Please write clearly in block capitals.

Centre number | 8 | 4 | 5 | 9 | 0

Candidate number | 4 | 5 | 2 | 3

Surname Matheson

Forename(s) Lewis

Candidate signature

I declare this is my own work.

A-level
PHYSICS
Paper 2

ALevelPhysicsOnline.com

Friday 9 June 2023 Morning Time allowed: 2 hours

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8–32	
TOTAL	

Materials

For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 85.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

Section A

Answer **all** questions in this section.

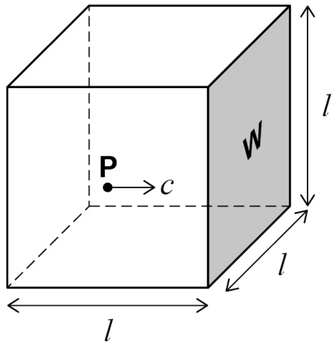
0 1 . 1 State what is meant by the internal energy of an ideal gas.

[1 mark]

The total kinetic energy of all the particles. ✓

Figure 1 shows a single gas particle **P** of an ideal gas inside a hollow cube.

Figure 1



The cube has side length l and volume V.
P has mass m and is travelling at a velocity c perpendicular to side **W**.

0 1 . 2 Explain why **P** has a change in momentum of $-2mc$ during one collision with **W**.

[1 mark]

Initial momentum: $p_i = mc$

Final momentum: $p_f = -mc$

Change in momentum $\Delta p = p_f - p_i = -mc - (mc)$

$\Delta p = -2mc$ ✓

0 1 . 3 **P** collides repeatedly with **W**.

Show that the frequency f of collisions is $\frac{c}{2l}$.

[1 mark]

$v = \frac{s}{t}$ $\quad \frac{v}{s} = \frac{1}{t}$ $\quad f = \frac{1}{t} = \frac{v}{s} = \frac{c}{2L}$ ✓

0 1 . 4 Deduce an expression, in terms of m, c and V, for the contribution of **P** to the pressure exerted on **W**.
Refer to appropriate Newton's laws of motion.

[2 marks]

$$F = \frac{\Delta p}{\Delta t} = \frac{-2mc}{2L/c}$$

Newton's 2nd Law ✓

$$p = \frac{F}{A} \qquad A = L^2$$

$$p = \frac{\frac{-2mc}{2L/c}}{L^2} = \frac{-\cancel{2}mc^2}{\cancel{2}L^3} = \frac{mc^2}{V}$$ ✓

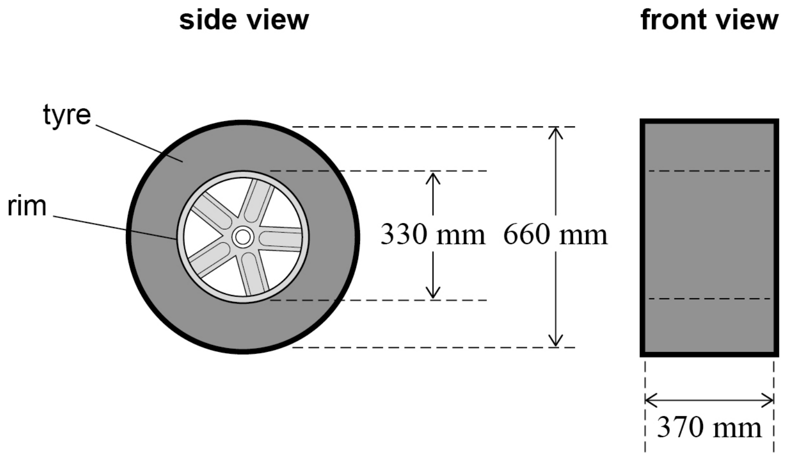
5

Turn over for the next question

0 2 **Figure 2** shows a wheel used in motorsport. A rubber tyre is fitted around a cylindrical metal rim. The tyre is filled with a gas.
The dimensions shown in **Figure 2** are for the volume of the gas in the tyre.

Assume that this volume remains constant throughout this question.

Figure 2



0 2 . 1 The mass of the wheel is measured when the gas in the tyre is at a pressure of 1.01×10^5 Pa.
More of the same gas is added to the tyre and the mass of the wheel is measured again.

Table 1 shows the pressure in the tyre and the mass of the wheel before and after the addition of the extra gas.
The gas is kept at a constant temperature of 100 °C.

Table 1

	Pressure in tyre / Pa	**Mass of wheel / kg**
Before	1.01×10^5	14.897
After	2.11×10^5	14.991

Determine, in $\mathrm{kg\ mol^{-1}}$, the molar mass of the gas.

[5 marks]

$V_{tyre} = V_{cyl} - V_{rim} = \pi r_{tyre}^{2} . w - \pi r_{rim}^{2} w$ ✓

$V_{tyre} = \pi \times 0.370 \times \left(\left(\frac{0.660}{2}\right)^{2} - \left(\frac{0.330}{2}\right)^{2}\right) = 0.0949 m^{3}$ ✓

$pV = nRT$ Before: $n = \frac{pV}{RT} = \frac{1.01 \times 10^{5} \times 0.0949}{8.31 \times 373} = 3.09$ mol ✓

$n = \frac{pV}{RT}$ After: $n = \frac{pV}{RT} = \frac{2.11 \times 10^{5} \times 0.0949}{8.31 \times 373} = 6.46$ mol

$\Delta n = 6.46 - 3.09 = 3.366$ mol ✓

$\Delta m = 14.991 - 14.897 = 0.094$ kg

$\frac{\Delta m}{\Delta n} = \frac{0.094}{3.366} = 0.0279$

molar mass = 0.028 ✓ $\mathrm{kg\ mol^{-1}}$

0 2 . 2 Motorsport regulations specify a minimum amount of gas in the tyre.

The amount of gas in the tyre is checked by measuring the pressure before the wheel is put onto the car. The regulations also specify a maximum temperature for the tyre when making this measurement.

Explain why a maximum temperature is specified.

[2 marks]

A higher temperature means a higher pressure in the tyre ✓ ∴ tyre could pass the check even if it had less than the minimum quantity of gas at this higher temperature. ✓

7

Turn over ►

0 3 . 1 Describe **two** properties of a radial gravitational field.

[2 marks]

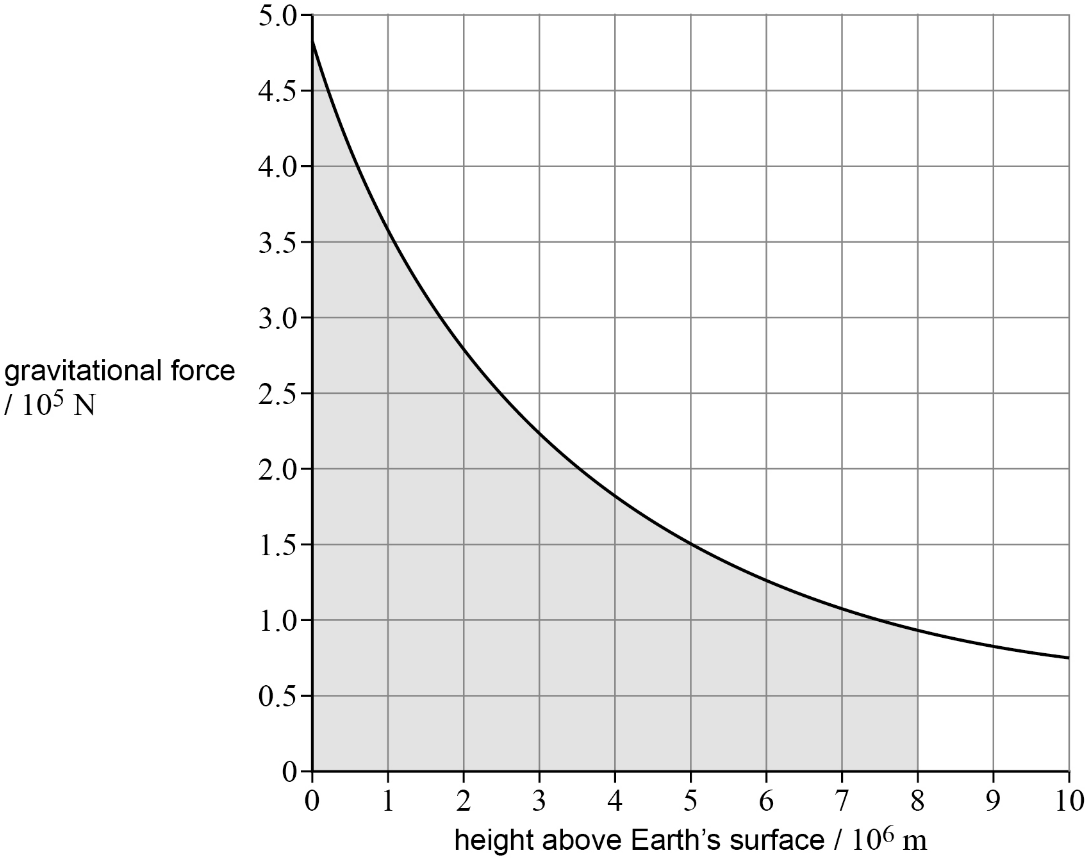
1 The field strength is inversely proportional to the distance squared. ✓

2 It is a region in which a mass experiences a force due to another mass. ✓

A space probe is launched from the Earth's surface.

