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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

6179287153

PHYSICS **9702/42**

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.

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	$\phi = -\dfrac{GM}{r}$
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 The Earth may be considered as a uniform sphere of radius 6.37×10^6 m.

Cambridge is at a point on the Earth's surface that has a latitude of 52.2° north of the Equator, as shown in Fig. 1.1.

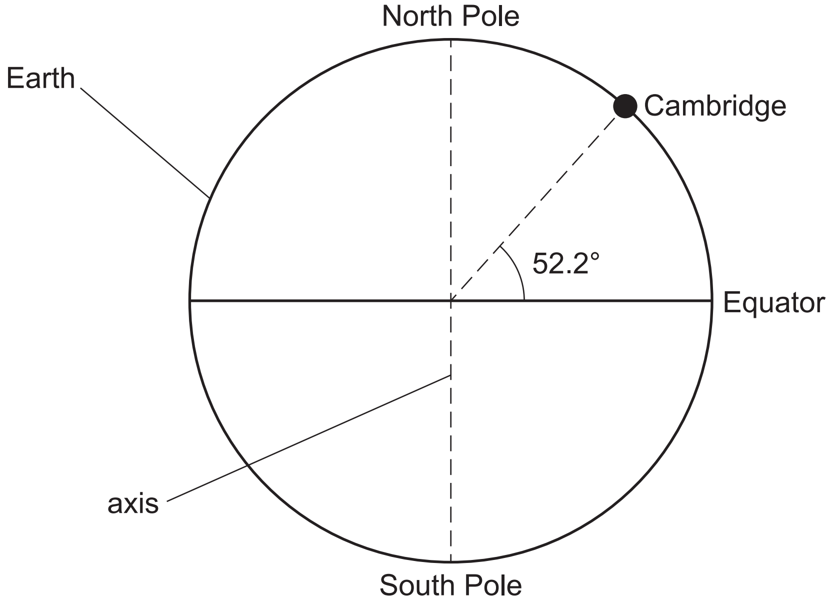

Fig. 1.1

As the Earth spins on its axis, Cambridge moves in a circle that is parallel to the Equator but with a smaller radius.

(a) (i) Show that the radius of the circle around which Cambridge moves is 3.90×10^6 m.

[1]

(ii) Calculate the speed at which Cambridge moves around the circle.

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

(b) A student of mass 58.6 kg stands on horizontal ground in Cambridge.

(i) Determine the magnitude of the resultant force that acts to cause the circular motion of the student.

resultant force = ... N [2]

(ii) On Fig. 1.2, draw an arrow to show the direction of the resultant force that acts on the student.

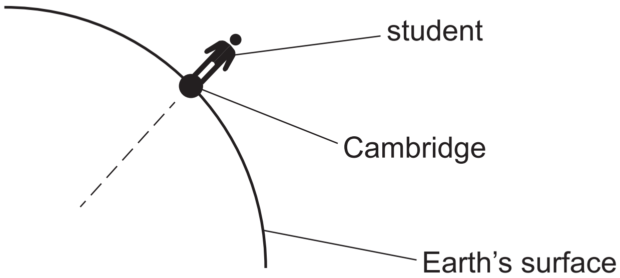

Fig. 1.2 (not to scale)

[1]

(iii) On Fig. 1.3, draw labelled arrows from the student to show the directions of the forces that act on the student to cause the resultant force in **(b)(ii)**.

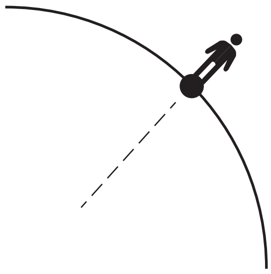

Fig. 1.3 (not to scale)

[2]

[Total: 9]

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

....

....

.... [2]

(b) One of the basic assumptions of the kinetic theory of gases is that there are no forces exerted between the molecules of the gas except during collisions.

State **two** other basic assumptions of the kinetic theory of gases.

1 ....

....

2 ....

....
[2]

(c) Hydrogen gas consists of molecules that each have a mass of 3.34×10^{-27} kg. Hydrogen may be considered to be an ideal gas.

A spherical balloon contains 0.0160 mol of hydrogen gas at a temperature of 282 K. At this temperature, the volume of gas in the balloon is 1.87×10^{-4} m^3.

