OCR RECOGNISING ACHIEVEMENT

**ADVANCED GCE** **2824**

**PHYSICS A**

Forces, Fields and Energy

**MONDAY 21 JANUARY 2008** Morning

Time: 1 hour 30 minutes

Candidates answer on the question paper.
**Additional materials:** Electronic Calculator

*CUP/T36536*

Candidate Forename

Candidate Surname

Centre Number

Candidate Number

**INSTRUCTIONS TO CANDIDATES**

- Write your name in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Do **not** write outside the box bordering each page.
- Write your answer to each question in the space provided.

**INFORMATION FOR CANDIDATES**

- The number of marks for each question is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is 90.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

**FOR EXAMINER'S USE**

| Qu. | Max. | Mark |
|---|---|---|
| 1 | 13 | |
| 2 | 13 | |
| 3 | 10 | |
| 4 | 12 | |
| 5 | 13 | |
| 6 | 14 | |
| 7 | 15 | |
| TOTAL | 90 | |

This document consists of **18** printed pages and **2** blank pages.

  

**Data**

| | |
|---|---|
| speed of light in free space, | $c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$ |
| permeability of free space, | $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$ |
| permittivity of free space, | $\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$ |
| elementary charge, | $e = 1.60 \times 10^{-19}\ \mathrm{C}$ |
| the Planck constant, | $h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$ |
| unified atomic mass constant, | $u = 1.66 \times 10^{-27}\ \mathrm{kg}$ |
| rest mass of electron, | $m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$ |
| rest mass of proton, | $m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$ |
| molar gas constant, | $R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$ |
| the Avogadro constant, | $N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$ |
| gravitational constant, | $G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$ |
| acceleration of free fall, | $g = 9.81\ \mathrm{m\,s^{-2}}$ |

## Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

refractive index, $n = \dfrac{1}{\sin C}$

capacitors in series, $\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

capacitor discharge, $x = x_0 e^{-t/CR}$

pressure of an ideal gas, $p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$

radioactive decay, $x = x_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \dfrac{0.693}{\lambda}$

critical density of matter in the Universe, $\rho_0 = \dfrac{3H_0^2}{8\pi G}$

relativity factor, $= \sqrt{(1 - \dfrac{v^2}{c^2})}$

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

sound intensity level, $= 10 \lg\left(\dfrac{I}{I_0}\right)$

Answer **all** the questions.

**1** A table-tennis ball is released from rest to fall to the floor. Air resistance causes the ball to reach terminal velocity before it reaches the floor. Fig. 1.1 shows graphs of the potential and kinetic energies of the ball against the distance fallen. Only the energy axis has been given a scale.