Figure 3 shows how the gravitational force acting on the space probe varies with height above the Earth's surface.

Figure 3



0 3 . 2 State the physical significance of the shaded area in **Figure 3**.

[1 mark]

Change in GPE of the probe as it moves from the Earth's surface to a height of 8×10^6 m ✓

At the Earth's surface,

- the gravitational field strength of the Sun is g_S
- the gravitational field strength of the Earth is g_E.

0 3 . 3 Calculate $\frac{g_S}{g_E}$.

distance from the Earth to the Sun = 1.50×10^{11} m

[2 marks]

$$g_s = \frac{G m_S}{r_{SE}^2} \qquad g_E = \frac{G m_E}{r_E^2}$$

$$\frac{g_s}{g_E} = \frac{m_S r_E^2}{m_E r_{SE}^2} = \frac{1.99 \times 10^{30} \times (6.37 \times 10^6)^2}{5.97 \times 10^{24} \times (1.50 \times 10^{11})^2} \checkmark$$

$\frac{g_S}{g_E}$ = 6.01×10^{-4} ✓

0 3 . 4 Explain why g_S is more important than g_E in predicting the motion of the space probe as it escapes from the Solar System.

[1 mark]

As r increases, the greater mass of the Sun has a greater effect than the mass of the Earth. ✓

Question 3 continues on the next page

Do not write outside the box

0 3 . 5 The space probe eventually reaches a point where the gravitational influence of the Solar System is negligible.
The probe is unpowered as it approaches an isolated interstellar body **X**.
The gravitational field of **X** changes the kinetic energy of the space probe.

Table 2 shows the distance of the space probe from the centre of mass of **X** and the speed for two positions **A** and **B** of the space probe.

Table 2

	Distance of space probe from centre of mass of X / 10^6 m	Speed of space probe / 10^3 m s^{-1}
A	6.0	1.1
B	0.17	1.3

The space probe has a mass of 4.9×10^4 kg.

Calculate the mass of **X**.

[4 marks]

$$\Delta E_k = \Delta E_p \quad ✓$$

$$\frac{1}{2}\cancel{m}v_B^2 - \frac{1}{2}\cancel{m}v_A^2 = \frac{G\cancel{m}M}{r_B} - \frac{G\cancel{m}M}{r_A}$$

$$\frac{1}{2}\left(v_B^2 - v_A^2\right) = GM\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

$$\overset{✓}{} \qquad \overset{✓}{}$$

$$\frac{1}{2}\left((1.3\times10^6)^2 - (1.3\times10^6)^2\right) = 6.67\times10^{-11} . M\left(\frac{1}{0.17\times10^6} - \frac{1}{6.0\times10^6}\right)$$

$$240\,000 = 3.81\times10^{-16} M$$

$$M = 6.295\times10^{20}$$

mass of **X** = 6.3×10^{20} ✓ kg

10

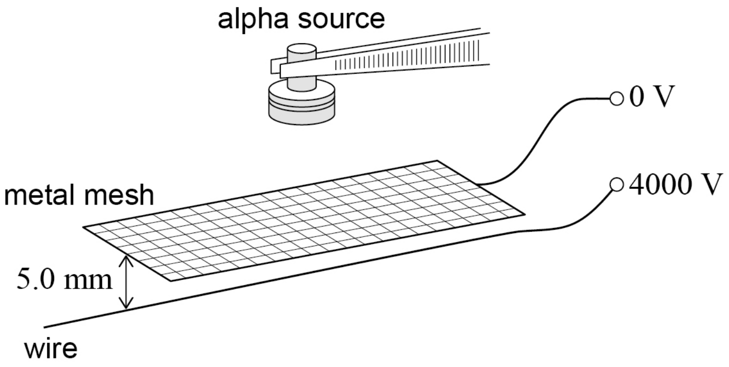
Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Turn over ►

0 4 **Figure 4** shows a spark detector used to detect alpha particles.

Figure 4

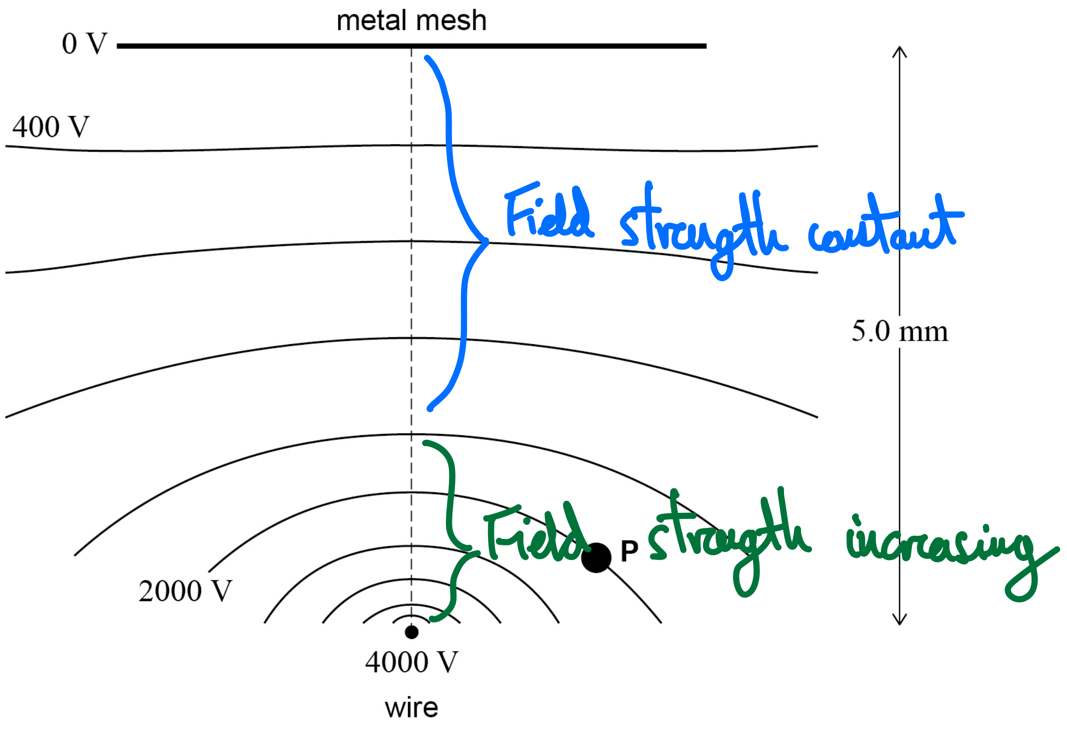


The detector consists of a metal mesh placed 5.0 mm above a wire.
A potential difference of 4000 V is applied between the mesh and the wire.

Molecules in the air between the mesh and the wire are ionised by an alpha particle and a spark is produced.

Figure 5 shows equipotentials between the mesh and the wire.

Figure 5



Field strength constant

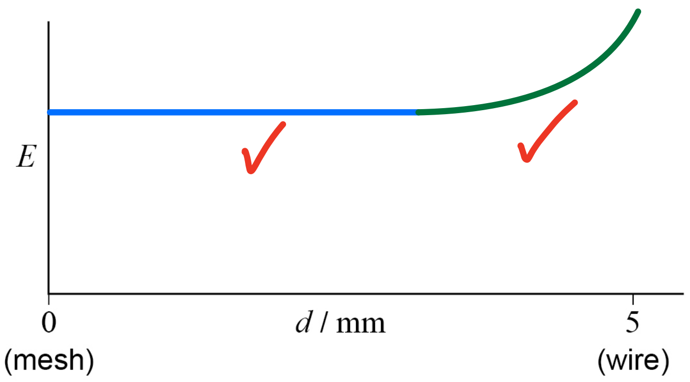
Field strength increasing

0 4 . 1 **Figure 5** shows a dashed line between the mesh and the wire.

