Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level PHYSICS

Paper 2

Monday 9 June 2025 Morning Time allowed: 2 hours

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.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7–31	
TOTAL	

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Section A

Answer **all** questions in this section.

0 1 Information about the radius of a nucleus can be deduced from the closest approach of alpha particles and from electron diffraction.

0 1 . 1 Alpha particles, each with a kinetic energy of $5.59\ \text{MeV}$, are fired at a thin foil made of gold $\left({}^{197}_{79}\text{Au}\right)$ atoms.

Some of the alpha particles are scattered through an angle of $180°$.

Estimate the radius of a ${}^{197}_{79}\text{Au}$ nucleus from this information.

[3 marks]

radius of nucleus = _____ m

0 1 . 2 Explain why your answer to Question **01.1** is an estimate.

[2 marks]

_____

_____

_____

_____

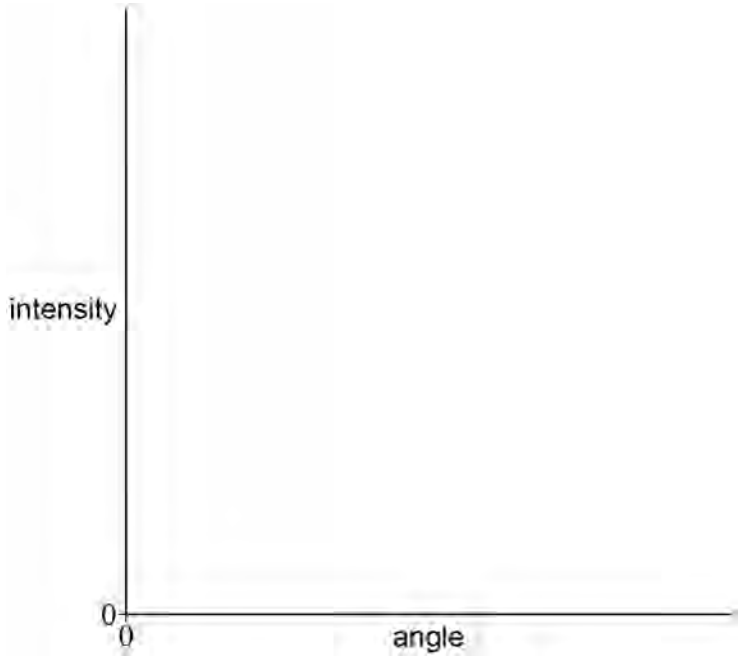
Do not write outside the box

0 1 . 3 Electron diffraction gives a more precise value for the radius of the nucleus.

Sketch, on **Figure 1**, a graph of intensity against angle for electron diffraction by a nucleus.
Go on to state the feature of this graph that is used to determine the radius of the nucleus.

[2 marks]

Figure 1



Question 1 continues on the next page

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0 1 . 4 Results from electron-diffraction experiments lead to the equation:

$$R = R_0 A^{\frac{1}{3}}$$

Show that the equation provides evidence for the constant density of nuclear material.
[2 marks]

9

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0 2 The derivation of the equation $pV = \frac{1}{3}Nm(c_{\text{rms}})^2$ is based on several assumptions.

0 2 . 1 One of these assumptions is that particle motion is random.

State what is meant by random particle motion.

[2 marks]

0 2 . 2 State **two** other assumptions required for this derivation.

[2 marks]

1

2

Question 2 continues on the next page

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0 2 . 3 When the temperature of a fixed mass of an ideal gas increases at constant pressure, the gas must expand.

Explain this expansion using the kinetic theory model.

[3 marks]

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The average kinetic energy of the particles of an ideal gas is equal to $\frac{3}{2}kT$.

This is **not** true for a real gas.

0 2 . 4 Helium behaves as an ideal gas.
The temperature of a sample of helium gas is increased from 27 °C to 77 °C.

Calculate the change in the average kinetic energy of a helium atom in the sample.

[1 mark]

change in average kinetic energy = _____ J

0 2 . 5 When an ideal gas is heated at constant volume, all of the energy supplied by heating is used to increase the average kinetic energy of the particles.

When water vapour is heated at constant volume, its specific heat capacity is 1400 J kg^{-1} K^{-1}.

Deduce whether water vapour behaves as an ideal gas when heated at constant volume.

mass of a water molecule = 3.0×10^{-26} kg

[3 marks]

_____

_____

11

Do not write outside the box

0 3 A radioisotope thermoelectric generator (RTG) uses radioactive decay to generate electrical energy.

A vehicle that is used to examine the surface of Mars includes an RTG that initially contains 3.23×10^{24} atoms of plutonium-238 $\left(^{238}_{94}\mathrm{Pu}\right)$.

0 3 . 1 Determine the initial mass of plutonium-238 in the RTG.

[2 marks]

initial mass = _____ kg

Do not write outside the box

0 3 . 2 The plutonium-238 undergoes alpha decay.
The energy released by this decay is converted into electrical energy with an efficiency of 4.58%.

The power provided by the RTG decreases over time as the plutonium-238 decays.

The vehicle requires a minimum electrical power of 29.6 W to operate.

Calculate the initial activity of the plutonium-238.
Go on to determine, in Earth years, the time for which the RTG can provide sufficient power for the vehicle to operate.

decay constant of plutonium-238 $= 2.51 \times 10^{-10}\ s^{-1}$
energy of alpha particle emitted by plutonium-238 $= 8.94 \times 10^{-13}\ J$

[5 marks]

initial activity = _____ Bq

time = _____ Earth years

Question 3 continues on the next page

Do not write outside the box

0 3 . 3 The vehicle has a battery-powered laser that is used to vaporise small samples of ice. On Mars, ice changes directly from solid to vapour at a temperature of $0\ °C$. The ice does not form a liquid.

The energy required to vaporise $1.0\ g$ of solid ice directly into water vapour is the same as the total energy required to melt $1.0\ g$ of ice and then to vaporise the melted ice.

The laser produces an output power of $1.0\ kW$ for a maximum time of $3.0\ s$ before its battery needs to be recharged.

The laser heats the ice from an initial temperature of $-25\ °C$ to a temperature of $0.0\ °C$. The laser then transfers energy to vaporise the ice at $0.0\ °C$.

Determine whether the laser is able to vaporise $1.0\ g$ of the ice that is initially at $-25\ °C$ before the battery needs to be recharged.

specific heat capacity of ice = $2.1\ kJ\ kg^{-1}\ K^{-1}$
specific latent heat of fusion of ice = $334\ kJ\ kg^{-1}$
specific latent heat of vaporisation = $2500\ kJ\ kg^{-1}$

[4 marks]

11

Do not write outside the box

0 4 . 1 Mimas and Enceladus are moons of Saturn.

Mimas orbits at a height of 1.28×10^8 m above the surface of Saturn.
The orbital period of Mimas is 0.94 Earth days.

Enceladus orbits at a height of 1.80×10^8 m above the surface of Saturn.

