at time t = 0. Fig. 9.1 shows the variation with t of the numbers of nuclei of X and of Y as the sample decays.

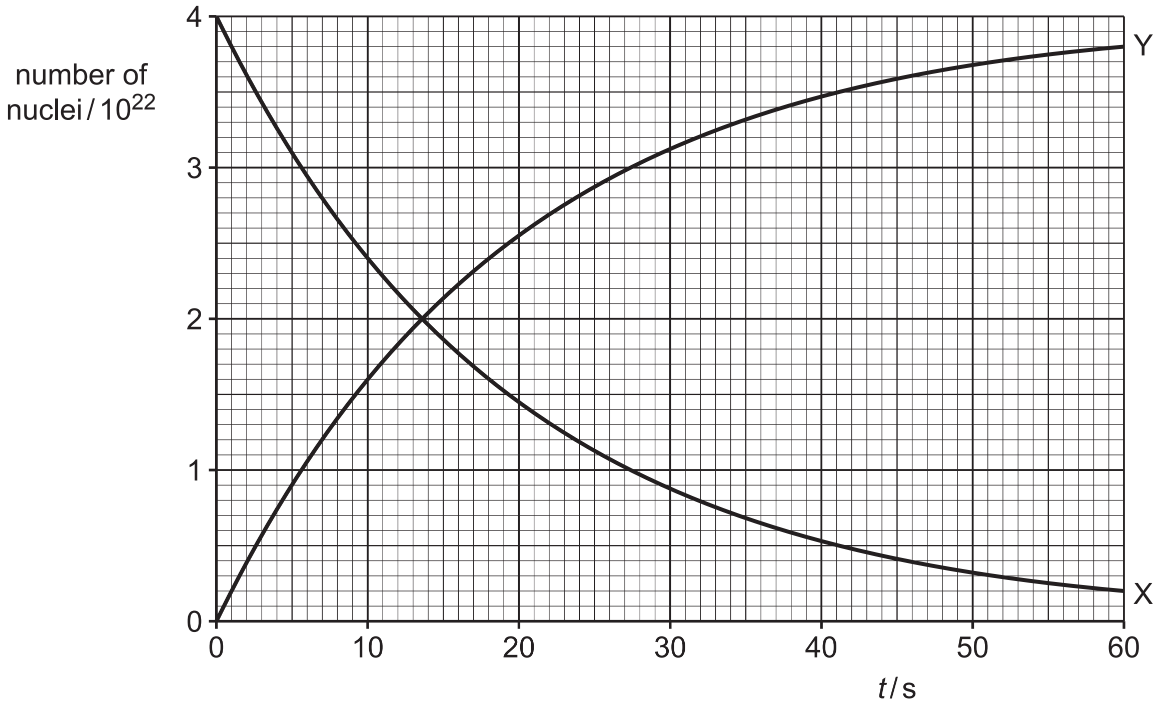

Fig. 9.1

(i) State the name of the quantity represented by the magnitude of the gradient of line X in Fig. 9.1.

.... [1]

(ii) State **three** conclusions about X or Y that may be drawn from Fig. 9.1. The conclusions may be qualitative or quantitative. Use the space below for any working that you need.

1 ....

....

2 ....

....

3 ....

.... [3]

(c) The mass of radioactive isotope X in the sample in **(b)** is 7.3×10^{-4} kg at time $t = 0$.

Determine the nucleon number of isotope X.

nucleon number = ... [3]

[Total: 8]

10 **(a)** **(i)** State what is meant by the luminosity of a star.

....

....

.... [2]

(ii) Explain how a standard candle in a distant galaxy can be used to determine the distance of the galaxy from an observer.

....

....

....

....

.... [3]

(b) The Sun has a radius of 6.96×10^8 m and a surface temperature of 5780 K.
Light from the Sun is observed to have a peak intensity at a wavelength of 501 nm.

(i) Calculate the luminosity of the Sun. Give a unit with your answer.

luminosity = ... unit .... [2]

(ii) Another star emits radiation that has a peak intensity at a wavelength of 624 nm.

Determine the surface temperature of this star.

surface temperature = ...K [2]

[Total: 9]

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