Sketch on **Figure 6** a graph to show how the magnitude E of the electric field strength varies with the distance d from the mesh along this dashed line.
No values are required on the E axis.

[2 marks]

Figure 6



An alpha particle passes through the mesh.
The alpha particle ionises an argon atom at **P** on **Figure 5**, releasing one electron.
The electron and the argon ion have no kinetic energy at **P**.
The electron then travels to the wire and the argon ion travels to the mesh.

0 4 . 2 Calculate the ratio $\dfrac{\text{speed of electron when it reaches the wire}}{\text{speed of argon ion when it reaches the mesh}}$.

Assume that the air has no effect on the motion of the electron or on the motion of the argon ion.

mass of argon ion = 6.64×10^{-26} kg

[2 marks]

Kinetic energy the same ✓ because they have the same charge in the same electric field.

$$\cancel{\tfrac{1}{2}} m_e V_e^2 = \cancel{\tfrac{1}{2}} m_{Ar} V_{Ar}^2$$

$$\frac{V_e}{V_{Ar}} = \sqrt{\frac{m_{Ar}}{m_e}} = \sqrt{\frac{6.64 \times 10^{-26}}{9.11 \times 10^{-31}}}$$

ratio = 270 ✓

Question 4 continues on the next page

Turn over ►

0 4 . 3 In practice, the air **does** affect the motion of the electron and the motion of the argon ion.

Suggest how the presence of air between the mesh and the wire changes the ratio in Question **04.2**.
No numerical detail is required.

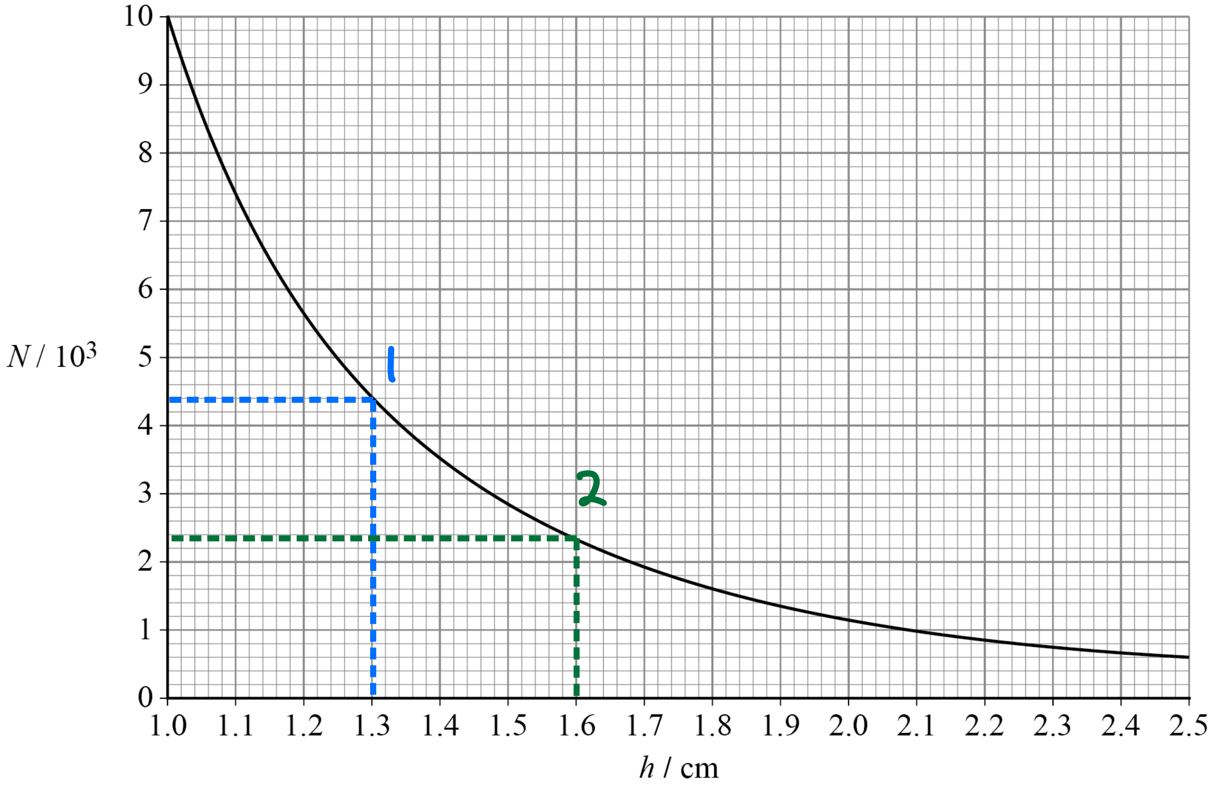
[1 mark]

Argon loses more energy due to collisions
$\therefore$ ratio > 270 ✓

0 4 . 4 The alpha source in **Figure 4** is moved to different heights h above the mesh.

Figure 7 shows how the number of sparks N produced in 10 minutes varies with h.
No sparks are produced when the source is not present.

Figure 7



Student **A** suggests that the spark rate obeys an inverse-square law.
Student **B** suggests that the spark rate decreases exponentially with h.

Determine whether either student is correct.

[3 marks]

A : If $N \propto \frac{1}{h^2}$ $Nh^2 = $ constant

$1 \rightarrow 4.4 \times 10^3 \times (0.013)^2 = 0.7436$ ✓

$2 \rightarrow 2.3 \times 10^3 \times (0.016)^2 = 0.5888$

} Not the same

∴ Not an inverse-square law

B: If $N \propto e^{-h}$ then N decreases by same proportion for equal intervals of h

$\frac{N_{1.0}}{N_{1.3}} = \frac{10}{44} = 2.27$

✓

$\frac{N_{1.3}}{N_{1.6}} = \frac{4.4}{2.3} = 1.91$

} Not the same ∴ not an exponential decay

Neither student is correct ✓

8

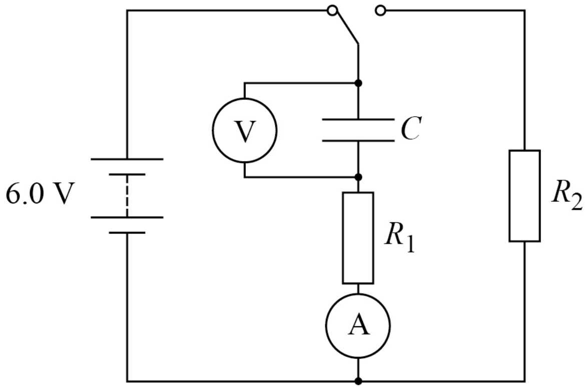
Turn over for the next question

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

0 5 **Figure 8** shows a circuit used to investigate the charge and discharge of a capacitor of capacitance C using resistors of resistances R_1 and R_2.

Figure 8



The battery has an emf of 6.0 V and negligible internal resistance.

0 5 . 1 Show that the time taken for the capacitor to charge from 2.0 V to 4.0 V is approximately $0.7R_1C$.