Calculate, in Earth days, the orbital period of Enceladus.

radius of Saturn = 5.8×10^7 m

[3 marks]

orbital period = _____ Earth days

Question 4 continues on the next page

Do not write outside the box

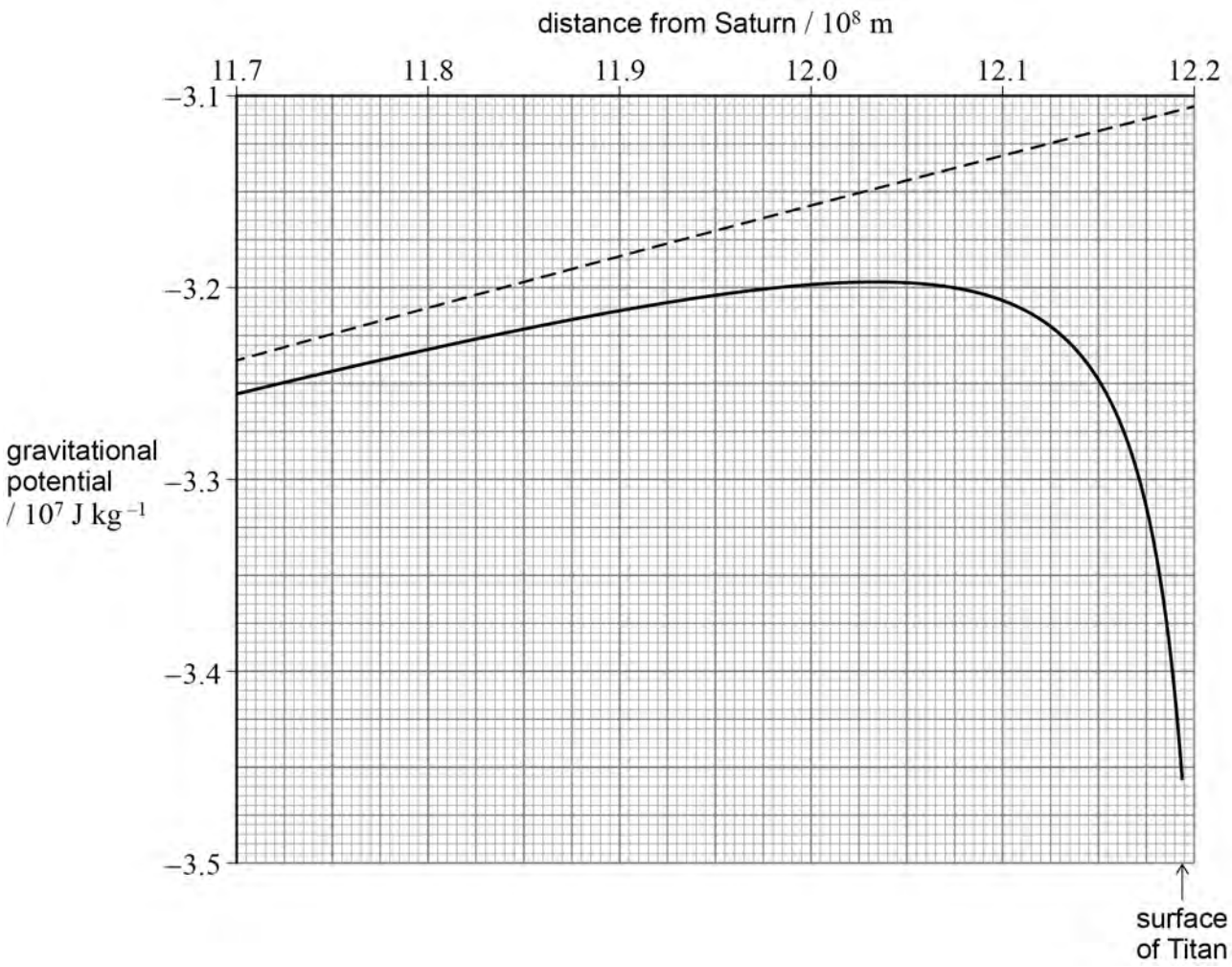
Titan is the largest moon of Saturn.

Figure 2 shows the variation of gravitational potential with distance from the centre of Saturn in the direction of Titan.

The dashed line shows the gravitational potential due to the mass of Saturn alone.

The solid line shows the total gravitational potential due to Saturn and Titan.
The solid line ends at the surface of Titan.

Figure 2



Do not write outside the box

0 4 . 2 A student suggests that, over the range of distances shown in **Figure 2**, the gravitational field strength due to the mass of Saturn alone is approximately constant.

Explain why the suggestion is correct.

[1 mark]

0 4 . 3 At a point **P**, the resultant gravitational field strength due to Saturn and Titan is zero.

Determine, using the solid line in **Figure 2**, the distance from Saturn to **P**.

[1 mark]

distance = _____ m

0 4 . 4 The centre of Titan is 12.22×10^8 m from the centre of Saturn.

Show that the gravitational potential due to the mass of Titan at a distance of 12.08×10^8 m from Saturn is about -7×10^5 J kg^{-1}.
Go on to determine the mass of Titan.

[3 marks]

mass = _____ kg

8

Do not write outside the box

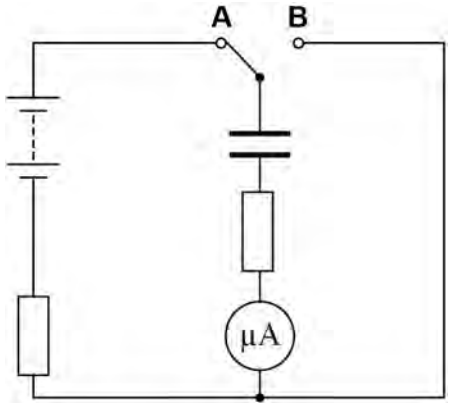
0 5 . 1 A material used between the plates of a capacitor has a dielectric constant of 7.0

State what is meant by a dielectric constant of 7.0

[1 mark]

Figure 3 shows a circuit that is used to charge and discharge a capacitor.

Figure 3



The battery has negligible internal resistance.

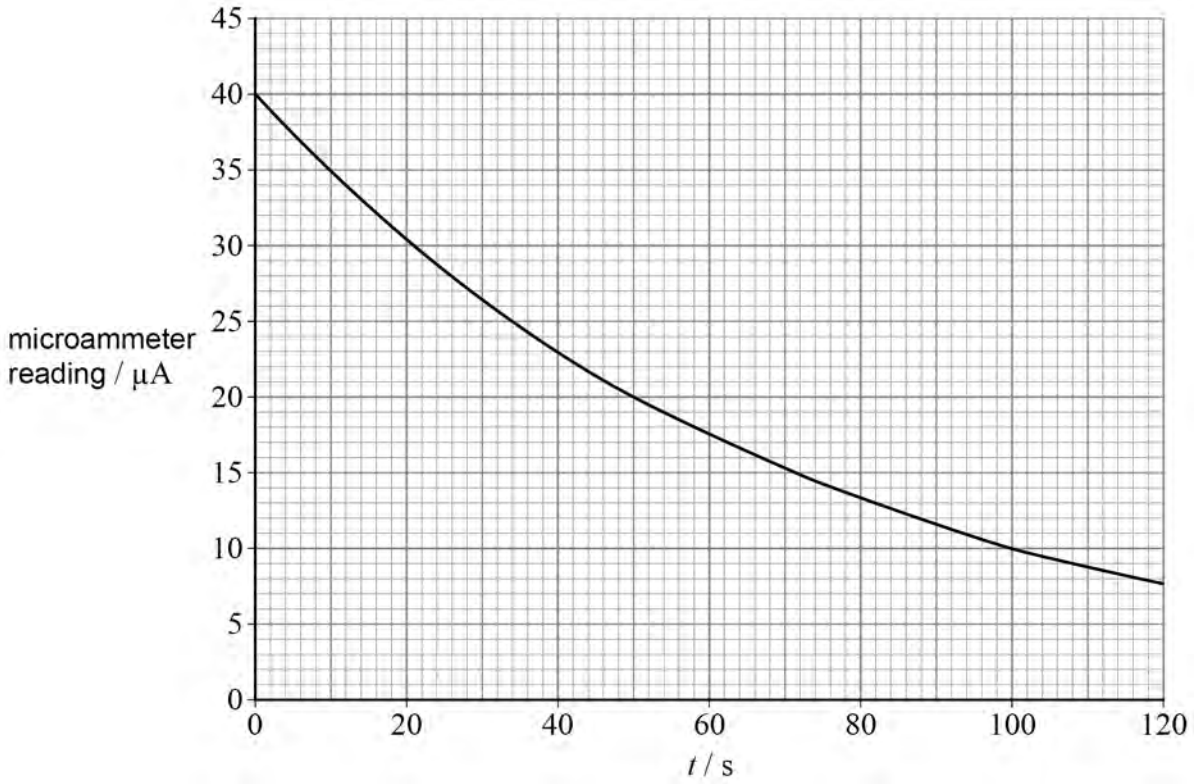
The two resistors in the circuit are identical.

