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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

6055671422

PHYSICS **9702/41**

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 (WW/SW) 342379/2

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	$f_o = \frac{f_s v}{v \pm v_s}$
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 **(a)** Define gravitational potential at a point.

....

....

.... [2]

(b) Mars is a planet that may be considered to be an isolated uniform sphere of radius 3.4×10^6 m.

A satellite of mass 122 kg is in orbit around Mars at a constant height of 1.7×10^6 m above the surface of the planet.

The height of the orbit is increased to 6.8×10^6 m above the surface. This increases the gravitational potential energy of the satellite by 5.1×10^8 J.

(i) Show that the mass of Mars is 6.4×10^{23} kg.

[3]

(ii) Calculate the gravitational potential ϕ at the surface of Mars. Give a unit with your answer.

ϕ = ... unit .... [2]

(c) The satellite in **(b)** is moved to an orbit in which the satellite remains at the same point above the surface of Mars.

(i) The orbit has a period of 25 hours.

State what can be deduced from this about the rotation of Mars on its axis.

....

.... [1]

(ii) State **one** other feature of this orbit.

....

.... [1]

[Total: 9]

2 A helium atom may be modelled as a nucleus surrounded by two electrons in diametrically opposite circular orbits, each of radius 170 pm, as shown in Fig. 2.1.

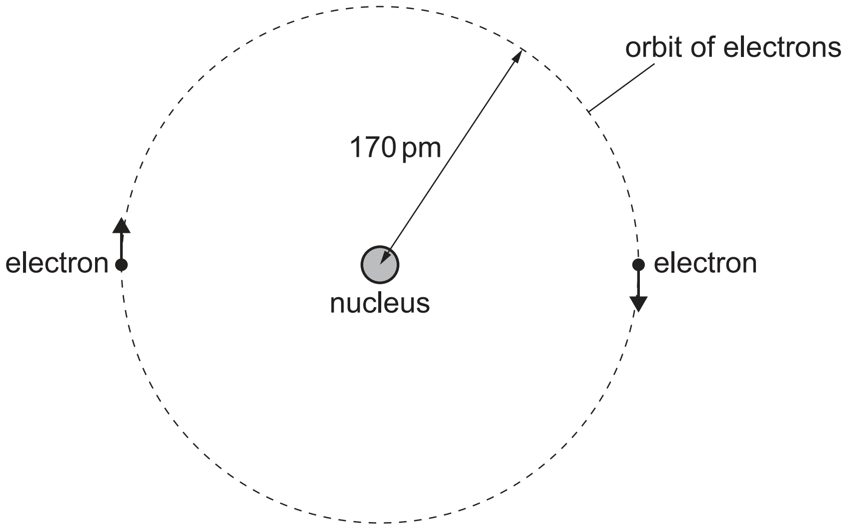

Fig. 2.1

(a) State Coulomb's law.

....

....

.... [2]

(b) **(i)** State the charge on the nucleus, in terms of the elementary charge *e*.

charge = ... *e* [1]

(ii) Show that the electric force between the nucleus and one of the electrons is 1.6×10^{-8} N.

[1]

(c) Assume that the force in **(b)(ii)** is the only force on the electrons.

(i) Calculate the speed of the orbiting electrons.

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

(ii) Calculate the period of the orbit of the electrons.

period = ... s [2]

(d) In practice, the orbit of each electron is affected by the presence of the other electron.

(i) For the position of one of the electrons, determine the ratio

$$\frac{\text{electric field strength due to the other electron}}{\text{electric field strength due to the nucleus}}.$$

ratio = ... [2]

(ii) Use your answer in **(d)(i)** to suggest and explain how the orbit of the electron is affected by the presence of the other electron.

....

.... [1]

[Total: 11]

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

....

....

.... [2]

(b) Explain why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion.

....

....

....

....

.... [3]

(c) An ice cube of mass 37.0 g at temperature 0.0 °C is placed in a beaker containing water of mass 208 g at temperature 26.4 °C.