[3 marks]

Charging: $V = V_0\left(1 - e^{\frac{-t}{RC}}\right)$

$\frac{V}{V_0} = 1 - e^{\frac{-t}{RC}}$ $\quad \ln\left(1 - \frac{V}{V_0}\right) = \frac{-t}{RC}$ $\quad t = -RC\ln\left(1 - \frac{V}{V_0}\right)$ ✓

$t_{2.0V} = -R_1C\ln\left(1 - \frac{2.0}{6.0}\right) = -R_1C\left(\ln\frac{2}{3}\right)$

✓

$t_{4.0V} = -R_1C\ln\left(1 - \frac{4.0}{6.0}\right) = -R_1C\left(\ln\frac{1}{3}\right)$

$t_{2.0\text{to}4.0V} = -R_1C\left(\ln\frac{1}{3}\right) - (-)R_1C\left(\ln\frac{2}{3}\right)$

$= R_1C\left(\ln\frac{2}{3} - \ln\frac{1}{3}\right) = R_1C\ln 2$

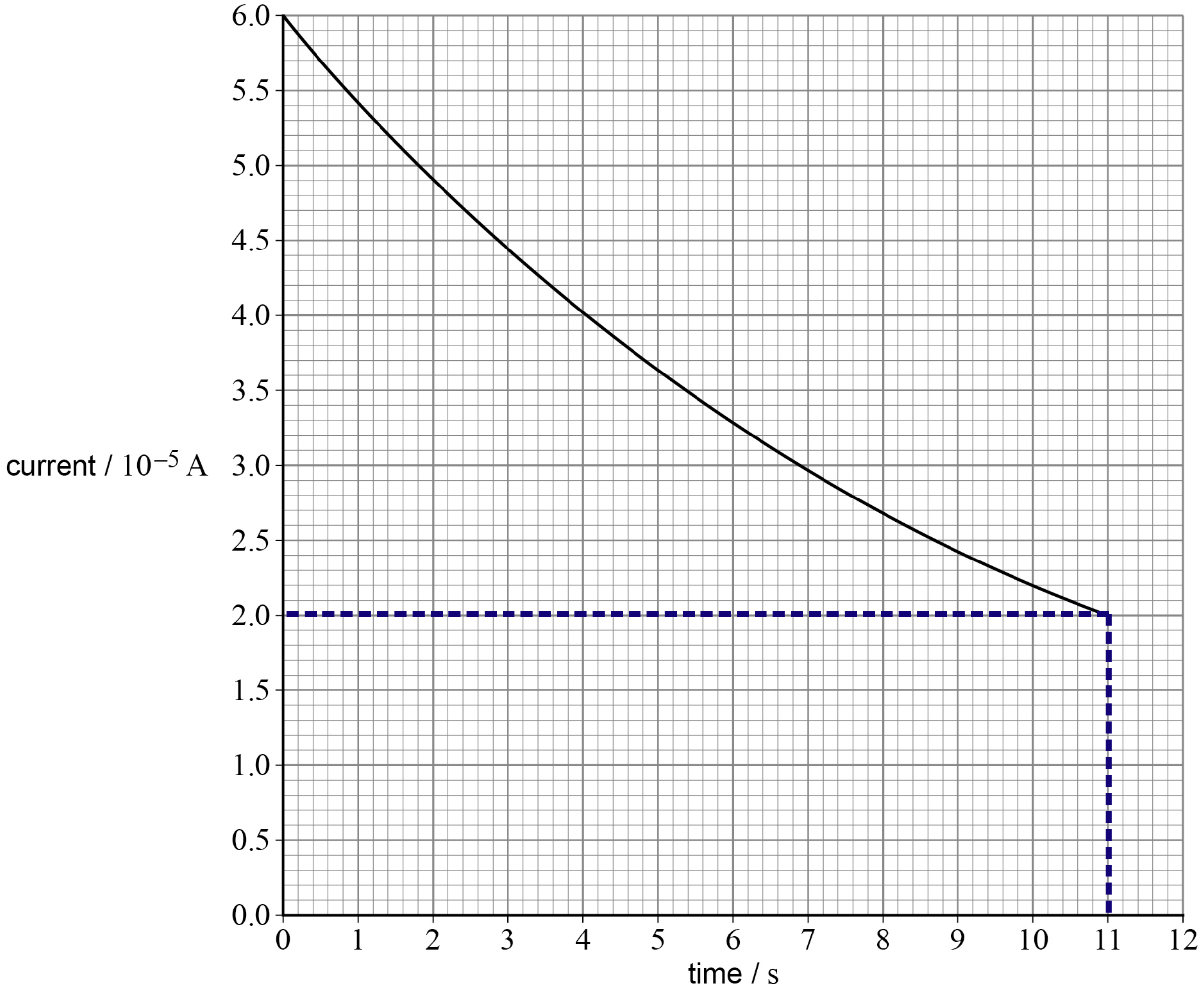
Question 5 continues on the next page

$= \underline{0.69R_1C}$ ✓ $\approx 0.7R_1C$

Turn over ►

The capacitor is fully discharged.
The capacitor is then charged until the potential difference (pd) across it is 4.0 V.
Figure 9 shows the variation with time of the ammeter reading as the capacitor is charged.

Figure 9



0 5 . 2 Show that the capacitance of the capacitor is about 1×10^{-4} F.

[4 marks]

$$I = I_0 e^{\frac{-t}{R_1 C}}$$

(From graph)

$$R_1 C = t \ln \frac{I}{I_0} = 11.0 \ln \frac{6.0}{2.0} = 12.08 \checkmark$$

$$\text{Where } R_1 = \frac{V}{I} = \frac{2.0}{2.0\times10^{-5}} \checkmark = 1.0\times10^{5}\,\Omega \checkmark$$

(2.0V across resistor when capacitor charged to 4.0V)

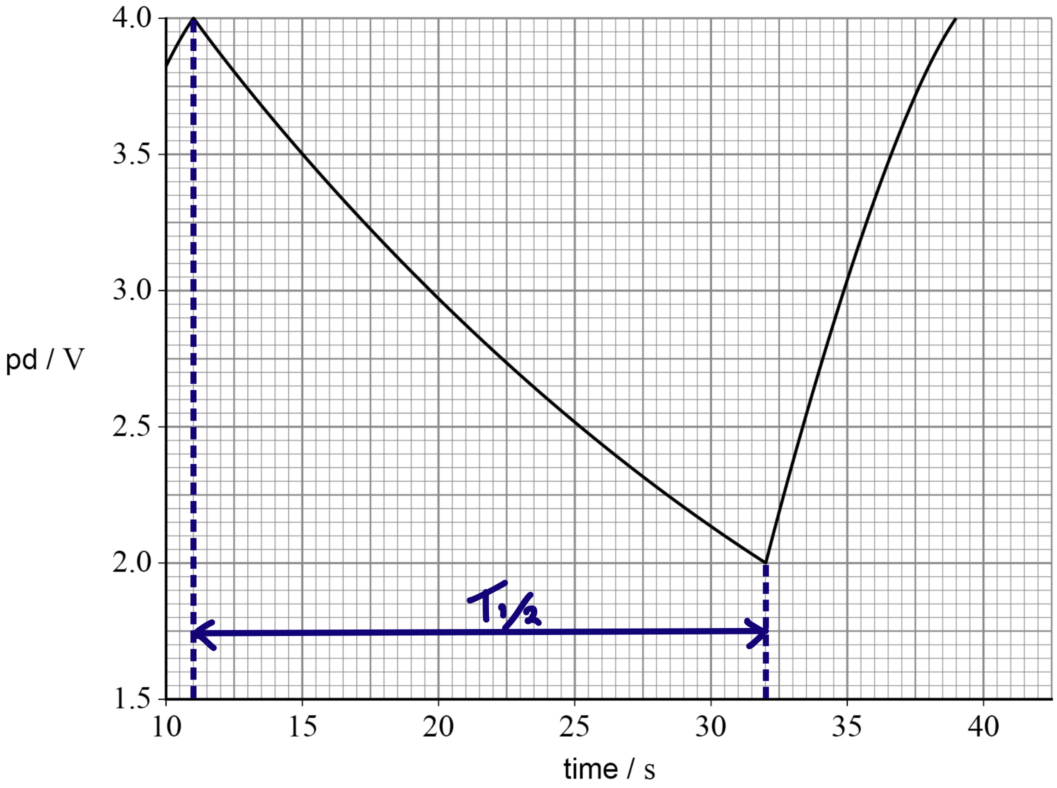
$$C = \frac{12.08}{1.0\times10^{5}} = \underline{1.2\times10^{-4}} \checkmark \approx 1\times10^{-4}\text{ F}$$

Question 5 continues on the next page

0 5 . 3 When the pd reaches 4.0 V the switch is immediately set to discharge the capacitor.
When the pd reaches 2.0 V the switch is immediately set to charge the capacitor.

Figure 10 shows how the pd across the capacitor varies with time.

Figure 10



Determine the value of R_2.

[3 marks]

$T_{1/2} = 32 - 11 = 21\ s$ ✓

$T_{1/2} = R_T C \ln 2$ ✓

$R_T = \frac{T_{1/2}}{C \ln 2} = \frac{21}{1.2\times10^{-4} \ln 2} = 2.507\times10^{5}\ \Omega$

$R_2 = R_T - R_1 = 2.507\times10^{5} - 1.0\times10^{5}$

$R_2 =$ 1.5×10^{5} ✓ Ω

10

0 6 . 1 Nuclear radii can be estimated using either alpha particles or high-energy electrons.