(i) Determine the pressure of the gas.

pressure = ... Pa [2]

(ii) Estimate the average separation of the hydrogen molecules in the gas.

average separation = ... m [2]

(d) **(i)** Use your answer in **(c)(ii)** to calculate the average gravitational force between adjacent molecules in hydrogen gas.

average force = ... N [2]

(ii) By considering the weight of a molecule, suggest with a reason whether your answer in **(d)(i)** is consistent with the assumption of the kinetic theory of gases that there are no forces exerted between molecules.

....

....

.... [1]

[Total: 11]

3 (a) State what is meant by two objects being in thermal equilibrium.

....

....

.... [2]

(b) Fig. 3.1 shows a type of thermometer called a constant volume gas thermometer.

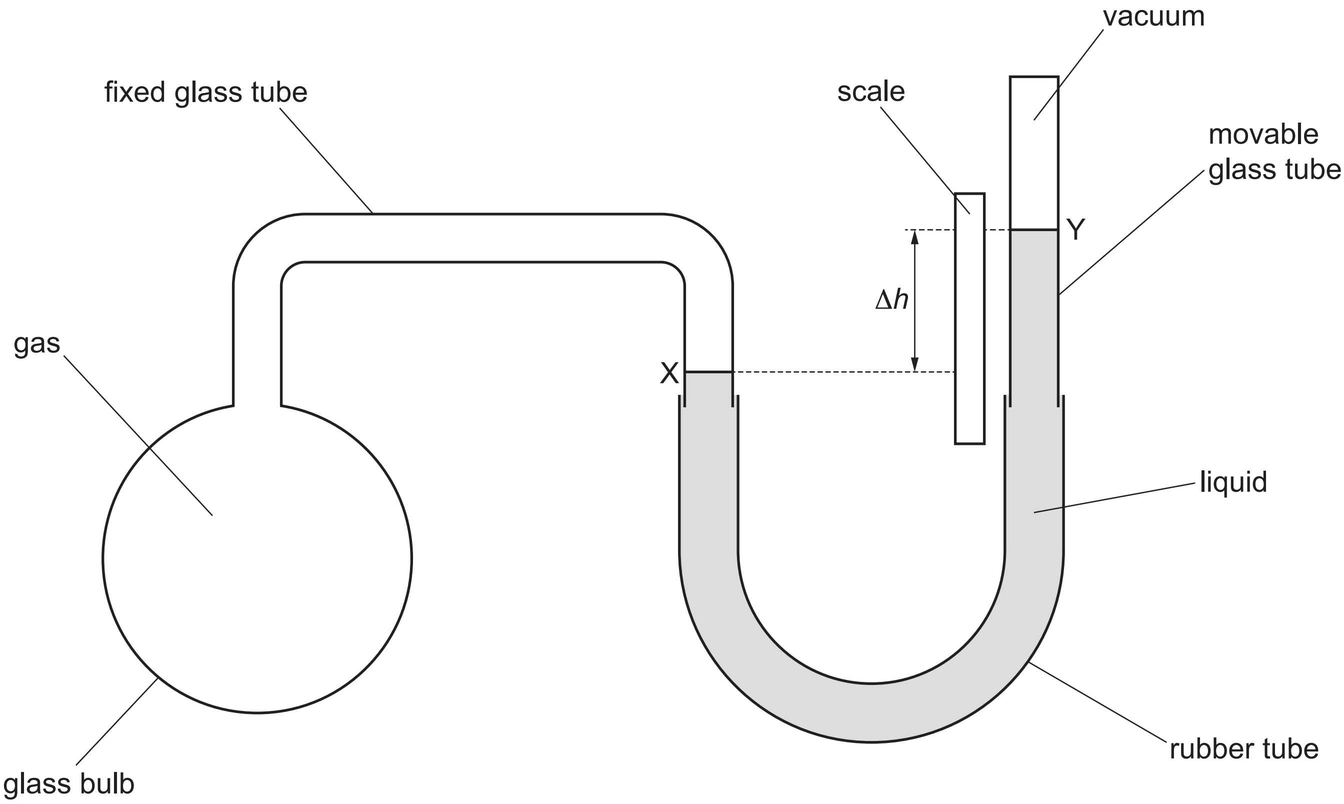

Fig. 3.1 (not to scale)

The thermometer is used to determine the thermodynamic temperature T of the gas in the glass bulb.