The capacitor is fully charged and the switch is then moved from position **A** to position **B** at time $t = 0$

Figure 4 shows the variation of the microammeter reading with t until $t = 120$ s.

Do not write outside the box

Figure 4



The time constant of the discharging circuit is T.

0 5 . 2 Determine T using **Figure 4**.

[2 marks]

$T =$ _____ s

0 5 . 3 Electronic engineers consider a capacitor to be fully discharged when $t = 5T$.

Calculate $\frac{\text{current when } t = 5T}{\text{current when } t = 0}$ as a percentage.

[2 marks]

$\frac{\text{current when } t = 5T}{\text{current when } t = 0} =$ _____ %

Turn over ►

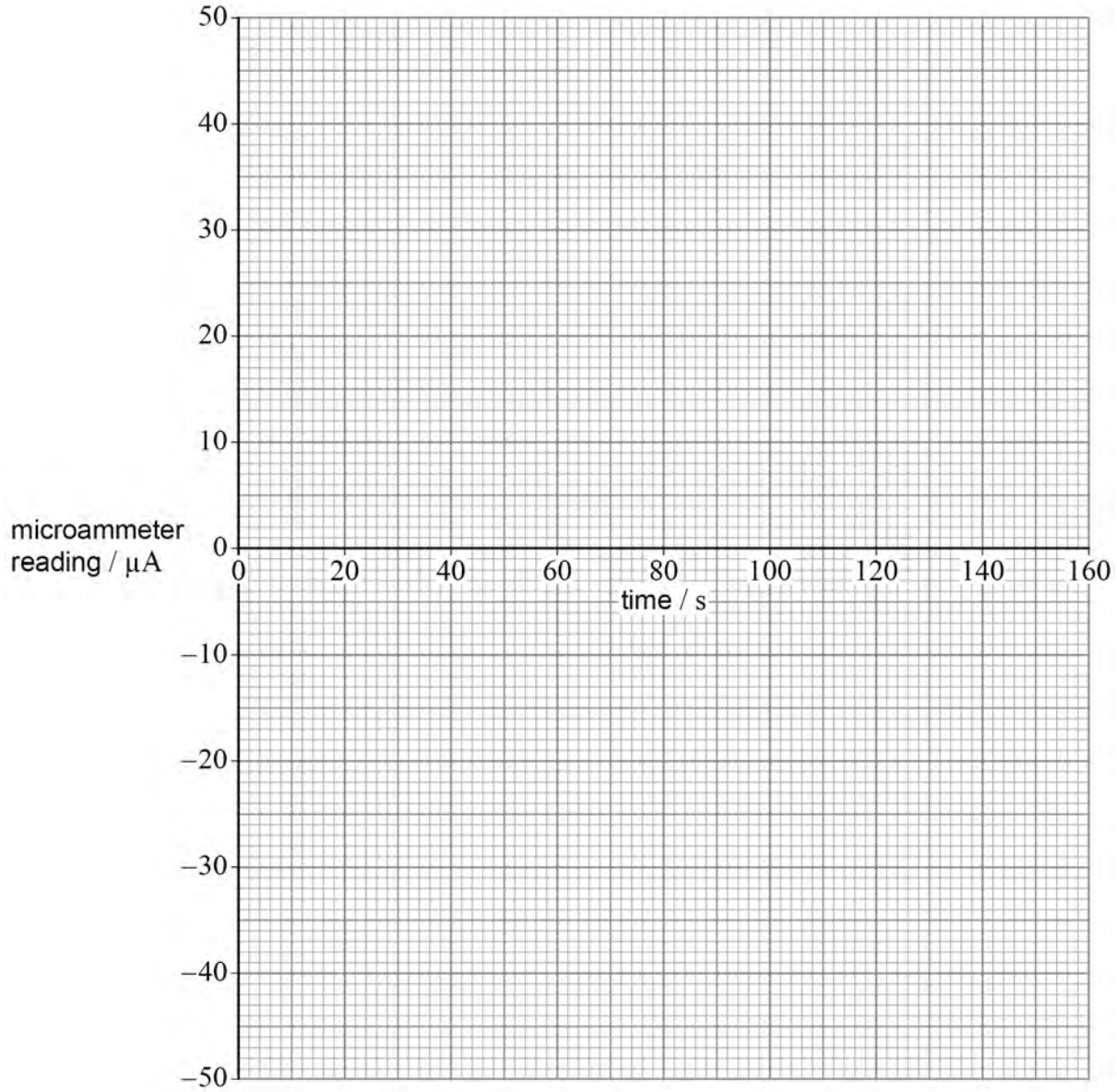
Do not write outside the box

0 5 . 4 The capacitor is fully discharged and then the switch is moved from position **B** to position **A** as shown in **Figure 3**.

Draw, on **Figure 5**, the variation of the microammeter reading with time after the switch is moved to position **A**.
In **Figure 5**, the time is 0 at the instant when the switch is moved to position **A**.

[3 marks]

Figure 5

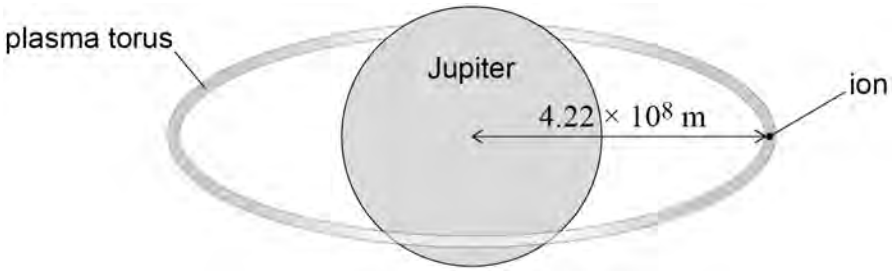


8

Do not write outside the box

0 6 Ions orbit Jupiter in a ring called a plasma torus as shown in **Figure 6**.
This question is about applying gravitational, magnetic and electric fields to a particle in the plasma.

Figure 6



An ion travels in a circular path at a speed of $74.2\ \text{km s}^{-1}$ and at a distance of $4.22 \times 10^8\ \text{m}$ from the centre of Jupiter.