State **two** advantages of using high-energy electrons rather than alpha particles for this estimate.

[2 marks]

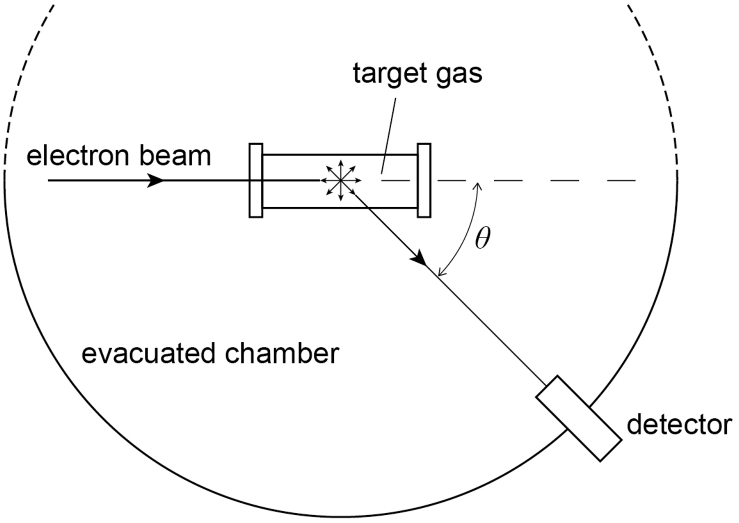
1 Electrons have a much smaller wavelength ∴ greater resolution. ✓

2 They can get closer to the nucleus as there is no electrostatic repulsion. ✓

Question 6 continues on the next page

0 6 . 2 **Figure 11** shows a beam of electrons, each with the same high energy, incident on a target gas.
The electrons are diffracted by the nuclei in the gas.
The intensities of these diffracted electrons are measured at various angles θ.
The data are used to determine the nuclear radius R of the atoms in the gas.

Figure 11

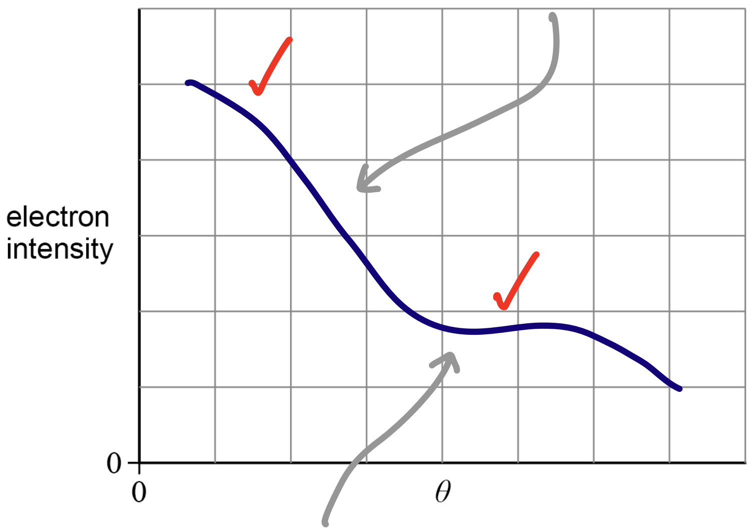


Sketch on **Figure 12** a graph showing how the electron intensity varies with θ.

[2 marks]

Figure 12

Decrease due to scattering



Due to electron diffraction (and destructive interference)

0 6 . 3 The radius R of a nucleus is related to its nucleon number by $R = R_0 A^{\frac{1}{3}}$.

Show that this equation is consistent with the idea that all nuclei have the same density.

[2 marks]

$$\rho = \frac{m}{V} = \frac{A \times m_{nucleon}}{4/3\, \pi \left(R_0 A^{1/3}\right)^3} \checkmark = \frac{m_{nucleon} \times \cancel{A}}{4/3\, \pi R_0^3 \cancel{A}}$$

$$\rho = \frac{m_{nucleon}}{4/3\, \pi R_0^3}$$

$m_{nucleon}$ and R_0 constant

$\therefore \rho$ independent of A ✓

0 6 . 4 The equation $R = R_0 A^{\frac{1}{3}}$ is derived from experimental data.

Suggest **one** reason why the constant density of nuclear material derived from this equation is only approximate.

[1 mark]

It ignores binding energy ∴ mass of nucleus is not exactly A × $m_{nucleon}$. ✓

0 6 . 5 The measured radius R of ${}^{35}_{17}\mathrm{Cl}$ is 4.02×10^{-15} m.

Calculate an estimate of

- the constant R_0
- the density of nuclear material.

[3 marks]

$R = R_0 A^{1/3}$

$$R_0 = \frac{R}{A^{1/3}} = \frac{4.02\times10^{-15}}{35^{1/3}} = 1.23\times10^{-15}\ \text{m}$$

$$\rho = \frac{m_{nucleon}}{4/3\, \pi R_0^3} = \frac{3 \times 1.67\times10^{-27}}{4 \times \pi \times (1.23\times10^{-15})^3} \checkmark = 2.148\times10^{17}$$

R_0 = 1.23×10^{-15} ✓ m   density = 2.15×10^{17} ✓ kg m^{-3}

10

0 7 . 1 Carbon is used as the moderator in some thermal nuclear reactors.

Identify **one** other material commonly used as a moderator.

[1 mark]

Heavy water ✓

0 7 . 2 State **two** benefits of slowing down the neutrons released during fission.

[2 marks]

1 Uranium-235 more likely to absorb the neutron. ✓

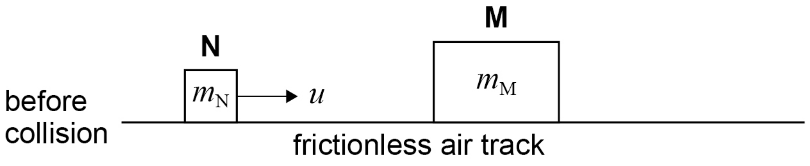
2 More likely to cause fission. ✓

0 7 . 3 The collision of a neutron with the nucleus of a moderator atom is modelled using two gliders on a horizontal frictionless air track.

In **Figures 13** and **14** the glider **N** of mass m_N represents the neutron and the glider **M** of mass m_M represents the moderator nucleus.

Figure 13 shows glider **N** travelling with initial speed u towards the stationary glider **M**.

Figure 13



The gliders collide. **N** rebounds with speed v as shown in **Figure 14**.

Figure 14

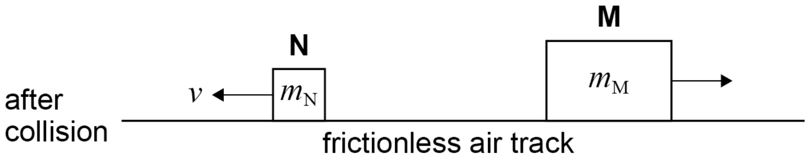
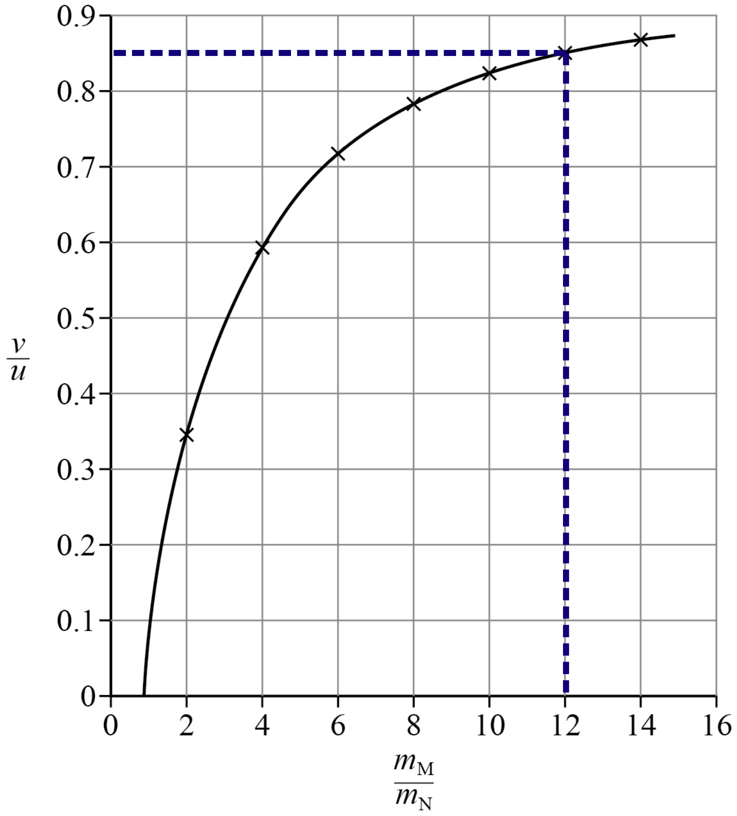


Figure 15 shows the variation of the ratio $\frac{v}{u}$ with the ratio $\frac{m_M}{m_N}$.

