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 1 June 2020 Afternoon Time allowed: 2 hours

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

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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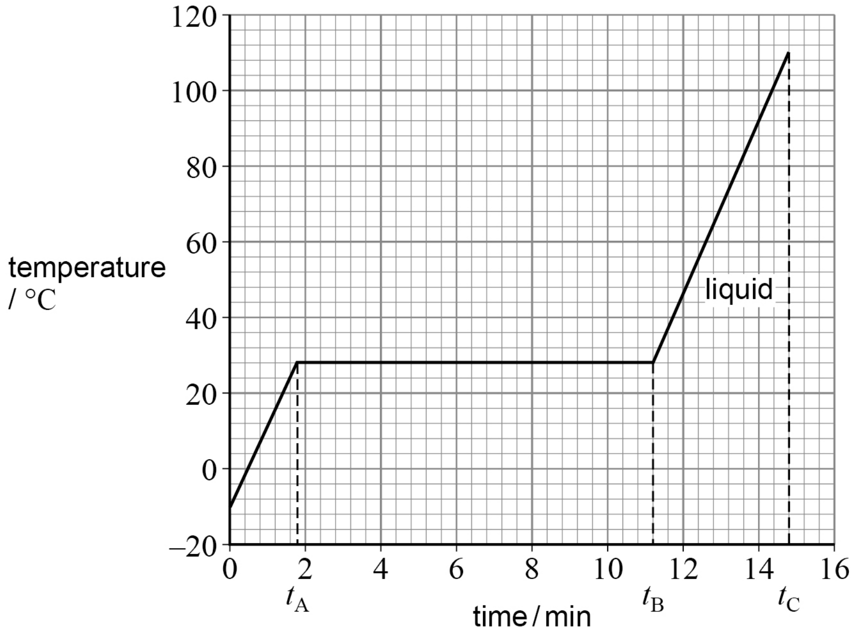
Section A

Answer **all** questions in this section.

0 1 A perfectly insulated flask contains a sample of metal **M** at a temperature of –10 °C.

Figure 1 shows how the temperature of the sample changes when energy is transferred to it at a constant rate of 35 W.

Figure 1



0 1 . 1 State the melting temperature of **M**.

[1 mark]

temperature = ______________________ °C

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0 1 . 2 Explain how the energy transferred to the sample changes the arrangement of the atoms during the time interval t_A to t_B.

[1 mark]

0 1 . 3 State what happens to the potential energy of the atoms and to the kinetic energy of the atoms during the time interval t_A to t_B.

[2 marks]

0 1 . 4 Describe how the motion of the atoms changes during the time interval t_B to t_C.

[1 mark]

Question 1 continues on the next page

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0 1 . 5 The sample has a mass of 0.25 kg.

Determine the specific heat capacity of **M** when in the liquid state.
State an appropriate SI unit for your answer.

[3 marks]

specific heat capacity = ____________________ unit = ______________

0 1 . 6 **Table 1** shows the specific latent heats of fusion l for elements that are liquid at similar temperatures to **M**.

Table 1

Element	Caesium	Gallium	Mercury	Rubidium
l / kJ kg^{-1}	16	80	11	26

M is known to be one of the elements in **Table 1**.

Identify **M**.

[2 marks]

M = ____________________

10

Do not write outside the box

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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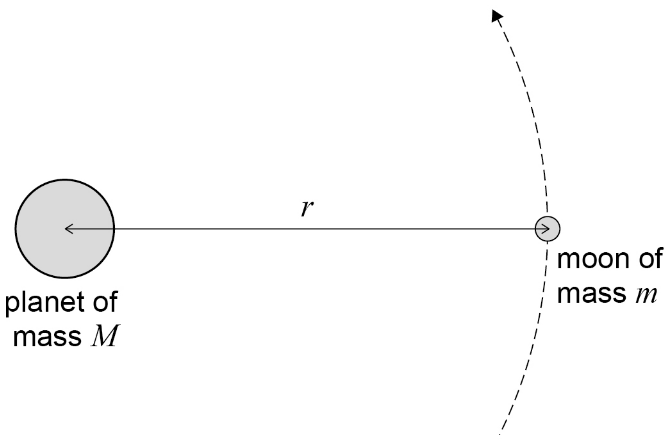
0 2 **Figure 2** shows a moon of mass m in a circular orbit of radius r around a planet of mass M, where $m << M$.

Figure 2



The moon has an orbital period T.
T is related to r by

$$T^2 = kr^3$$

where k is a constant for this planet.