When all the ice has melted, and all the water in the beaker has reached thermal equilibrium, the final temperature of all the water is 10.3 °C.

The specific heat capacity of water is 4.18 $J g^{-1} °C^{-1}$.

The beaker has negligible specific heat capacity and is perfectly insulated from the surroundings.

Determine a value, to three significant figures, for the specific latent heat of fusion of water.

specific latent heat of fusion = ... $J g^{-1}$ [4]

[Total: 9]

4 **(a)** **(i)** State what is meant by the internal energy of a system.

....

....

.... [2]

(ii) Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

....

....

....

.... [2]

(b) A sample of an ideal gas at thermodynamic temperature T has internal energy U.

The gas is compressed so that its temperature increases to $3T$.
During this compression, work W is done on the gas.

The gas is then cooled at constant volume so that its temperature decreases to $2T$.

Complete Table 4.1 to show, in terms of some or all of W, T and U, the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas for each of the two processes.

Table 4.1

	work done on gas	thermal energy supplied to gas	increase in internal energy of gas
compression	$+W$		
cooling			

[4]

[Total: 8]

5 A cuboidal block floats in a liquid with its base horizontal, as shown in Fig. 5.1.

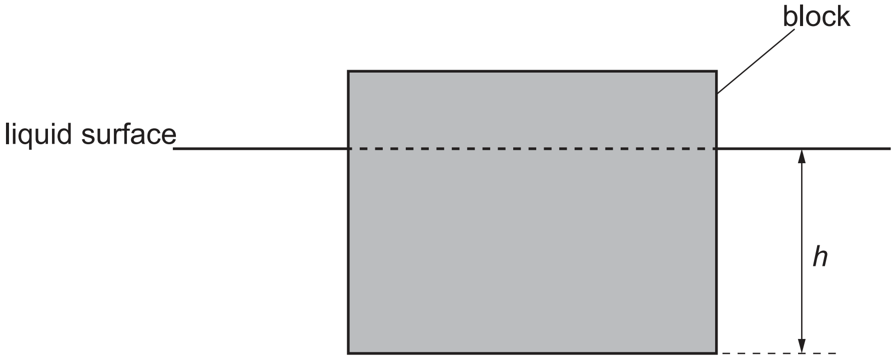

Fig. 5.1

The base of the block is at a depth h below the surface of the liquid.

The block is displaced downwards by a small distance and then released so that it oscillates.

Fig. 5.2 shows the variation with h of the acceleration a of the block.

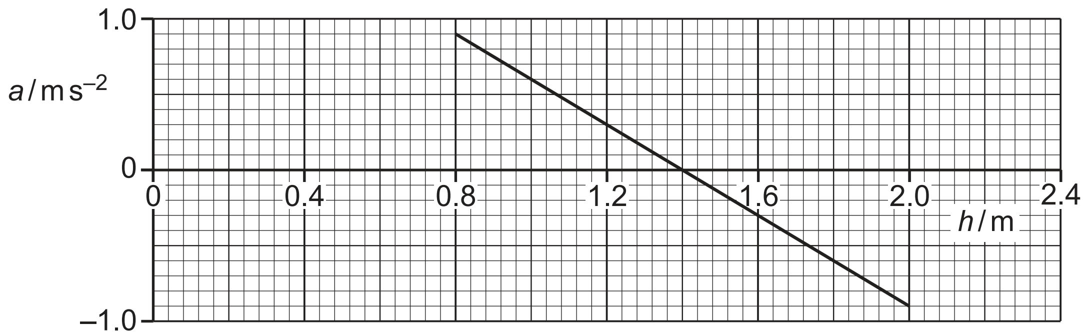

Fig. 5.2

Fig. 5.3 shows the variation with h of the kinetic energy E_K of the block.