The glass bulb is immersed in the environment for which the temperature is to be measured. The height of the movable glass tube is then adjusted so that the level of the liquid on the left-hand side aligns with the reference line X marked on the fixed glass tube. The reference line Y is marked on the side of the movable glass tube. The level of the liquid at Y is higher than at X as a result of the pressure of the gas in the glass bulb.

The difference in height Δh between the liquid levels at X and Y is then measured using the scale. The thermodynamic temperature T of the gas is directly proportional to the pressure of the gas. This pressure is directly proportional to Δh.

(i) The value of Δh can be used to calculate the pressure of the gas. In order to do this, the gravitational field strength is used, along with a property of the liquid.

State the property of the liquid that is used to calculate the pressure.

.... [1]

(ii) Before the measurement of Δh can be made, the glass bulb needs to reach thermal equilibrium with the environment for which the temperature is to be measured.

State **two** disadvantages of using a constant volume gas thermometer to measure temperature.

1 ....

....

2 ....

....
[2]

(iii) Suggest **one** situation in which a constant volume gas thermometer would be an appropriate type of thermometer to choose for measuring temperature.

....

....

.... [1]

(iv) Level X aligns with 2.31 cm on the scale. At 0 °C, level Y aligns with 8.69 cm.

At temperature θ, level Y aligns with 7.83 cm on the scale.

Determine a value for θ in °C.

θ = ... °C [3]

[Total: 9]

4 A cylinder contains a fixed mass of an ideal gas at pressure $2Y$ and volume $6X$.

The gas undergoes a sequence of changes from its initial state A, through states B, C and D, then finally back to its initial state A, as shown in Fig. 4.1.

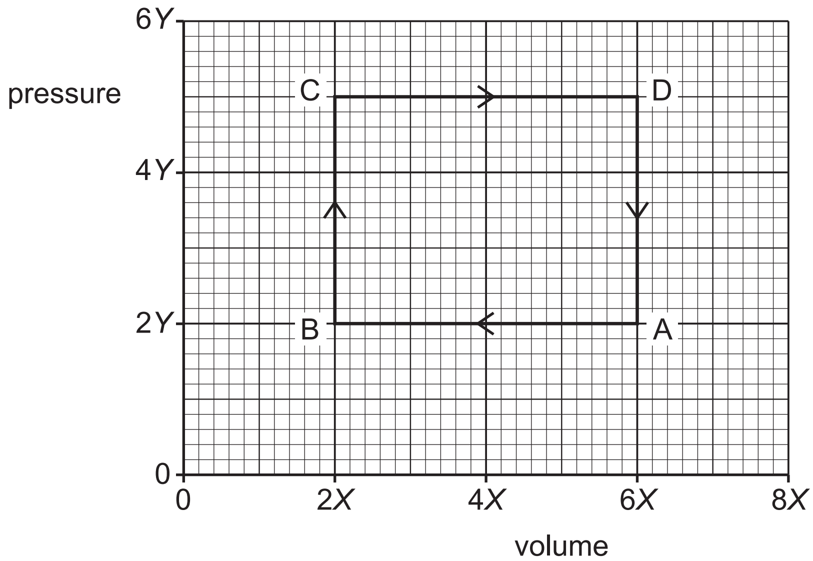

Fig. 4.1

Fig. 4.2 shows the variation with time of the internal energy of the gas.