0 6 . 1 Student **A** suggests that the gravitational force acting on the ion due to Jupiter provides the centripetal acceleration of the ion.

Deduce whether this suggestion is correct.

mass of Jupiter = $1.90 \times 10^{27}\ \text{kg}$

[3 marks]

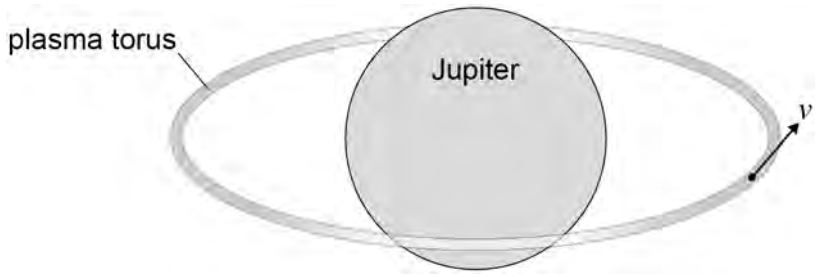
Question 6 continues on the next page

Do not write outside the box

Student **B** suggests that the magnetic field of Jupiter alone can cause the ion to move in the circular path.

Figure 7 shows the direction of the velocity v of the ion in the plasma torus.
v is tangential to the plasma torus.

Figure 7



The ion has a positive charge.

Student **B**'s suggestion requires a magnetic field to act at the position of the ion.

0 6 . 2 Draw an arrow on **Figure 7** to show the direction of this magnetic field.

[1 mark]

Do not write outside the box

The ion has a charge of $+3.20 \times 10^{-19}$ C and a mass of 5.31×10^{-26} kg.

0 6 . 3 The ion moves with a speed of 74.2 km s^{-1} in a circle of radius 4.22×10^{8} m.

Calculate the magnitude of the magnetic flux density required for this motion.
State, in fundamental (base) units, the unit for your answer.
Ignore any contribution from the gravitational field.

[3 marks]

magnetic flux density = _____ unit = _____

0 6 . 4 An electric field of strength $371 \ \mu\text{V m}^{-1}$ can also accelerate the ion.

Calculate the acceleration of the ion due to this electric field.

[3 marks]

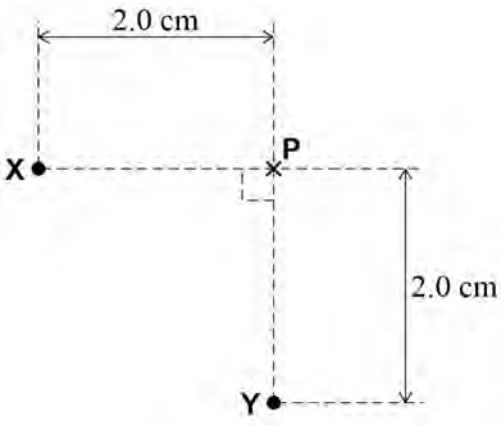
acceleration = _____ m s^{-2}

Question 6 continues on the next page

Do not write outside the box

0 6 . 5 The plasma torus contains two ions **X** and **Y** as shown in **Figure 8**.
X has a charge of $+2e$.
Y has a charge of $+1e$.
Assume that each ion acts as a point charge.

Figure 8



Calculate the magnitude of the resultant electric field strength at point **P** in **Figure 8** due to the two ions.

[3 marks]

resultant electric field strength = _____ $\mathrm{V\ m^{-1}}$

13

END OF SECTION A

Do not write outside the box

Section B

Each of Questions **07** to **31** 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 7 An object on the surface of a moon has an escape velocity v. The moon has a density ρ and radius R.

Another moon **X** has a density 2ρ and radius $\frac{R}{3}$.

What is the escape velocity for an object on the surface of **X**?

[1 mark]

A $\frac{2}{9}v$ 

B $\frac{\sqrt{2}}{3}v$ 

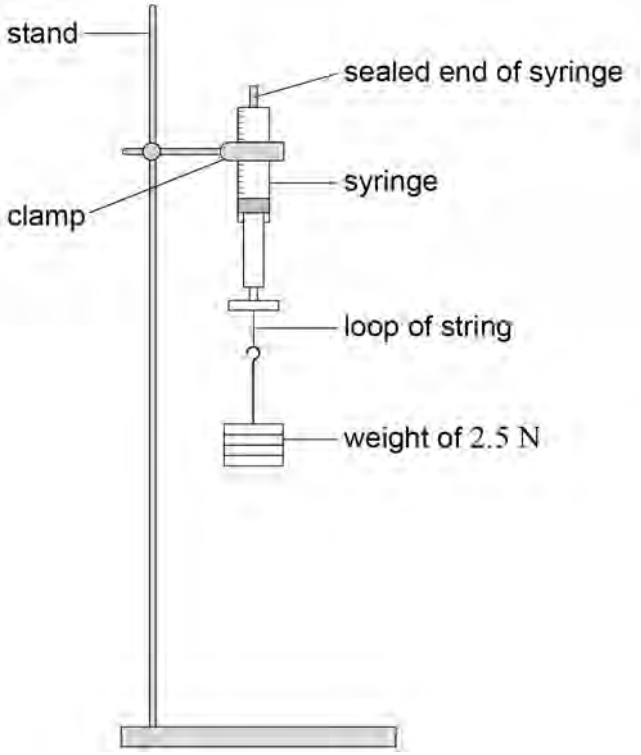
C $\sqrt{\frac{2}{3}}v$ 

D $\frac{2}{\sqrt{3}}v$ 

Do not write outside the box

0 8 In an investigation of Boyle's law, a sealed syringe of cross-sectional area 1.0×10^{-4} m^2 contains 12 cm^3 of gas. The gas is initially at atmospheric pressure.

A weight of 2.5 N is then suspended from the plunger of the syringe as shown in the diagram.



The temperature of the gas in the syringe and the atmospheric pressure are constant.

atmospheric pressure = 1.0×10^5 Pa

What is the new volume of gas in the syringe?

[1 mark]