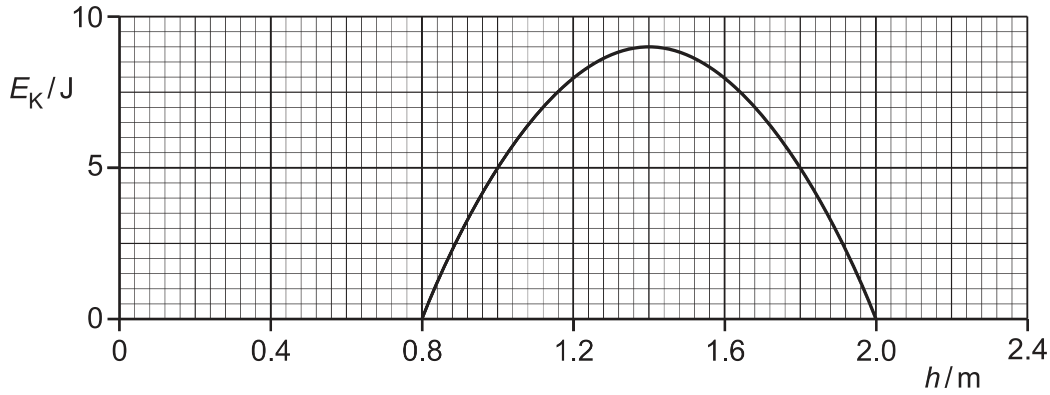

Fig. 5.3

(a) **(i)** Determine the amplitude of the oscillations.

amplitude = ... m [1]

(ii) State what the line in Fig. 5.2 shows about the nature of the oscillations.

.... [1]

(b) State **three** other quantitative conclusions that can be drawn from Fig. 5.2 and Fig. 5.3 about the block and its oscillations. Use the space for any working.

1 ....

....

2 ....

....

3 ....

....

[3]

(c) On Fig. 5.4, sketch the variation with h of the potential energy E_P of the oscillations.

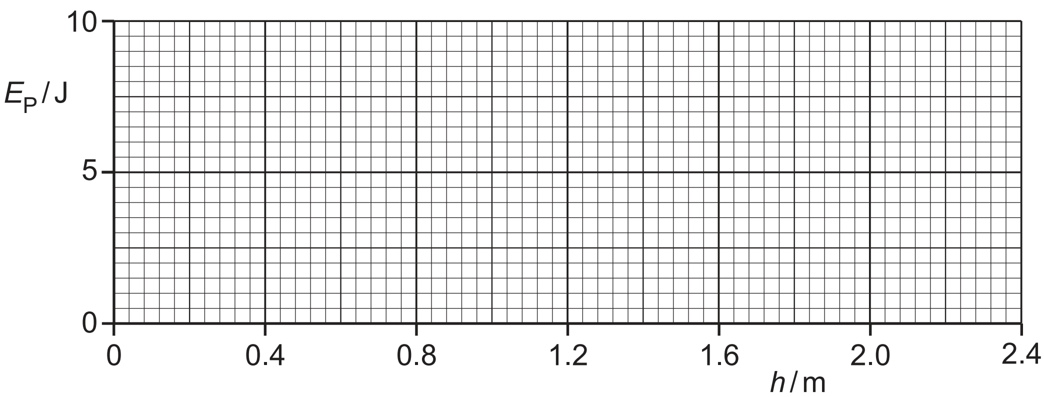

Fig. 5.4

[3]

[Total: 8]

6 Fig. 6.1 shows a circuit that rectifies an alternating input voltage V_{IN} and produces an output voltage V_{OUT} across a resistor R.