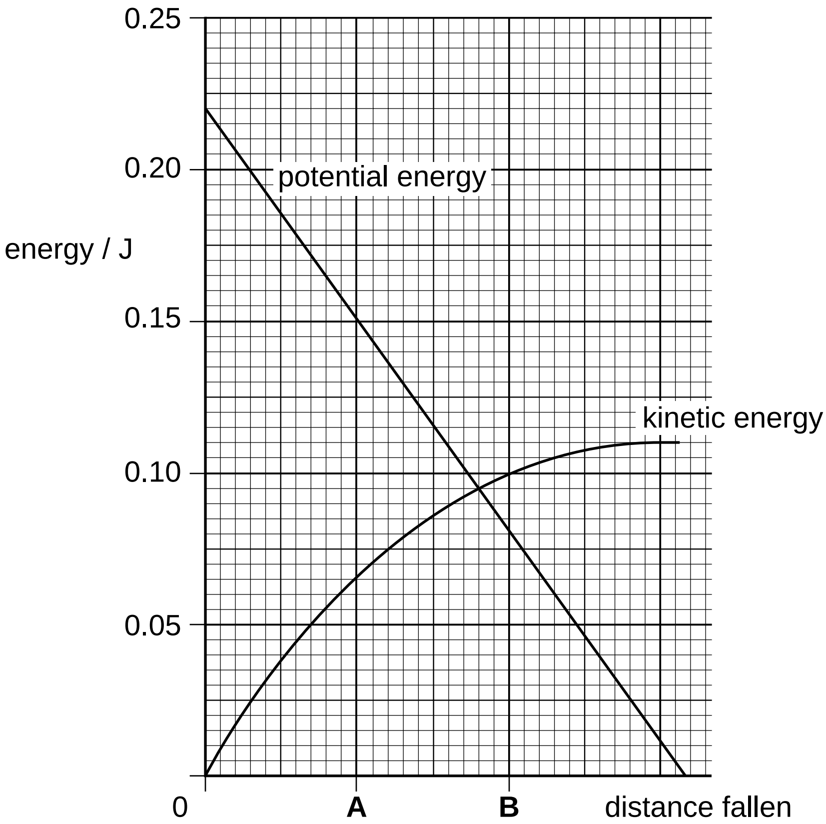


**Fig. 1.1**

The mass of the ball is 0.014 kg.

**(a)** Use Fig. 1.1 to calculate the height $h$ from which the ball is dropped. The floor is taken as the zero of potential energy.

$h$ = ...................................................... m [2]

**(b)** Describe how the kinetic energy of the ball is changing as it falls between **A** and **B** as indicated on Fig. 1.1.

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**(c)** **(i)** Show that the terminal velocity of the ball is about $4\,m\,s^{-1}$.

[2]

**(ii)** Calculate the drag force on the ball at its terminal velocity.

drag force = ...................................................... N [1]

**(iii)** Calculate the energy loss per second as the ball falls at its terminal velocity.

energy loss per second = .................................................... W [2]

**(d)** The ball bounces on the floor. 20% of the ball's kinetic energy is lost in the bounce. Calculate the change in momentum of the ball at the bounce. Give a suitable unit for your answer.

momentum change = .......................... unit.......................... [4]

[Total: 13]

**2** **(a)** Define the terms *internal energy of a body* and *specific heat capacity of a material*.

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**(b)** A cake of mass 0.90 kg is cooked in an oven at a temperature of 180 °C. It is turned out of the baking tin onto a rack to cool in a kitchen at 20 °C. Calculate the energy released from the cake in cooling. Take the specific heat capacity of the cake to be 990 $J\,kg^{-1}\,K^{-1}$.

energy release = ...................................................... J [3]

**(c)** The oven of volume 0.10 $m^3$ also cools from 180 °C to 20 °C.

**(i)** Calculate the change in the mass $\Delta m$ of air in the oven between the two temperatures. The pressure in the oven remains at atmospheric pressure $1.0 \times 10^5$ Pa.

molar mass of air = 0.030 $kg\,mol^{-1}$

$\Delta m$ = .................................................... kg [4]

**(ii)** Calculate the ratio

$$\frac{\text{mean speed of air molecules at } 180\,°\text{C}}{\text{mean speed of air molecules at } 20\,°\text{C}}.$$

ratio = ............................................................[3]

[Total: 13]

**3** Fig. 3.1 shows a rotating fairground ride where a seat **S** of mass *m* is suspended by a light chain. When the ride rotates at a constant speed *v*, the chain makes an angle *θ* with the vertical so that the seat is a distance *r* from the axis of rotation.