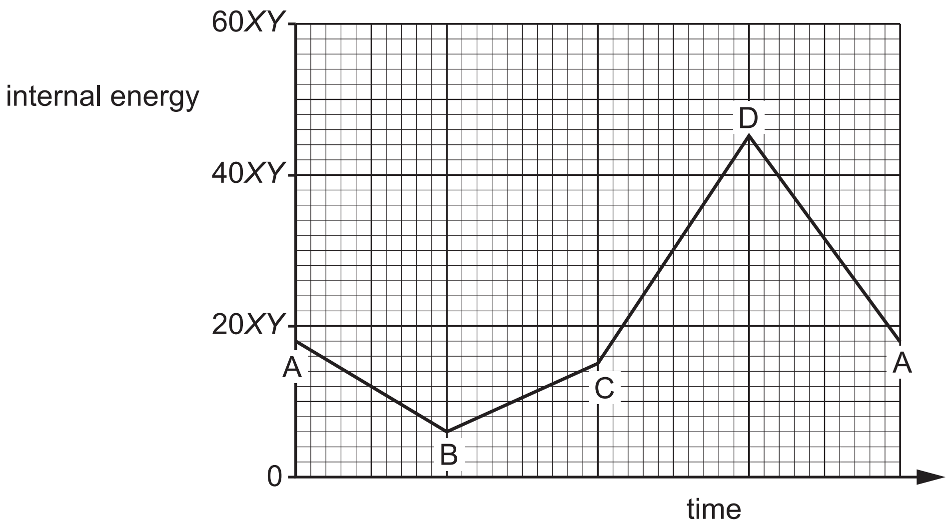

Fig. 4.2

(a) State the first law of thermodynamics.

....

....

.... [2]

(b) **(i)** Use Fig. 4.1 and Fig. 4.2 to determine the general expression for the internal energy U of the gas when it has pressure p and volume V.

U = ... [1]

(ii) An ideal gas at thermodynamic temperature T contains N molecules.

Use your answer in **(b)(i)** and the equation of state for an ideal gas to deduce an expression for U in terms of N and T. Identify any other symbols you use.

U = ... [2]

(c) Determine expressions, in terms of X and Y, for the work W done on the gas during:

(i) change AB

W = ... [1]

(ii) change CD.

W = ... [1]

(d) Use your answers in **(c)** and the first law of thermodynamics to determine an expression, in terms of X and Y, for the net thermal energy Q supplied to the gas during one full cycle ABCDA. Explain your reasoning.

Q = ... [3]

[Total: 10]

5 A steel ball on the end of a thin string oscillates with small oscillations, as shown in Fig. 5.1.

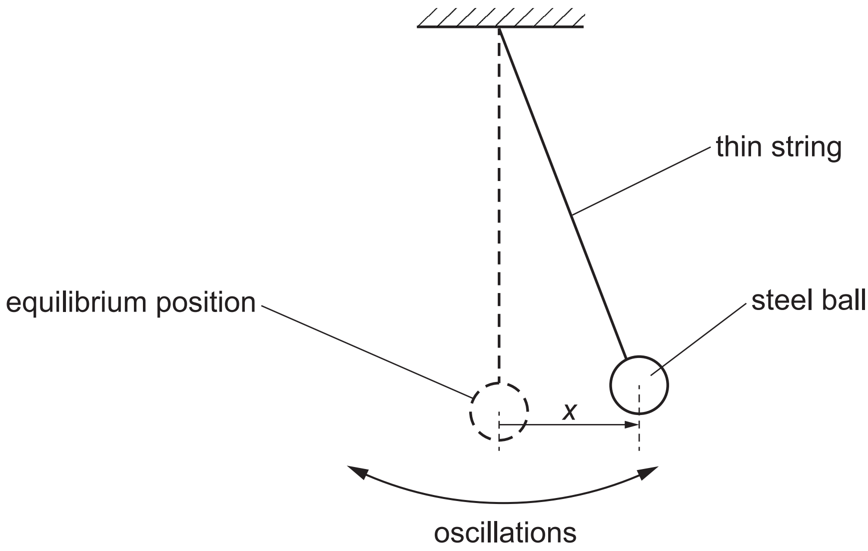

Fig. 5.1 (not to scale)

The displacement of the centre of the ball from its equilibrium position is x.

(a) Fig. 5.2 shows the variation with x of the acceleration a of the ball.

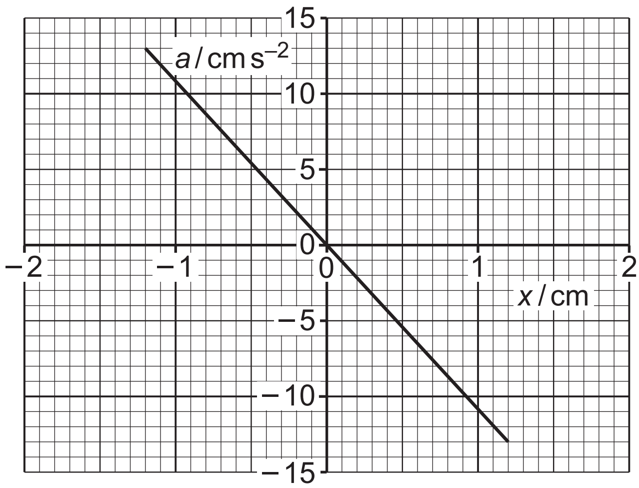

Fig. 5.2

(i) Explain how Fig. 5.2 shows that the oscillations of the ball are simple harmonic.