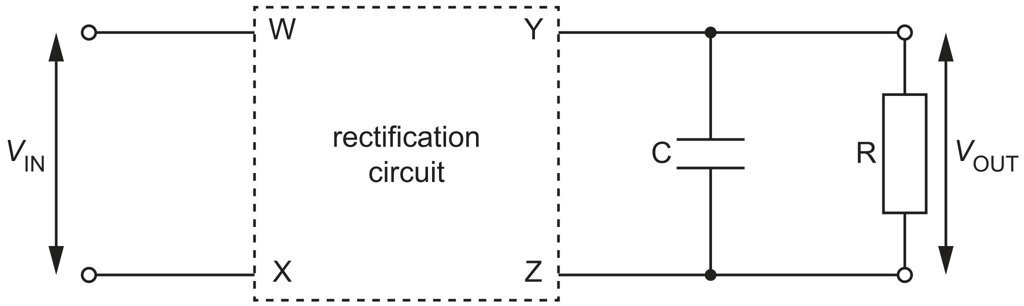

Fig. 6.1

The four terminals of the rectification circuit are labelled W, X, Y and Z.
A capacitor C is connected in parallel with resistor R.

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

....

.... [1]

(ii) State the purpose of capacitor C.

....

.... [1]

(b) Fig. 6.2 shows the variations with time t of the potential differences (p.d.s) V_{IN} and V_{OUT}.

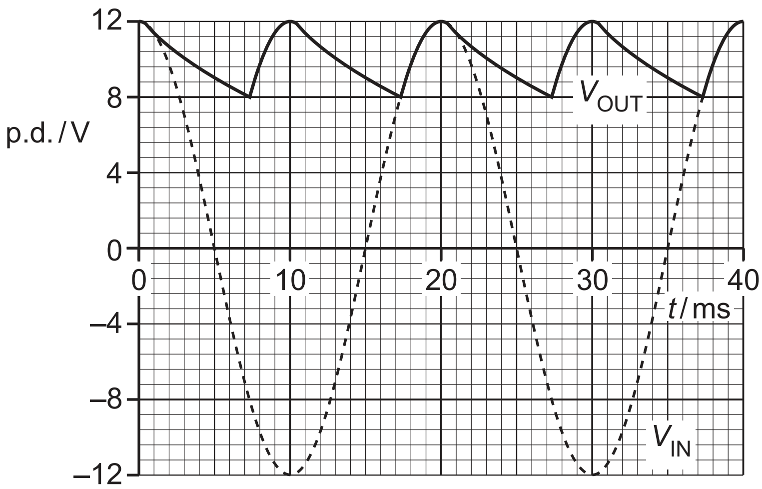

Fig. 6.2

(i) The variation of V_{IN} with t can be represented by

$$V_{IN} = A \cos Bt$$

where A and B are constants.

Determine the values of A and B. Give a unit with your answer for A.

A = ... unit ....

B = ... rad s^{-1} [2]

(ii) Determine the type of rectification produced by the circuit in Fig. 6.1.

.... [1]

(iii) On Fig. 6.3, draw the circuit diagram for the components inside the rectification circuit.

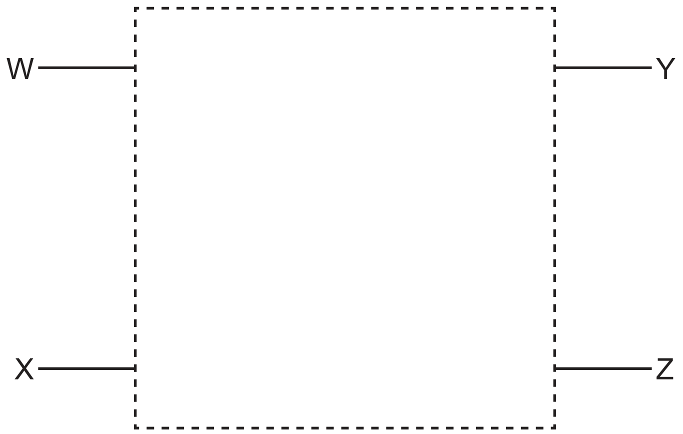

Fig. 6.3

[2]

(iv) Determine a value for the time constant for the discharge of the capacitor C through the resistor R in Fig. 6.1.

time constant = ... s [3]

(c) The capacitor C has a capacitance of 570 μF.