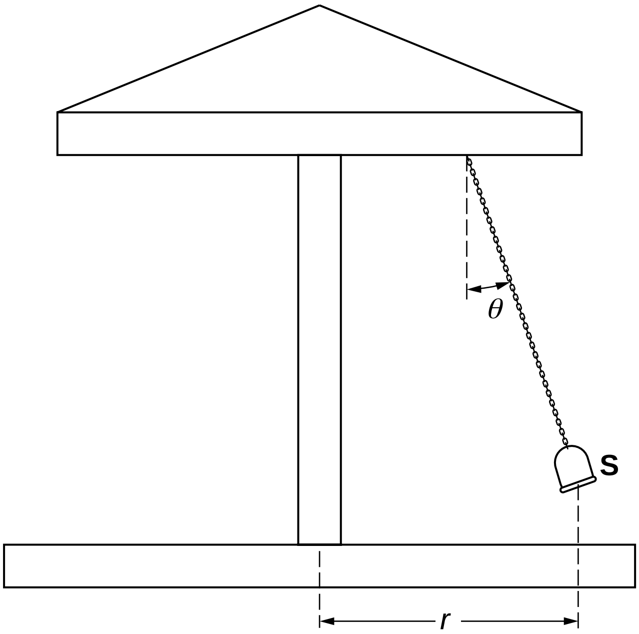


**Fig. 3.1**

**(a) (i)** On Fig. 3.1 draw and label arrows to represent the forces acting on the seat. [2]

**(ii)** By referring to the forces in **(i)**, explain the condition necessary for the seat to move in a horizontal circle.

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...................................................................................................................................[2]

**(iii)** Write down an algebraic expression for the magnitude *F* of the resultant force on the seat in terms of *m*, *r* and *v*.

[1]

**(b)** **(i)** When the ride rotates, the seat is travelling in a circle of radius 5.0 m at a constant speed of 4.2 m s$^{-1}$. Show that the angle $\theta$ is about 20°.

[4]

**(ii)** When a child occupies the seat during a ride at 4.2 m s$^{-1}$, will the angle $\theta$ remain at 20° or will it change? Explain your answer.

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[Total: 10]

**4** A small conducting sphere is attached to the end of an insulating rod. It carries a charge of $+5.0 \times 10^{-9}$ C.

**(a)** Fig. 4.1 shows the sphere held at the midpoint between two parallel metal plates. The plates are uncharged. When the sphere was inserted, negative charges were induced on the parts of the plates closest to it.

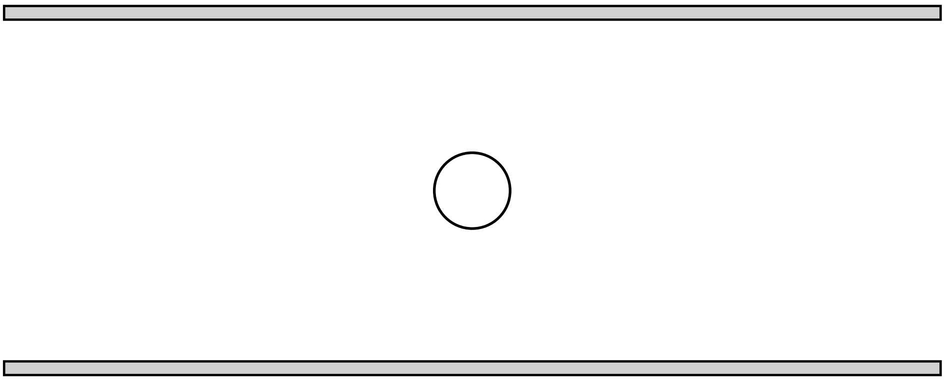

**Fig. 4.1**

Draw at least **six** electric field lines between the sphere and the plates. [3]

**(b)** The plates, which are 4.0 cm apart, are now connected to a 50 000 V supply.

Calculate

**(i)** the magnitude of the electric field strength *E* between the plates

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

**(ii)** the magnitude *F* of the force on the sphere, treated as a point charge of $+5.0 \times 10^{-9}$ C.

*F* = ...................................................... N [2]

**(c)** Fig. 4.2 shows a second identically charged sphere attached to a top-pan balance by a vertical insulating rod. The original charged sphere is clamped vertically above the second sphere such that their centres are 4.0 cm apart.

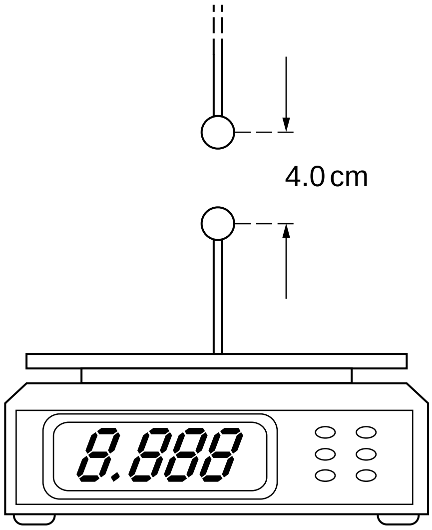


**Fig. 4.2**

**(i)** Show that the force between the two spheres acting as point charges is about 0.14 mN.

[3]