Figure 15



Show that when $\frac{m_M}{m_N}$ is 12, **N** loses about 30% of its initial kinetic energy in the collision.

[2 marks]

$$\frac{E_K \text{ final}}{E_K \text{ initial}} = \frac{\cancel{1/2}\,\cancel{m_N}\,v^2}{\cancel{1/2}\,\cancel{m_N}\,u^2} = \frac{v^2}{u^2}$$

When $m_M/m_N = 12$, $\frac{v}{u} = 0.85$

$\frac{v^2}{u^2} = 0.85^2 = 0.7225$ ✓ ≈ 70% of original, 30% of energy lost. ✓

Question 7 continues on the next page

0 7 . 4 In a reactor, the speed of a fast-moving neutron is reduced by a series of y random collisions with carbon-12 nuclei.

The final kinetic energy E_f of the neutron is

$$E_f = E_0 e^{-by}$$

where E_0 is the initial kinetic energy of the neutron and $b = 0.73$

A thermal neutron has kinetic energy equivalent to that of the average particle of an ideal gas with a temperature of 350 K.

One neutron has an initial kinetic energy of 1.0 MeV.

Calculate the minimum value of y required so that this neutron becomes a thermal neutron.

[3 marks]

$E_f \rightarrow E_{K\,final} = \frac{3}{2}kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 350 = 7.245 \times 10^{-21}$ J ✓

$E_0 \rightarrow E_k\ initial = 1.0 \times 10^6 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-13}$ J ✓

$E_f = E_0 e^{-by}$ $\quad \ln \frac{E_f}{E_0} = -by$

$y = \frac{\ln(E_f/E_0)}{-b} = \frac{\ln(7.245 \times 10^{-21} / 1.6 \times 10^{-13})}{-0.73}$

$y = 23.16$

$y =$ 23 ✓

0 7 . 5 Explain, with reference to **Figure 15**, why elements with a small nucleon number are preferred as moderator materials.

[2 marks]

Lower nucleon number produces a greater change in E_K ✓ ∴ fewer collisions needed. ✓

10

END OF SECTION A

Section B

Each of Questions **08** to **32** is followed by four responses, **A**, **B**, **C** and **D**.

For each question select the best response.

Only **one** answer per question is allowed.
For each question, completely fill in the circle alongside the appropriate answer.

CORRECT METHOD ●   WRONG METHODS ⊗ ⊙ ▨ ✓

If you want to change your answer you must cross out your original answer as shown. ☒

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. ☒

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sheets for this working.

0 8 A 1000 W heater is 75% efficient. The heater is used to increase the temperature of some water from 10 °C to 85 °C in 7 hours.

What mass of water is heated?

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

[1 mark]

A 1.0 kg ○

B 13 kg ○

C 60 kg ● ✓

D 110 kg ○

$$Q = mc\Delta\theta = Pt$$

$$m = \frac{Pt}{c\Delta\theta} = \frac{1000 \times 7 \times 3600 \times 0.75}{4200 \times (85-10)}$$

$$= 60$$

0 9 Which can lead to a value for the absolute zero of temperature?

[1 mark]

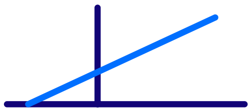
A Boyle's law ○

B Brownian motion ○

C Charles's law ● ✓

D Rutherford scattering ○

$V \propto T$



1 0 Two protons are separated by a distance of 1×10^{-9} m.

Which is an estimate of $\dfrac{\text{electric repulsion force}}{\text{gravitational attraction force}}$ for these two protons?

[1 mark]

A 10^{18} ○

B 10^{28} ○

C 10^{36} ● ✓

D 10^{45} ○

$$\frac{F_E}{F_g} = \frac{Q_1Q_2/4\pi\varepsilon_0\cancel{r^2}}{Gm_1m_2/\cancel{r^2}}$$

$$= \frac{(1.6\times10^{-19})^2/4\pi\times8.85\times10^{-12}}{6.67\times10^{-11}\times(1.67\times10^{-27})^2} = 1.2\times10^{36}$$

1 1 Data are collected for the mass M, radius R and escape velocity u for each planet in the Solar System.

The data show that u is directly proportional to

[1 mark]

A $\left(\dfrac{M}{R}\right)^{-\frac{1}{2}}$ ○

B $\left(\dfrac{M}{R}\right)^{\frac{1}{2}}$ ● ✓

C $\dfrac{M}{R}$ ○

D $\left(\dfrac{M}{R}\right)^{2}$ ○

$$E_K = E_p$$

$$\frac{1}{2}\cancel{m}u^2 = \frac{G\cancel{m}M}{R}$$

$$u = \sqrt{\frac{2GM}{R}} \propto \sqrt{\frac{M}{R}}$$

Turn over for the next question

1 2 A satellite is in a circular orbit at a height h above the surface of a planet of mass M and radius R.

What is the linear speed of the satellite?

[1 mark]

A $\frac{\sqrt{GM}}{(R+h)}$ ○

B $\sqrt{\frac{GM}{(R+h)}}$ ● ✓

C $\frac{GM}{\sqrt{R+h}}$ ○

D $\frac{GM}{(R+h)}$ ○

$$F_g = F_c$$

$$\frac{G\cancel{m}M}{r^{\cancel{2}}} = \frac{\cancel{m}v^2}{\cancel{r}} \qquad r = R+h$$

$$\frac{GM}{R+h} = v^2 \qquad v = \sqrt{\frac{GM}{R+h}}$$

1 3 Which statement is **not** true for a satellite in a geostationary orbit?

[1 mark]

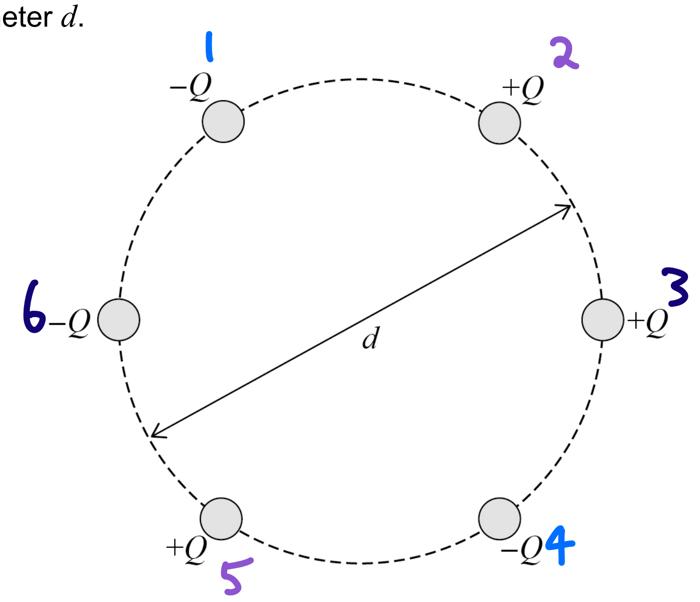
A The satellite orbits in the plane of the Earth's equator. ○

B The satellite has the same angular velocity as a point on the Earth's surface. ○

C The satellite takes 24 hours to orbit the Earth. ○

D Signals from the satellite can be sent to any point on the Earth's surface during one orbit. ● ✓

1 4 Six metal spheres, each carrying a charge of magnitude Q, are equally spaced around a circle of diameter d.



What is the magnitude of the field strength at the centre of the circle?