A 3 cm^3 ⬭

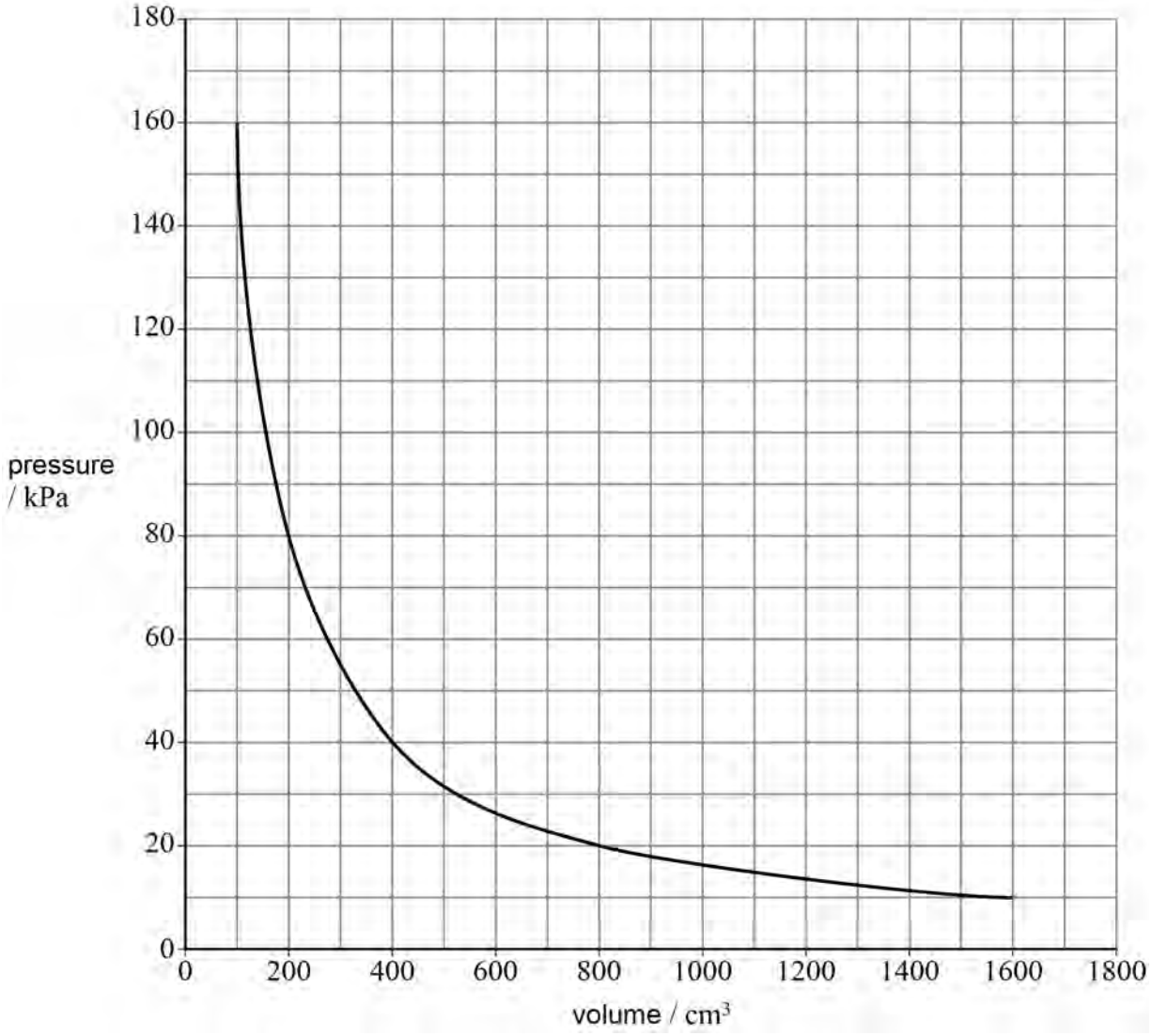
B 9 cm^3 ⬭

C 16 cm^3 ⬭

D 48 cm^3 ⬭

Do not write outside the box

0 9 The graph shows the variation of pressure with volume for a constant mass of a gas.



The temperature of the gas:

[1 mark]

A decreases as the pressure increases. ⬭

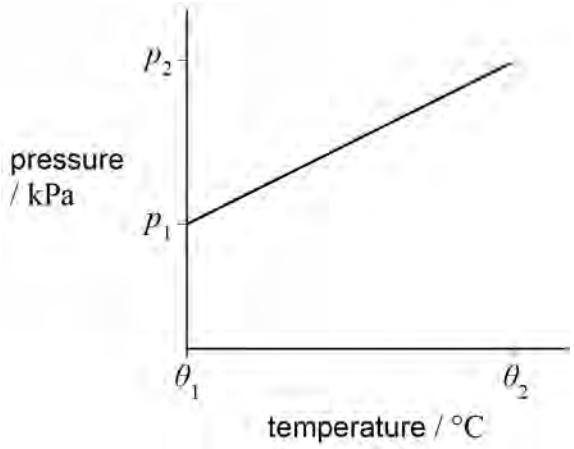
B increases as the pressure increases. ⬭

C is constant as the pressure increases. ⬭

D is a maximum when the pressure is 40 kPa. ⬭

Do not write outside the box

1 0 The graph shows how the pressure of a fixed mass of gas varies with temperature. The gas has a constant volume.



Which expression gives a value for absolute zero in °C?

[1 mark]

A $p_2\left(\frac{\theta_2-\theta_1}{p_2-p_1}\right)-\theta_1$ ⬭

B $\theta_1-p_1\left(\frac{\theta_2-\theta_1}{p_2-p_1}\right)$ ⬭

C $p_2-\left(\frac{p_2-p_1}{\theta_2-\theta_1}\right)\theta_2$ ⬭

D $\theta_2-p_2\left(\frac{p_2-p_1}{\theta_1-\theta_2}\right)$ ⬭

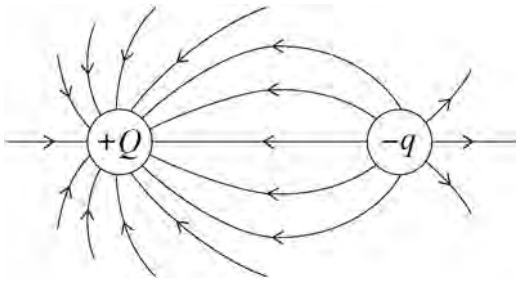
Do not write outside the box

1 1 Two charged metal spheres have charges $+Q$ and $-q$.
The magnitude of $+Q$ is greater than the magnitude of $-q$.

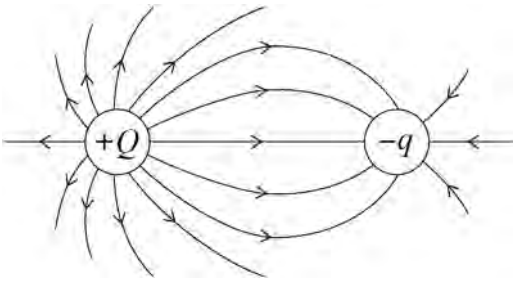
In which diagram are the electric field lines correct?

[1 mark]

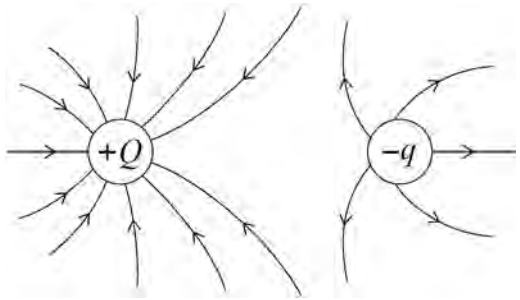
A



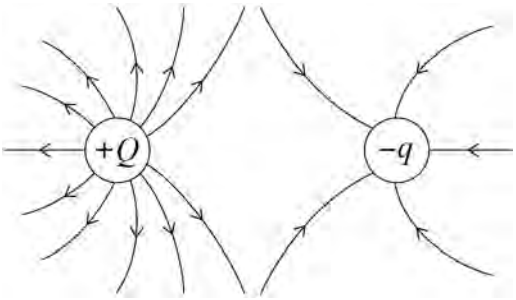
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

Turn over for the next question

Do not write outside the box

1 2 Two metal spheres each have radius r and charge Q. The force between them is F when the distance between their centres is x.

Two other metal spheres each have radius $\frac{r}{2}$ and charge $2Q$.

What is the force between these two spheres when the distance between their centres is x?

[1 mark]

A $4F$ ⬭

B $2F$ ⬭

C F ⬭

D $\frac{F}{2}$ ⬭

1 3 A particle has mass m and charge q.