....

....

.... [2]

(ii) Determine the period T of the oscillations.

T = ... s [3]

(b) At time t = 0, when the displacement of the ball has its maximum value, the ball is immersed in a trough containing thick oil so that the ball is just below the surface of the oil. This results in the subsequent motion of the ball being heavily damped.

(i) State what is meant by damping.

....

....

.... [2]

(ii) On Fig. 5.3, sketch a possible variation of the displacement x of the ball with t between t = 0 and t = 2T.

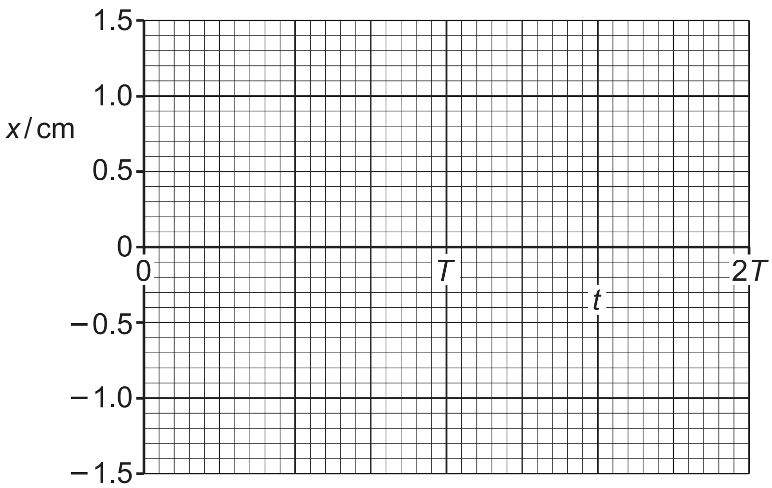

Fig. 5.3

[3]

[Total: 10]

6 **(a)** Define electric field at a point.

....

.... [1]

(b) An isolated conducting sphere in a vacuum has a capacitance of 69 pF.
The charge on the sphere is +83 pC.

(i) On Fig. 6.1, draw field lines to represent the electric field outside the sphere due to the charge on the sphere.

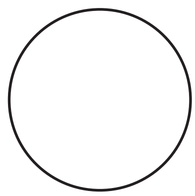

Fig. 6.1

[2]

(ii) Calculate the electric potential at the surface of the sphere.

electric potential = ... V [2]

(iii) Determine the radius of the sphere.

radius = ... m [2]

(iv) Calculate the electric field strength E at the surface of the sphere. Give a unit with your answer.

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

(c) The sphere in **(b)** is discharged by connecting it to earth (0 V) through a resistor of resistance 120 MΩ.

Calculate the time taken for the charge to fall to 26 pC.

time = ... s [2]

[Total: 11]

7 An alternating voltage V varies with time t according to

$$V = 18\cos 40\pi t$$

where V is in V and t is in s.

(a) For the alternating voltage:

(i) show that the period is 0.050 s

[1]

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

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

(b) On Fig. 7.1, sketch the variation of V with t for values of t from t = 0 to t = 100 ms.

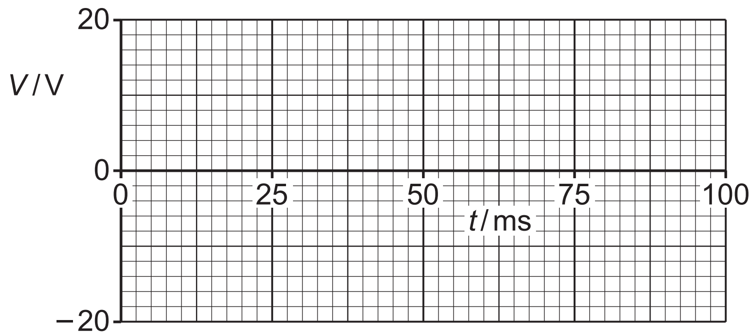

Fig. 7.1

[3]

(c) The alternating voltage is rectified to produce an output voltage across a load resistor R, as shown in Fig. 7.2.