**(ii)** The balance can record masses to the nearest 0.001 g. The initial reading on the balance before the original charged sphere is clamped above the second sphere is 8.205 g. Calculate the final reading on the balance.

final reading = ...................................................... g [2]

[Total: 12]

**5** Fig. 5.1 shows a horizontal copper wire placed between the opposite poles of a permanent magnet. The wire is in a state of tension and is clamped at each end. The length of the wire in the field of flux density 0.032 T is 6.0 cm.

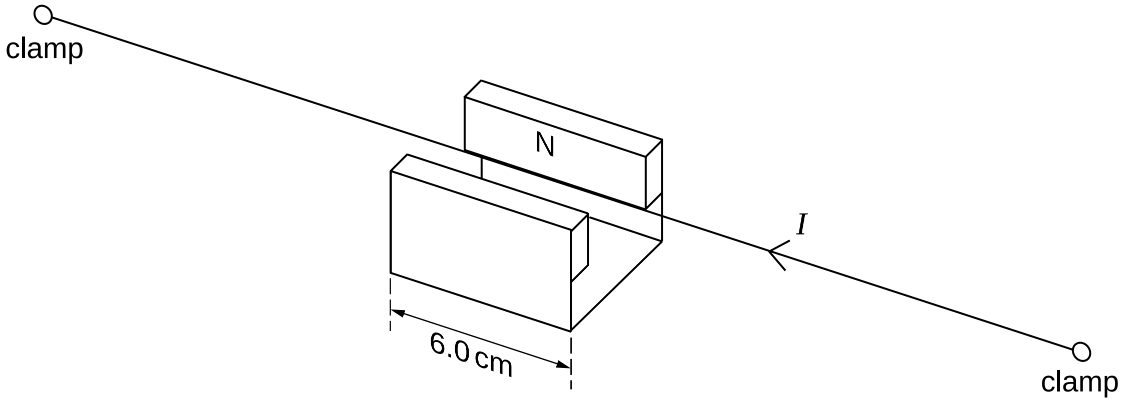


**Fig. 5.1**

**(a)** A direct current $I$ is passed through the wire.

**(i)** On Fig. 5.1 draw and label an arrow **F** to indicate the direction of the force on the wire. [1]

**(ii)** Calculate the magnitude $F$ of the force when $I$ = 2.5 A.

$F$ = ...................................................... N [2]

**(b)** The direct current is changed to an alternating current of constant amplitude and variable frequency, causing the wire to oscillate. Fig. 5.2 shows how the acceleration of the wire at the centre point between the poles varies with time when the frequency of the current is at the fundamental natural frequency of the wire.