Use your answer in **(b)(iv)** to determine the resistance of resistor R.

resistance = ... Ω [2]

[Total: 12]

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

....

....

.... [2]

(b) A particle of mass *m* and charge +*Q* moves at speed *v* into a region where there is a uniform magnetic field, as shown in Fig. 7.1.

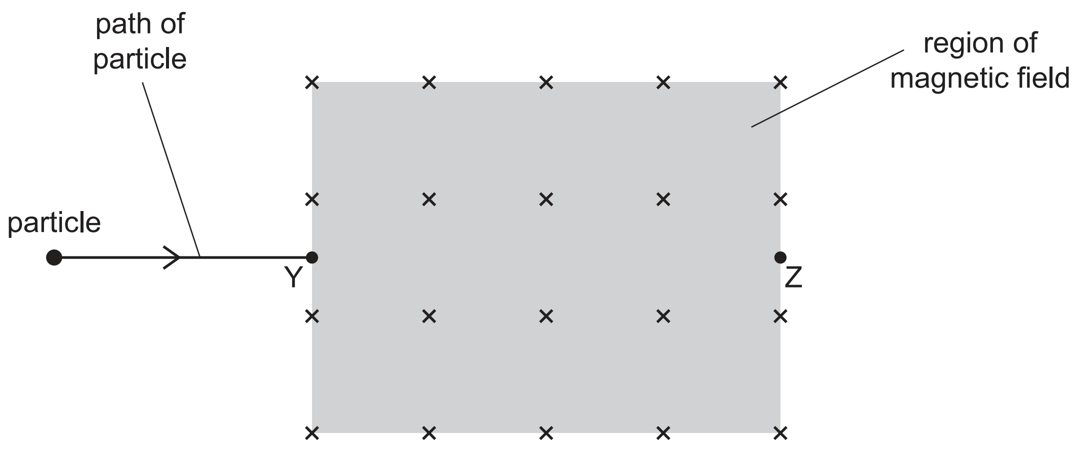

Fig. 7.1

The uniform magnetic field is into the page and has flux density *B*. The particle enters the region of the field at point Y.

(i) State an expression, in terms of some or all of m, Q, B and v, for the magnetic force F that acts on the particle when it is at point Y.

F = ... [1]

(ii) On Fig. 7.1, draw an arrow at point Y to indicate the direction of the force in **(b)(i)**. [1]

(iii) On Fig. 7.1, draw a line to show a possible path for the particle through the region of the magnetic field. [1]

(c) **(i)** Explain how an electric field can be used with the magnetic field to ensure that the particle in **(b)** now passes through point Z.

....

....

....

....

.... [3]

(ii) Derive an expression for v in terms of B and the electric field strength E.

v = ... [2]

[Total: 10]

8 **(a)** State what is meant by the de Broglie wavelength.

....

.... [1]

(b) Calculate the de Broglie wavelength of an electron moving at a speed of $4.9 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

wavelength = ... m [2]

(c) State **one** similarity and **one** difference between an electron and a positron.

similarity: ....

....

difference: ....

....

[2]

(d) An electron moving at a speed of $4.9 \times 10^{7}\,\mathrm{m\,s^{-1}}$ collides with a positron that is travelling at the same speed in the opposite direction. As a result of the collision, two gamma-ray photons are produced.

(i) State the name of this type of reaction.

.... [1]

(ii) State what happens to the electron and to the positron.

....

....

.... [2]

(iii) Explain why two gamma-ray photons are produced, rather than just one.

....

.... [1]

(iv) Show that the kinetic energy of the electron before the collision is 1.1×10^{-15} J.

[1]

(v) Use the information in **(d)(iv)** to determine, to three significant figures, the wavelength associated with the gamma radiation emitted in the collision.

wavelength = ... m [3]

[Total: 13]

9 **(a)** Define activity of a radioactive sample.

....

.... [1]

(b) Explain why the variation with time of the activity of a radioactive sample is exponential in nature.

....

....

....

....