The particle is moved a distance d through a potential difference V.

What is the change in electric potential energy?

[1 mark]

A qV ⬭

B $\frac{V}{q}$ ⬭

C $\frac{qV}{d}$ ⬭

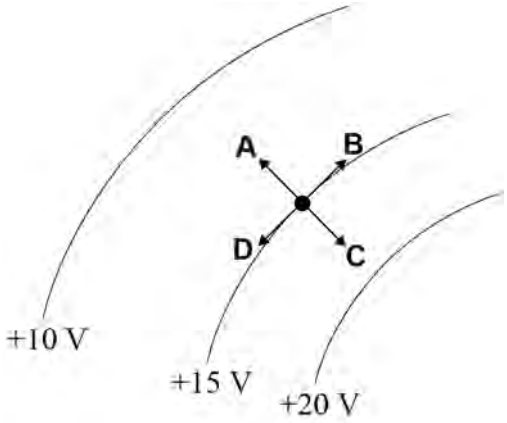
D $\frac{V}{qm}$ ⬭

Do not write outside the box

1 4 The diagram shows an electron in an electric field represented by equipotentials.

Which arrow shows the direction of the electric force on the electron?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

1 5 The diagram shows point charges **Q** and **q**.

Q and **q** have charges of opposite sign.

The magnitude of the charge of **Q** is greater than the magnitude of the charge of **q**.

The electric field strength is zero at one of the points **A**, **B**, **C** or **D**.

At which point is the electric field strength zero?

[1 mark]

A ⬭

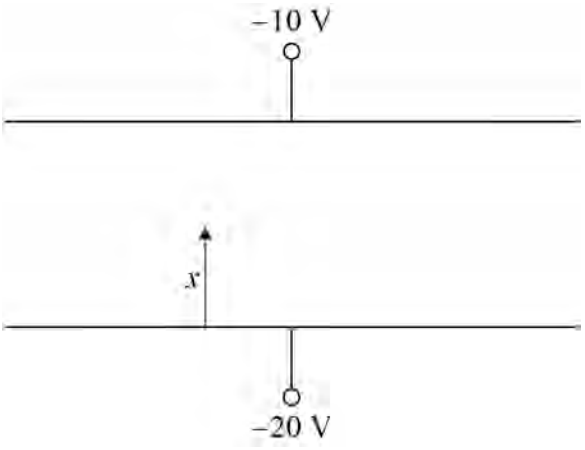
B ⬭

C ⬭

D ⬭

Do not write outside the box

1 6 The diagram shows two parallel conducting plates at potentials of -20 V and -10 V.

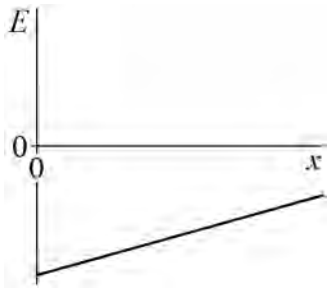


The displacement x is measured from the bottom (-20 V) plate.

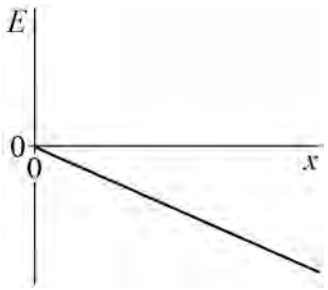
Which graph shows how the electric field strength E varies with x?

[1 mark]

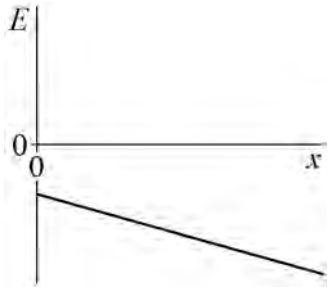
A



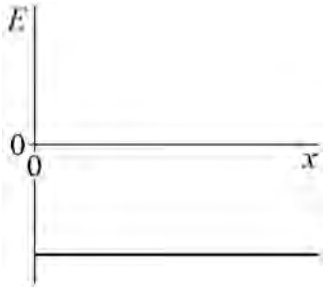
B



C



D



A ⬭

B ⬭

C ⬭

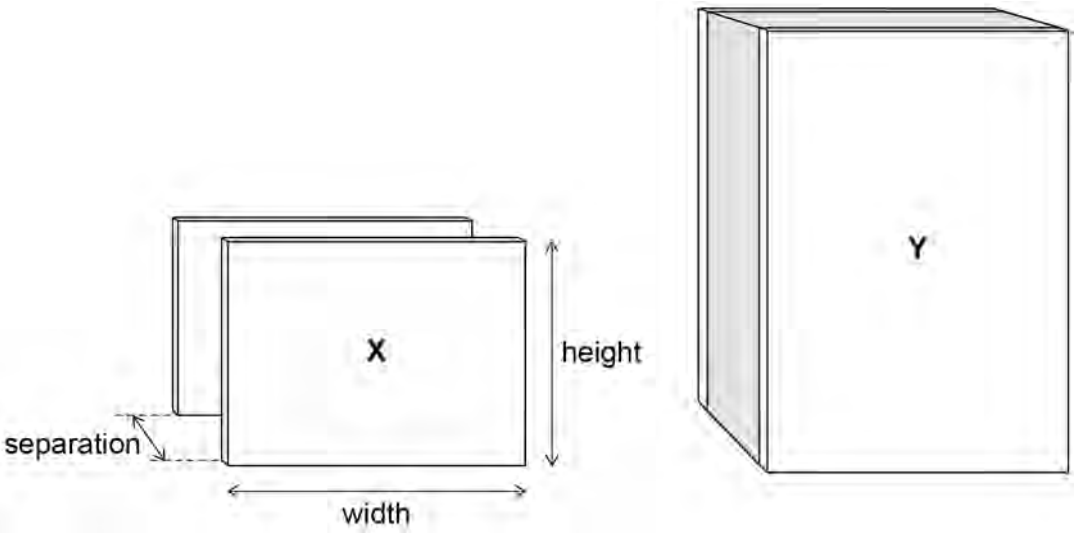
D ⬭

Do not write outside the box

1 7 A parallel-plate capacitor **X** with the plates separated by air has a capacitance of $100\ \mu F$.

Another parallel-plate capacitor **Y** has plates that are double the height of the plates of **X**.

The plates of **Y** have the same separation and the same width as the plates of **X**.
The space between the plates of **Y** is filled with a material of dielectric constant 3.0



What is the capacitance of **Y**?

[1 mark]

A $67\ \mu F$ ⬭

B $150\ \mu F$ ⬭

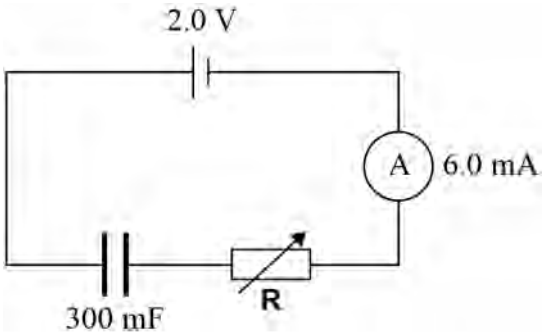
C $600\ \mu F$ ⬭

D $1200\ \mu F$ ⬭

Turn over for the next question

Do not write outside the box

1 8 A capacitor is initially uncharged and is then charged using a constant current. This is achieved by reducing the resistance of a variable resistor **R** as the charge on the capacitor increases.