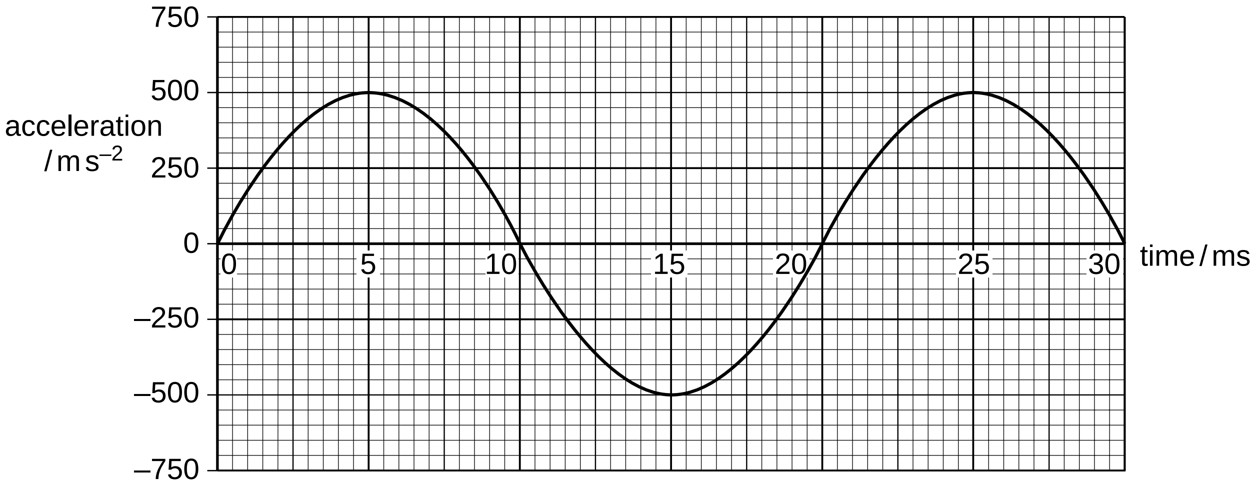


**Fig. 5.2**

**(i)** Calculate the frequency of the alternating current.

frequency = .................................................. Hz [2]

**(ii)** Explain whether the maximum acceleration of all points on the wire between the poles is the same or not. A sketch may help your answer.

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**(c)** The amplitude of vibration of the wire at the centre point between the poles varies with the frequency of the current as shown in Fig. 5.3.

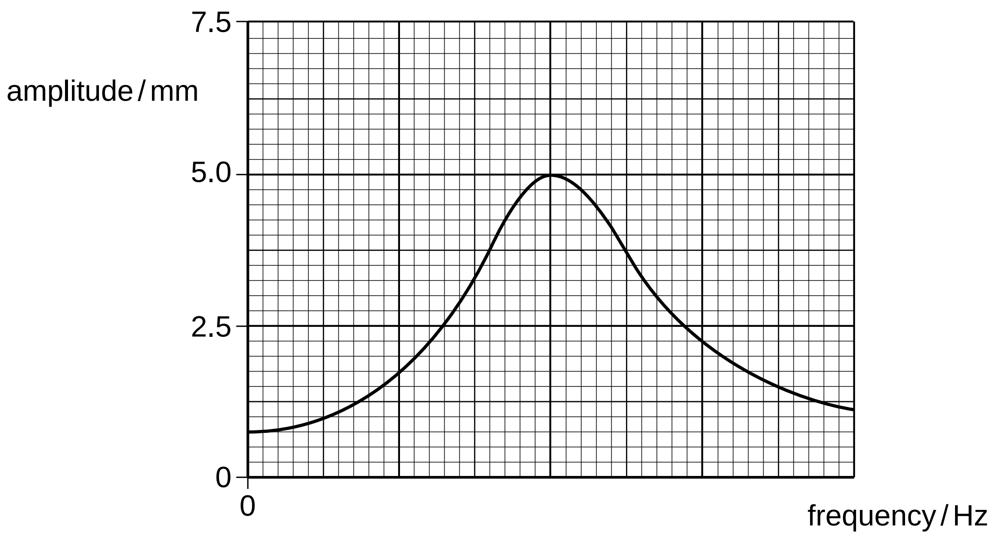


**Fig. 5.3**

**(i)** State the term used to describe this effect. ..................................................................[1]

**(ii)** Add the scale to the frequency axis of Fig. 5.3. [1]

**(iii)** A student sticks some small pieces of paper to the wire to see the vibration of the wire more easily. However this increases the damping of the vibration. On Fig. 5.3 sketch the graph that you would expect to see for greater damping. [3]

[Total: 13]

**6** Two radioactive isotopes which are serious health hazards to human beings are strontium-90 and caesium-137. Both decay by $\beta^-$-emission.

**(a)** The nuclear equations for each of the decays are shown below with letters substituted for some of the numbers.

$$^{90}_{38}\text{Sr} \longrightarrow {}^{90}_{Z}\text{Y} + \beta^-$$

$$^{137}_{55}\text{Cs} \longrightarrow {}^{A}_{A\text{-}N}\text{Ba} + \beta^-$$

Write down the numerical values of the two letters Z and N. State what each represents.

Z.......................................................................................................................................

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N .......................................................................................................................................