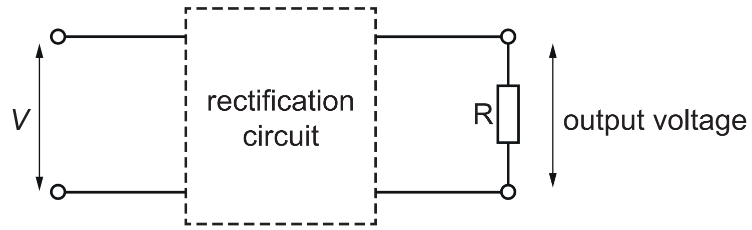

Fig. 7.2

Fig. 7.3 shows the variation with t of the power P in the load resistor.

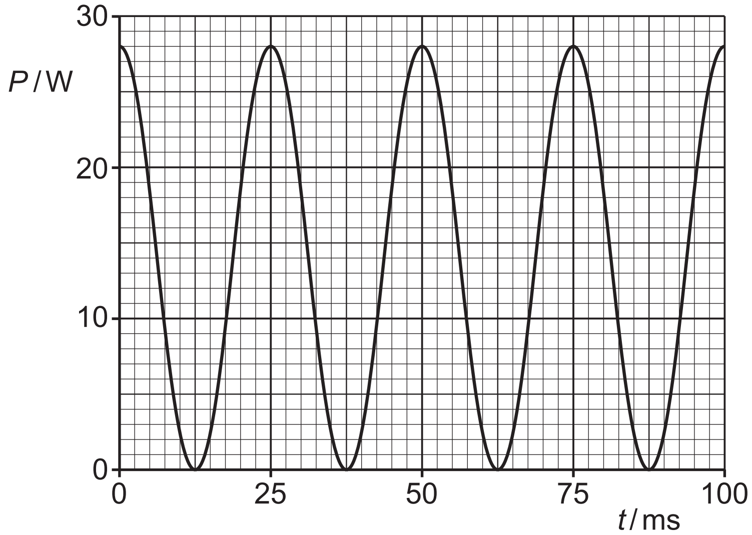

Fig. 7.3

State **three** conclusions that can be drawn from Fig. 7.3. The conclusions may be qualitative or quantitative. Use the space for any working.

1 ....

....

2 ....

....

3 ....

....

[3]

[Total: 8]

8 Fig. 8.1 shows the three lowest-frequency lines in the part of the emission spectrum for hydrogen that relates to electron transitions to the ground state (level $n = 1$).

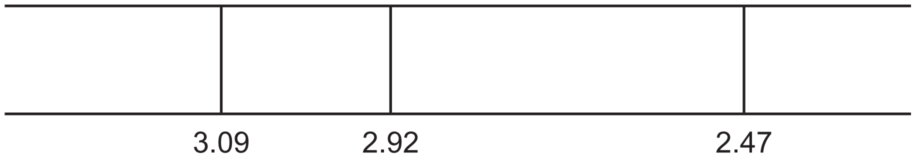

Fig. 8.1 (not to scale)

The numbers represent the frequencies, in 10^{15} Hz, associated with the spectral lines.

(a) Use the photon model of electromagnetic radiation to explain how the existence of spectral lines in the emission spectrum provides evidence for discrete electron energy levels in the hydrogen atom.

....

....

....

....

.... [3]

(b) The energy of the ground state (level $n = 1$) in a hydrogen atom is –13.6 eV.

(i) Calculate the energy, in J, of the ground state.

energy = ... J [1]

(ii) Show that the energy difference between levels $n = 1$ and $n = 2$ is 10.2 eV.

[2]

(iii) Complete Table 8.1 to show the energy differences from the ground state, and the energies of the levels up to $n = 4$, in the hydrogen atom. Use the space for any working.

Table 8.1

level	(energy difference from $n = 1$) / eV	energy / eV
$n = 4$		
$n = 3$		
$n = 2$	10.2	
$n = 1$	0.0	–13.6

[4]

[Total: 10]

9 (a) State what is meant by the mass defect of a nucleus.

....

....

.... [2]

(b) The nuclear fusion reaction for the formation of helium-4 from deuterium is represented by

$$^{2}_{1}\text{H} + ^{2}_{1}\text{H} \rightarrow ^{4}_{2}\text{He}.$$

Table 9.1 shows the masses of the nuclides involved in this reaction.