The capacitor has a capacitance of $300\ \text{mF}$ and is fully charged in a time $t = 100\ \text{s}$.
The cell has an emf of $2.0\ \text{V}$ and negligible internal resistance.
The charging current is $6.0\ \text{mA}$.

What is the resistance of **R** at $t = 30\ \text{s}$?

[1 mark]

A $58\ \Omega$ ⬭

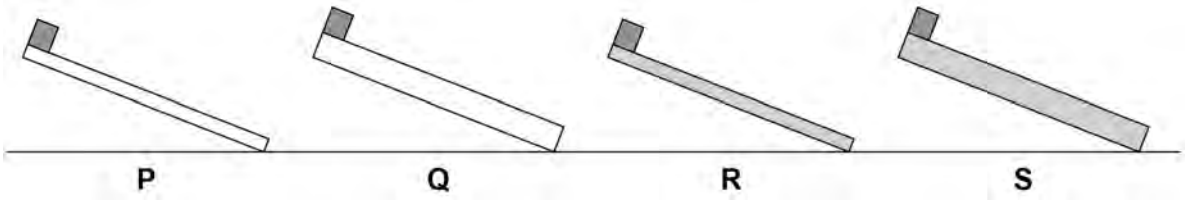
B $100\ \Omega$ ⬭

C $233\ \Omega$ ⬭

D $333\ \Omega$ ⬭

Do not write outside the box

1 9 Four identical magnets slide down four ramps **P**, **Q**, **R** and **S** of the same length and width. The slope of each ramp is the same.



The table shows the resistivity and thickness of each ramp.

	Resistivity	**Thickness**
P	ρ	d
Q	ρ	$2d$
R	2ρ	d
S	2ρ	$2d$

Friction is the same for each ramp.
The time t for each magnet to slide down the entire length of its ramp is measured.

Which row shows the ramp with the smallest t and the ramp with the largest t?

[1 mark]

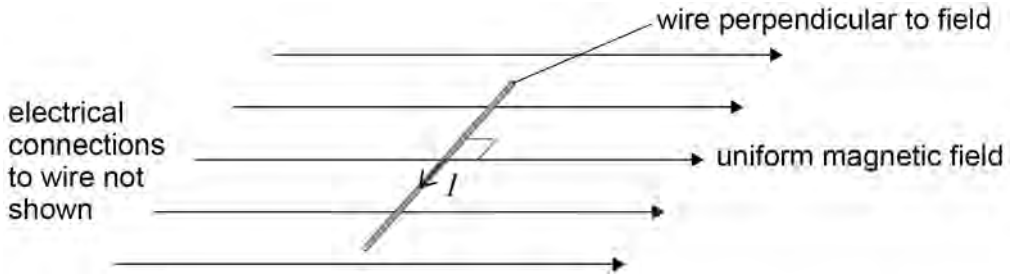
	Smallest *t*	**Largest *t***	
A	**R**	**S**	⬭
B	**R**	**Q**	⬭
C	**Q**	**S**	⬭
D	**Q**	**P**	⬭

Turn over ►

Do not write outside the box

2 0 A horizontal wire is perpendicular to a horizontal uniform magnetic field of flux density B. The wire has length L and diameter d. The current in the wire is I.

The magnetic force acting on the wire is equal in magnitude and opposite in direction to the weight of the wire so that the wire is supported.



The wire is replaced with a second wire in the same orientation and position.

The second wire is made of the same material and has length $\frac{L}{2}$ and diameter $2d$.

What current is required to support the second wire?

[1 mark]

A $\frac{I}{2}$ ⬭

B I ⬭

C $2I$ ⬭

D $4I$ ⬭

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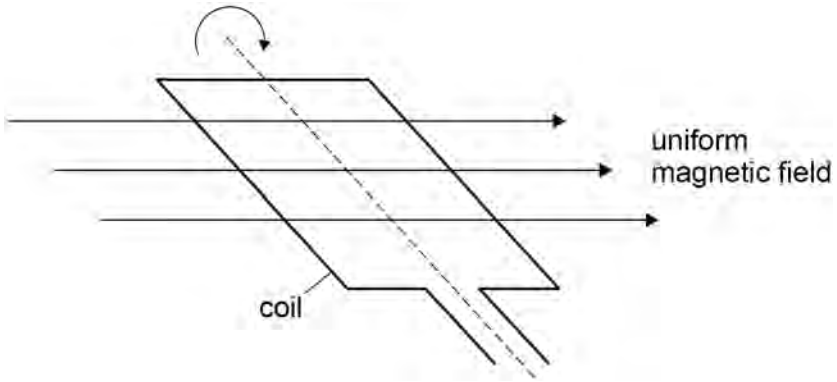
2 1 A coil rotates at a constant angular speed in a uniform horizontal magnetic field.
The diagram shows the instant when the plane of the coil is horizontal.



cross-sectional area of coil = 20×10^{-3} m^2
number of turns in coil = 500 turns
magnetic flux density = 50 mT
frequency of rotation = 50 Hz

What is the mean induced emf, in V, as the coil rotates through π rad from the position shown?

[1 mark]

A 0 ⬭

B 0.50 ⬭

C 100 ⬭

D 157 ⬭

Turn over for the next question

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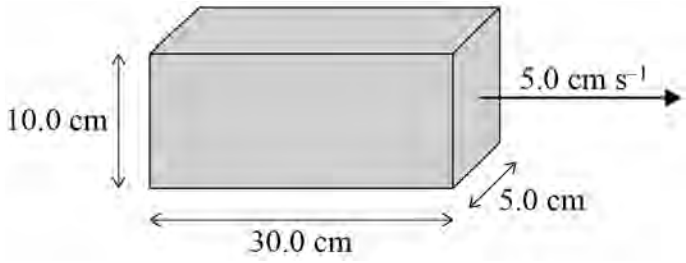
2 2 A metal block has dimensions $30.0\ \text{cm} \times 10.0\ \text{cm} \times 5.0\ \text{cm}$ as shown.



The block is moved at a constant horizontal velocity of $5.0\ \text{cm s}^{-1}$ through a uniform vertical magnetic field so that an emf is induced across the block.

The magnetic field has a magnetic flux density of $2.5\ \text{mT}$.

What is the induced emf?

[1 mark]

A $150\ \mu\text{V}$ ⬭

B $37.5\ \mu\text{V}$ ⬭

C $12.5\ \mu\text{V}$ ⬭

D $6.25\ \mu\text{V}$ ⬭

2 3 A transformer is used to connect an ac power supply to a $100\ \text{W}$ filament lamp.

When the lamp is operating at its rated power, the power supply has a peak potential difference of $50\ \text{V}$ and supplies a peak current of $5.0\ \text{A}$.

What is the efficiency of the transformer?