.... [3]

(c) A sample contains a single radioactive isotope that decays to form a stable isotope.

The sample has an activity of 180 Bq at time t = 0.
At a time 8.4 minutes later, the activity is 120 Bq.

(i) Determine the decay constant, in min^{-1}, of the radioactive isotope.

decay constant = ... min^{-1} [2]

(ii) Use your answer in **(c)(i)** to determine the half-life, in min, of the radioactive isotope.

half-life = ... min [1]

(iii) On Fig. 9.1, sketch the variation of the activity A of the sample with t for values of t between t = 0 and t = 24 min.

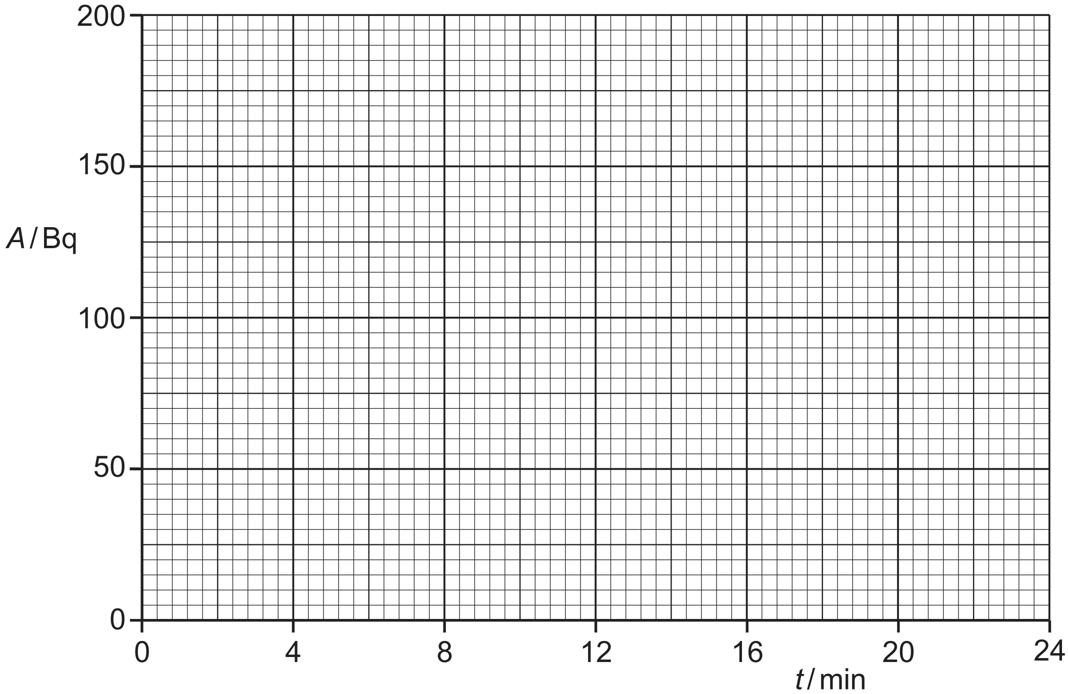

Fig. 9.1

[3]

[Total: 10]

10 **(a)** State Hubble's law.

....

....

.... [2]

(b) A star in a distant galaxy emits radiation that has a maximum intensity of emission at a wavelength of 4.62×10^{-7} m.

Observations of the galaxy made on the Earth detect the maximum intensity of emission from the star at a wavelength of 4.91×10^{-7} m.

(i) Explain why the observed wavelength and the emitted wavelength have different values.

....

....

.... [2]

(ii) Calculate the speed of the star relative to the Earth.

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

(iii) The wavelength of maximum intensity of emission is used to determine a value for the surface temperature of the star.

Explain how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength.

....

....

.... [2]

(c) A value for the Hubble constant is $2.3 \times 10^{-18}\,s^{-1}$.

Use your answer in **(b)(ii)** to determine the distance of the star in **(b)** from the Earth.

distance = ... m [2]

[Total: 10]

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