[1 mark]

1 & 4 cancel   2 & 5 cancel

3 & 6 combine

A 0 ○

B $\frac{Q}{\pi\varepsilon_0 d^2}$ ○

C $\frac{2Q}{\pi\varepsilon_0 d^2}$ ● ✓

D $\frac{4Q}{\pi\varepsilon_0 d^2}$ ○

$$r^2 = \frac{d^2}{4}$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2} - \frac{-Q}{4\pi\varepsilon_0 r^2}$$

$$= \frac{2Q}{\cancel{4}\pi\varepsilon_0 . d^2/\cancel{4}} = \frac{2Q}{\pi\varepsilon_0 . d^2}$$

1 5 Two point charges are separated by a distance of 200 mm.
The force of attraction between them is 180 μN.
The distance between the point charges is increased by 400 mm.

What is the new force of attraction?

[1 mark]

$$F = k . \frac{Q_1 Q_2}{r^2}$$

A 20 μN ● ✓

B 45 μN ○

C 60 μN ○

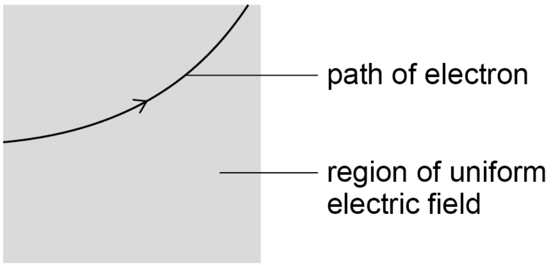
D 90 μN ○

$r_1 = 200$ mm $r_2 = 600$ mm

$r_2 = 3r_1$ $r_2^2 = 9r_1^2$

$$F_2 = \frac{1}{9}F_1 = \frac{180}{9} = 20$$

1 6 The diagram shows the path of an electron in a uniform electric field.
The electron moves in a vertical plane.



The direction of the electric field is

[1 mark]

A vertically down the plane. ● ✓

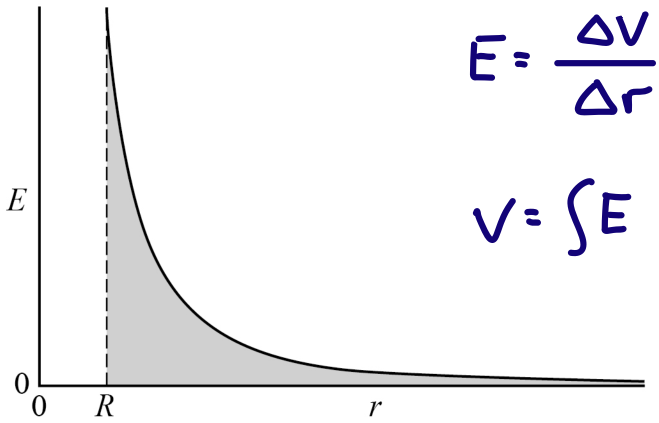
B vertically up the plane. ○

C horizontally into the plane. ○

D horizontally out of the plane. ○

Electron deflected up
Field direction is the direction in which a +ve charge would be deflected ∴ opposite to e^-

1 7 The graph shows the variation of electric field strength E surrounding a charged sphere of radius R. The distance from the centre of the sphere is r.



$$E = \frac{\Delta V}{\Delta r}$$

$$V = \int E \, dr = \text{area}$$

The total area under the curve from R to infinity is

[1 mark]

A the capacitance of the sphere. ○

B the charge held on the sphere. ○

C the electric potential of the sphere. ● ✓

D the energy needed to remove an electron from the sphere. ○

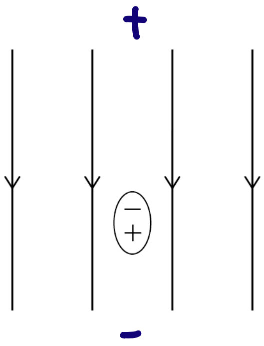
Turn over for the next question

1 8 A polar molecule is in an external electric field.

Which diagram shows the orientation of the polar molecule?

[1 mark]

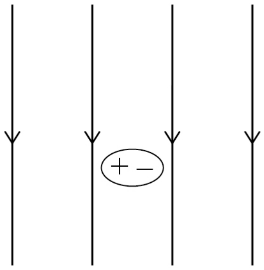
A



● ✓

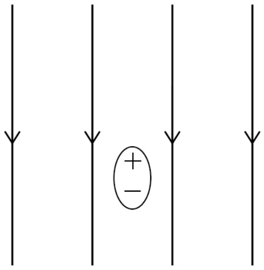
Opposites attract

B



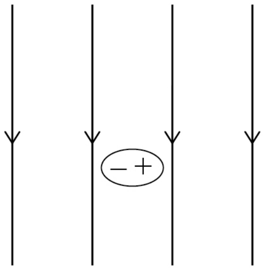
○

C



○

D



○

1 9 An alpha particle is moving towards a stationary gold nucleus. The alpha particle has a kinetic energy of 9.0×10^{-13} J when it is a large distance from the gold nucleus. The gold nucleus contains 79 protons.

What is the closest possible distance of approach of the alpha particle to the gold nucleus?

[1 mark]

A 2.5×10^{-16} m ○

B 2.0×10^{-14} m ○

C 4.0×10^{-14} m ● ✓

D 2.0×10^{-7} m ○

$E_K = E_e$

$$9.0\times10^{-13} = \frac{2\times79\times(1.6\times10^{-19})^2}{4\pi\times8.85\times10^{-12}\times r}$$

$r = 4.04\times10^{-14}$ m

2 0 A wire is at right angles to a uniform magnetic field and carries an electric current. The wire is 150 mm in length.

When the current in the wire is increased by 4.0 A, the force acting on the wire increases by 3.6×10^{-3} N.

What is the magnetic flux density of the field?

[1 mark]

A 6.0×10^{-6} T ○

B 6.0×10^{-3} T ● ✓

C 1.7×10^{2} T ○

D 1.7×10^{5} T ○

$F = BIL$

$\Delta F = F_2 - F_1$

$\Delta F = BL(I_2 - I_1)$

$$B = \frac{\Delta F}{L(I_2 - I_1)} = \frac{3.6\times10^{-3}}{0.150\times4.0}$$

$= 6.0\times10^{-3}$

Turn over for the next question

2 1 A beam consists of ionised atoms of two isotopes of an element.
When the beam enters a uniform magnetic field, the ions move in circular paths.
The ions have the same charge and travel at the same speed when they enter the magnetic field.

Which statement is true?

[1 mark]

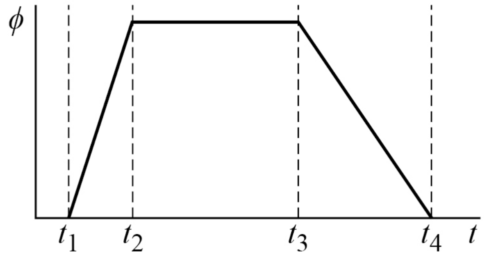
A The force acting on an ion is different for each isotope. ○

B The radius of the path followed by an ion is different for each isotope. ● ✓

C The kinetic energy of an ion increases for both isotopes. ○

D The acceleration of an ion is the same for both isotopes. ○

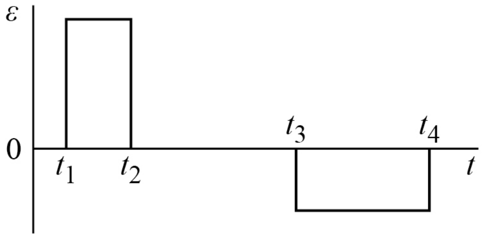
2 2 The magnetic flux ϕ in a coil varies with time t as shown.



Which graph shows how the emf ε induced in the coil varies with t?

[1 mark]

A

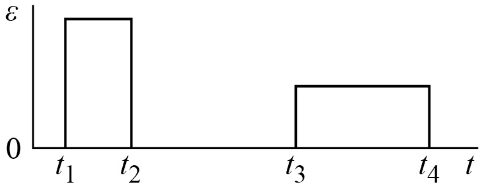


● ✓

$\mathcal{E} \propto \frac{d\phi}{dt}$

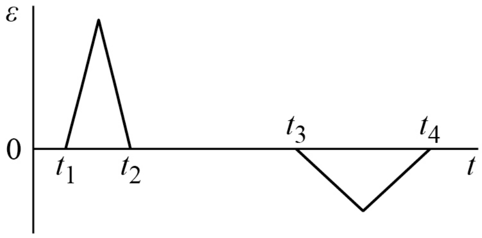
$\mathcal{E} \propto$ gradient

B



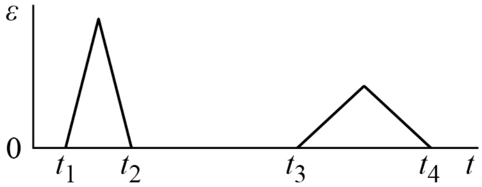
○

C



○

D



○

2 3 The distance between the wing tips of a metal aircraft is 30 m.
The aircraft flies horizontally at a steady speed of $100\ \text{m s}^{-1}$.
The aircraft passes through a vertical magnetic field of flux density 2.0×10^{-7} T.