[1 mark]

A 80% ⬭

B 57% ⬭

C 40% ⬭

D 28% ⬭

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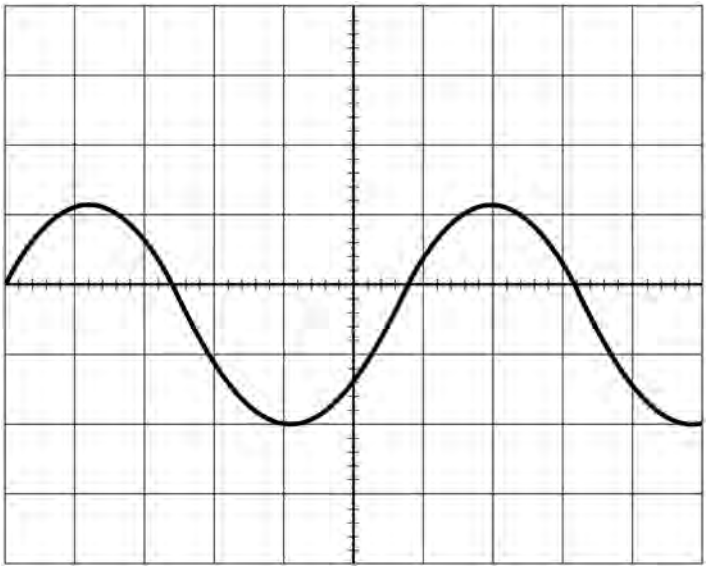
2 4 The diagram shows an ac signal displayed on an oscilloscope screen.



The time base is set to $5\ \mu s\ div^{-1}$.

What is the frequency of the signal?

[1 mark]

A 34 kHz ⬭

B 37 kHz ⬭

C 42 kHz ⬭

D 83 kHz ⬭

2 5 A radiation meter is placed at a distance d from a source of gamma radiation.
The corrected count rate is 800 counts per second.

When the radiation meter is moved a further 10 cm from the source the corrected count rate is 600 counts per second.

What is d?

[1 mark]

A 8.7 cm ⬭

B 13 cm ⬭

C 30 cm ⬭

D 64 cm ⬭

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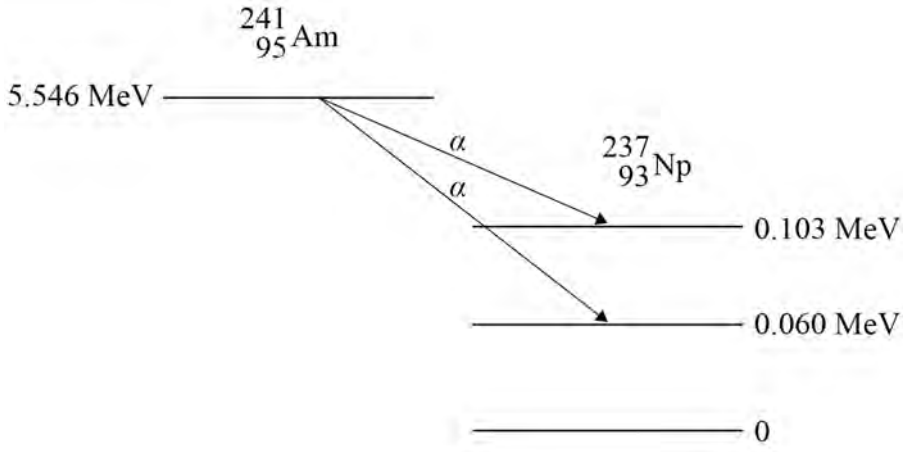
2 6 $^{241}_{95}\text{Am}$ decays to one of two excited states of $^{237}_{93}\text{Np}$ by emitting an alpha particle.

The excited $^{237}_{93}\text{Np}$ nucleus then decays with the emission of a gamma photon.

The diagram shows the energy levels involved in the decay of $^{241}_{95}\text{Am}$.



What is the energy of the emitted gamma photon that has the shortest wavelength?

[1 mark]

A 5.546 MeV ⬭

B 5.486 MeV ⬭

C 0.103 MeV ⬭

D 0.043 MeV ⬭

2 7 Which decay produces an atom with electrons in excited states?

[1 mark]

A $^{223}_{88}\text{Ra} \rightarrow {}^{219}_{86}\text{Rn} + {}^{4}_{2}\alpha$ ⬭

B $^{90}_{38}\text{Sr} \rightarrow {}^{90}_{39}\text{Y} + \text{e}^{-} + \overline{\nu}_{\text{e}}$ ⬭

C $^{23}_{12}\text{Mg} \rightarrow {}^{23}_{11}\text{Na} + \text{e}^{+} + \nu_{\text{e}}$ ⬭

D $^{123}_{53}\text{I} + \text{e}^{-} \rightarrow {}^{123}_{52}\text{Te} + \nu_{\text{e}}$ ⬭

Do not write outside the box

2 8 Polonium-210 decays into lead-206 by emitting an alpha particle.

mass of nucleus of polonium-210 = 209.983 u
mass of nucleus of lead-206 = 205.975 u
mass of alpha particle = 4.003 u

Assume that the recoil speed of the lead nucleus is negligible.

What is the kinetic energy of the emitted alpha particle?

[1 mark]

A 5.0 meV ⬭

B 4.0 MeV ⬭

C 4.7 MeV ⬭

D 3.7 GeV ⬭

2 9 Which is **not** a use of water in the nuclear industry?

[1 mark]

A to absorb neutrons released from fission ⬭

B to cool a nuclear reactor ⬭

C to shield radiation produced by nuclear waste ⬭

D to slow neutrons to thermal speeds ⬭

3 0 The purpose of a moderator in a thermal nuclear reactor is to:

[1 mark]

A absorb neutrons to reduce the reaction rate. ⬭

B add neutrons to start the chain reaction. ⬭

C remove heat from the reactor. ⬭

D slow neutrons to thermal speeds. ⬭

Turn over for the next question

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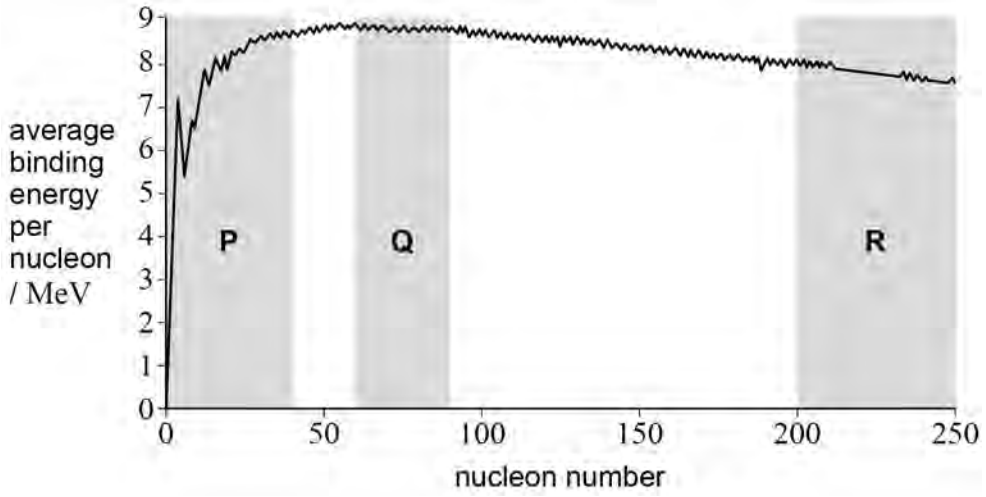
3 1 The plot of average binding energy per nucleon is shown.
P, **Q** and **R** indicate regions of the plot.



In which region or regions labelled on the plot do nuclei undergo fission to release energy?
[1 mark]

A **P** only ⬭

B **P** and **R** ⬭

C **Q** and **R** ⬭

D **R** only ⬭

25

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