Table 9.1

nuclide	nuclide mass / u
$^{2}_{1}\text{H}$	2.013 553
$^{4}_{2}\text{He}$	4.001 505

Calculate the energy released in the formation of 1.00 mol of helium-4.

energy = ... J [4]

(c) The star Sirius has a radius of 1.19×10^9 m and loses mass due to nuclear fusion at a rate of 1.09×10^{11} kg s^{-1}. Assume that the power of the radiation emitted by the star is equal to the power released by this process.

(i) Determine a value for the luminosity of Sirius. Give a unit with your answer.

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

(ii) Use your answer in **(c)(i)** to determine the surface temperature of Sirius.

surface temperature = ... K [2]

(d) Explain how cosmologists use standard candles to estimate the distance of a galaxy from the Earth.

....

....

....

....

.... [3]

[Total: 13]

10 **(a)** State what is meant by contrast in an X-ray image.

....

.... [1]

(b) X-rays of intensity I_0 are incident normally on a structure, as shown in Fig. 10.1.

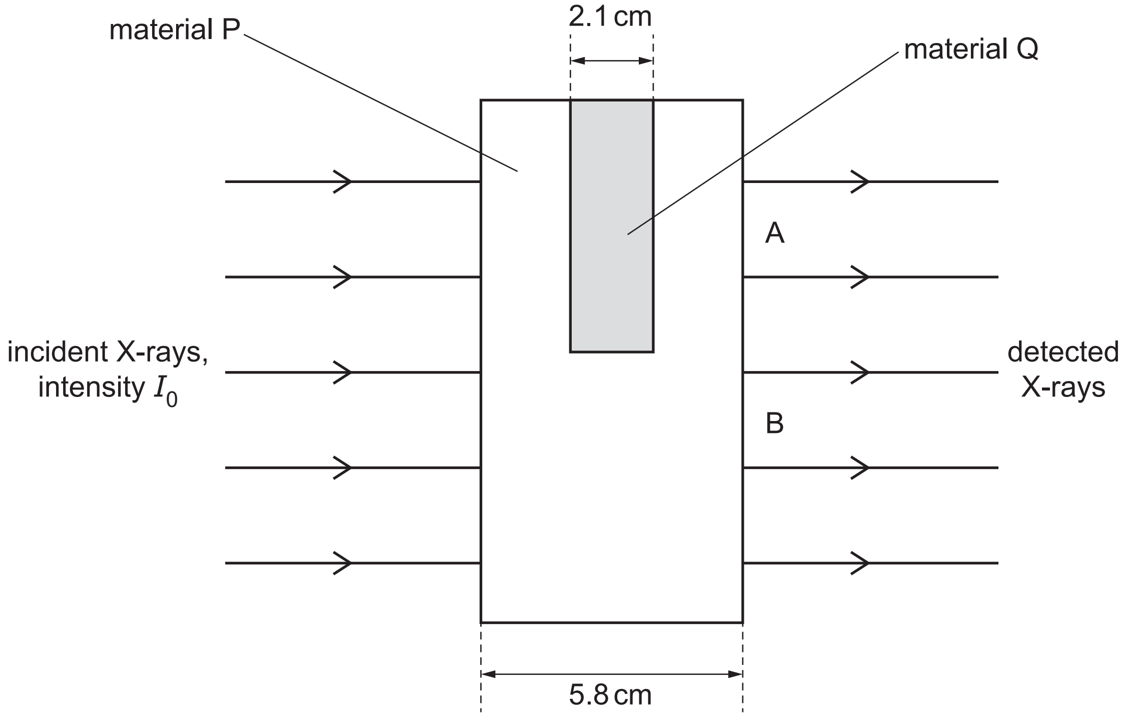

Fig. 10.1

Material P has a linear attenuation coefficient of $0.35\,\text{cm}^{-1}$.
The X-rays emerging from the structure in region A have an intensity of $0.053I_0$.

(i) Show that the intensity of the X-rays emerging in region B is $0.13I_0$.

[1]

(ii) Determine the linear attenuation coefficient μ of material Q.

μ = ... cm^{-1} [3]

(iii) Use the information in **(b)(i)** to suggest why the X-rays emerging from the structure form an image that has poor contrast.

....

....

.... [1]

(c) Explain how X-rays are used in computed tomography (CT) scanning to produce a three-dimensional image of an internal structure.

....

....

....

....

.... [3]

[Total: 9]

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