What is the emf induced between its wing tips?

[1 mark]

A 0.2 μV ○

B 20 μV ○

C 300 μV ○

D 600 μV ● ✓

$\varepsilon = BLv$

$= 2.0 \times 10^{-7} \times 30 \times 100$

$= 6.0 \times 10^{-4}$ V

$= 600 \times 10^{-6}$ V

2 4 A circular coil with a radius of 0.10 m has 200 turns.
The coil rotates at 50 revolutions per second about an axis which is perpendicular to a uniform magnetic field and in the plane of the coil.
The magnetic flux density of the field is 0.20 T.

What is the maximum emf induced in the coil?

[1 mark]

$\omega = 50\ \text{rev s}^{-1} = 50 \times 2\pi = 100\pi\ \text{rad s}^{-1}$

A 63 V ○

B 126 V ○

C 195 V ○

D 395 V ● ✓

$\varepsilon_{max} = BAN\omega$

$= 0.20 \times \pi \times 0.10^2 \times 200 \times 100\pi$

$= 394.8$

2 5 After radioactive waste is removed from a cooling pond, it is often stored in underground caves.
This is to protect workers from the effects of

A alpha particles from nuclides with a large decay constant. ○

B alpha particles from nuclides with a small decay constant. ○

C gamma radiation from nuclides with a large decay constant. ○

D gamma radiation from nuclides with a small decay constant. ● ✓

2 6 Alpha particle scattering can be demonstrated using a thin gold foil.

Which statement about this demonstration is **not** true?

[1 mark]

A The foil is thin enough to assume that alpha particles are deflected only once. ○

B Nuclei are more massive than alpha particles which allows the alpha particles to be deflected by more than 90°. ○

C The number of alpha particles deflected backwards is greater than the number that pass straight through the foil. ● ✓

D Deflections of alpha particles by electrons in the foil are much smaller than deflections due to nuclei. ○

2 7 A transformer for use in a 230 V ac supply is 90% efficient.
The transformer provides a current of 3.00 A at 12.0 V.

What is the current in the primary coil?

[1 mark]

efficiency

$$\eta = \frac{P_{out}}{P_{in}} = \frac{I_s V_s}{I_p V_p}$$

A 0.141 A ○

B 0.156 A ○

C 0.174 A ● ✓

D 5.75 A ○

$$I_p = \frac{I_s V_s}{V_p \eta} = \frac{3.00 \times 12.0}{230 \times 0.90} = 0.1739$$

2 8 The random nature of radioactive decay means that it is never possible to predict

[1 mark]

A when a particular nucleus will decay. ● ✓

B whether a β^- particle or a β^+ particle is emitted. ○

C the approximate time taken for the activity to decrease to a specified value. ○

D the approximate thickness of an absorber needed to reduce the count rate to a specified value. ○

29 Radiation is used to measure the thickness of an aluminium sheet accurately.
The thickness of the sheet is about 0.5 mm.

Which type of radiation is most appropriate for the measurement?

[1 mark]

A α ○

B β^- ● ✓

C β^+ ○

D γ ○

30 Tritium is a radioactive nuclide used in 'Exit' signs.
When a sign was manufactured the activity of the tritium in it was 37 MBq.
After 10 years the tritium in the sign has an activity of 21 MBq.

What will the activity be 15 years after it was manufactured?

[1 mark]

A 12 MBq ○

B 13 MBq ○

C 16 MBq ● ✓

D 17 MBq ○

$$\frac{37}{21} = 1.76$$

$$\frac{37}{1.76^{15/10}} = 15.8$$

31 The mass of fuel in a nuclear reactor decreases at a rate of 4.0×10^{-6} kg per hour.

What is the rate at which energy is transferred due to nuclear fission?

[1 mark]

A 4.0×10^{7} W ○

B 1.0×10^{8} W ● ✓

C 6.0×10^{8} W ○

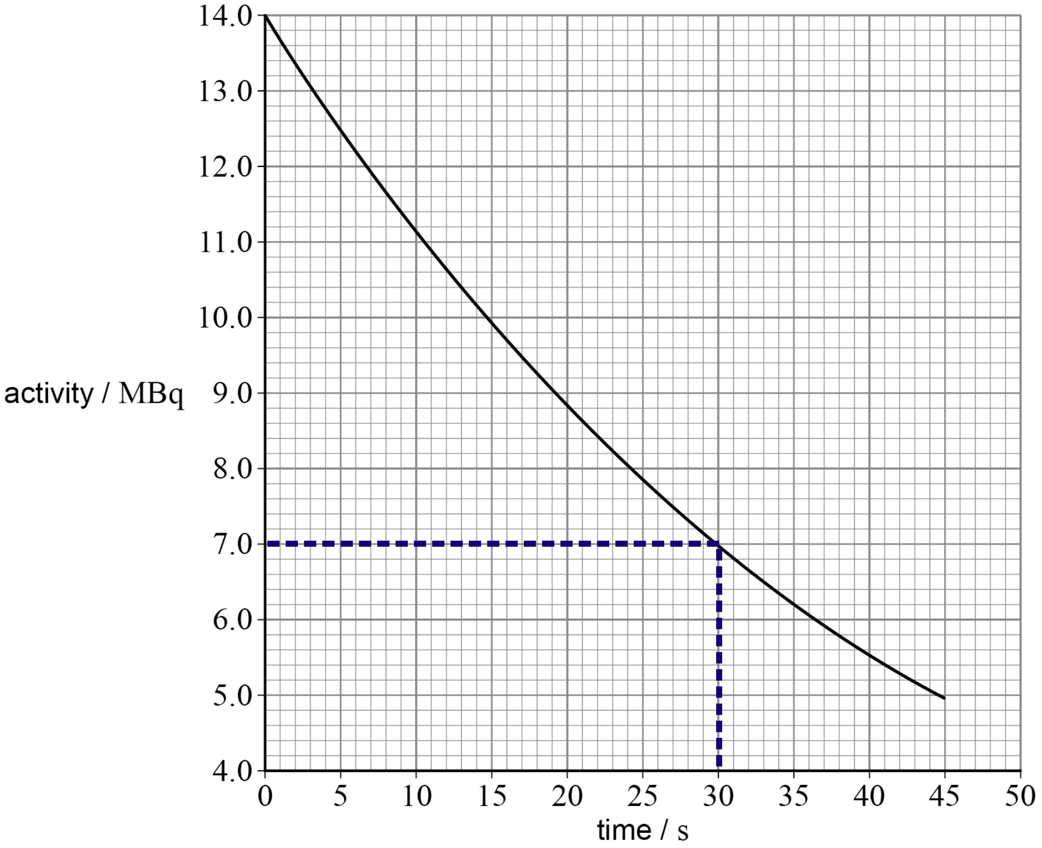
D 3.6×10^{10} W ○

$$P = \frac{E}{t} = \frac{mc^2}{t} = \frac{m}{t} . c^2$$

$$= \frac{4.0 \times 10^{-6}}{60 \times 60} \times 9.00 \times 10^{16}$$

$$= 1.0 \times 10^{8}$$

3 2 The graph shows the variation of activity with time for a sample of a nuclide **X**.



What was the initial number of nuclei of **X** in the sample?

[1 mark]

A 4.67×10^5 ○

B 3.0×10^8 ○

C 4.2×10^8 ○

D 6.1×10^8 ● ✓

$$\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{30} = 0.023$$

$$A = \lambda N_0 \quad N_0 = \frac{A}{\lambda}$$

$$N_0 = \frac{14 \times 10^6}{0.023} = 6.06 \times 10^8$$

END OF QUESTIONS

25

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required. Write the question numbers in the left-hand margin.**

Question number	**Additional page, if required. Write the question numbers in the left-hand margin.**

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Copyright information