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**(b)** The radioactive decay law can be written in the form

$$A = \lambda N$$

where $A$ is the activity, $\lambda$ is the decay constant and $N$ is the number of undecayed nuclei.

**(i)** Define the term *activity*.

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**(ii)** Caesium-137 has a half-life of 30 years. Calculate the decay constant.

1 year = $3.15 \times 10^7$ s

$\lambda$ = .................................................... $s^{-1}$ [2]

**(c)** The radioactive dust cloud from the Chernobyl explosion in 1986 contained caesium-137. Fig. 6.1 shows the graph of the number of undecayed nuclei of caesium-137 remaining in a dust particle against time after the explosion.

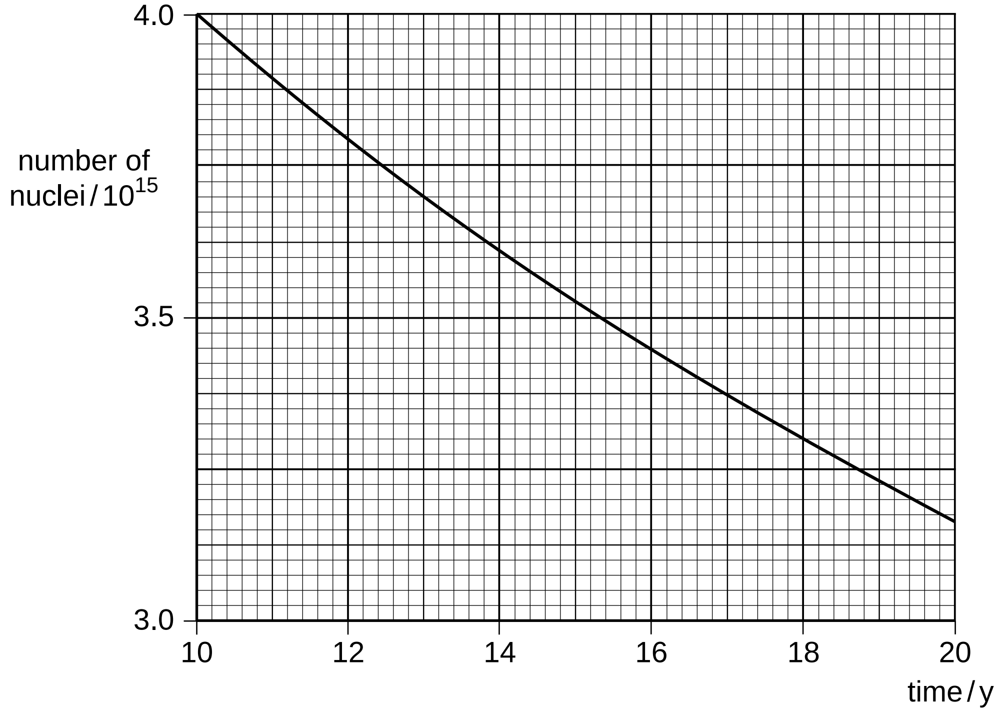


**Fig. 6.1**

**(i)** Use Fig. 6.1 to calculate the activity of the caesium dust particle after 15 years.

activity = .................................................... Bq [2]

**(ii)** Use data from the graph to show that the initial number of nuclei of caesium-137 in the dust particle is about $5.0 \times 10^{15}$.

[3]

**(iii)** Hence show that the original mass of caesium-137 in the dust particle is about 1 µg.

[2]

[Total: 14]

**7** In this question, four marks are available for the quality of written communication.

**(a)** X-rays can be described as electromagnetic radiation and electrons as charged particles. Both can be diffracted.
Explain the conditions necessary for each of them to produce observable diffraction.
Explain how X-rays and electrons can be used in separate experiments to find the spacing of atoms and their arrangements in solid materials.
A space has been left for you to draw suitable diagram(s), if you wish to illustrate your answer.

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**(b)** State the relative sizes of atoms and nuclei.
Electrons can be used to give evidence for the radius and structure of the nucleus but X-rays cannot. Explain why this is so.

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Quality of Written Communication [4]

[Total: 15]

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