0 2 . 1 Show that $k = \dfrac{4\pi^2}{GM}$

[3 marks]

Do not write outside the box

Table 2 gives data for two of the moons of the planet Uranus.

Table 2

Name	***T* / days**	***r* / m**
Miranda	1.41	1.29×10^8
Umbriel	4.14	**X**

0 2 . 2 Calculate the orbital radius **X** of Umbriel.

[2 marks]

orbital radius = ____________________ m

0 2 . 3 Calculate the mass of Uranus.

[3 marks]

mass = ____________________ kg

Question 2 continues on the next page

Table 3 gives data for three more moons of Uranus.

Table 3

Name	Mass / kg	Diameter / m
Ariel	1.27×10^{21}	1.16×10^{6}
Oberon	3.03×10^{21}	1.52×10^{6}
Titania	3.49×10^{21}	1.58×10^{6}

0 2 . 4 Deduce which moon in **Table 3** has the greatest escape velocity for an object on its surface.
Assume the effect of Uranus is negligible.

[3 marks]

Do not write outside the box

0 2 . 5 A spring mechanism can project an object vertically to a maximum height of $1.0\ \mathrm{m}$ from the surface of the Earth.

Determine whether the same mechanism could project the same object vertically to a maximum height greater than $100\ \mathrm{m}$ when placed on the surface of Ariel.

[3 marks]

14

Turn over for the next question

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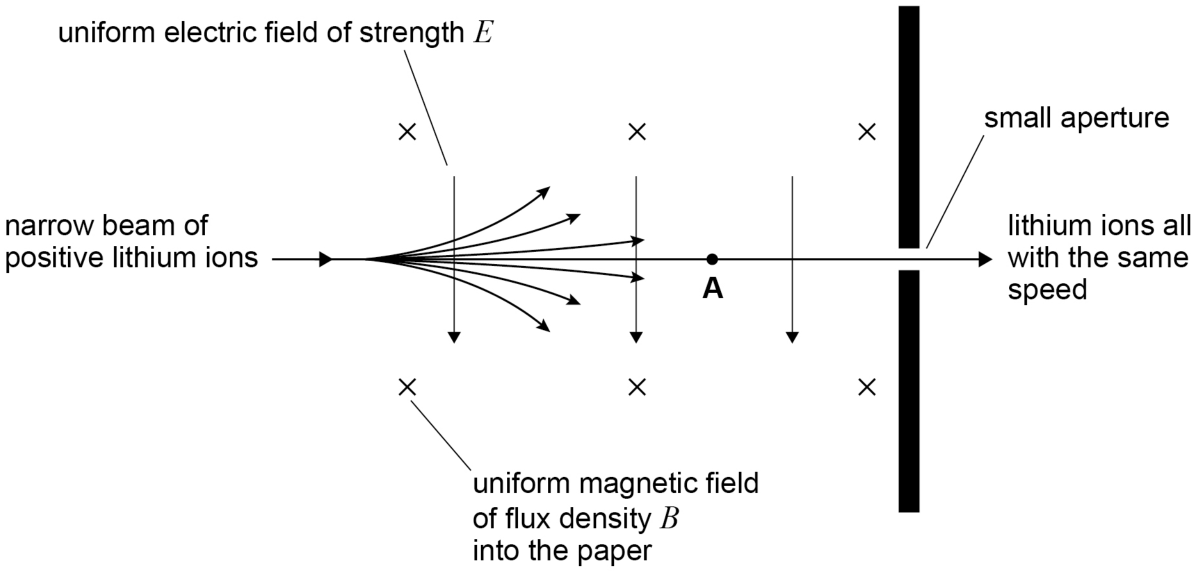
0 3 Mass spectrometers are used to measure the masses of ions.

Figure 3 shows one part of a mass spectrometer.

Figure 3



A narrow beam consists of positive lithium ions travelling at different speeds.
The beam enters a region where there is an electric field and a magnetic field.
The directions of the uniform electric field of strength E and the uniform magnetic field of flux density B are shown on **Figure 3**.

Most ions are deflected from their original path.
Lithium ions that travel at one particular speed are not deflected, and pass through the small aperture.

0 3 . 1 The positive lithium ion **A** in **Figure 3** moves at a speed v.

Draw **two** labelled arrows on **Figure 3** to show the directions of the electric force F_E and the magnetic force F_M acting on **A**.

[1 mark]

Do not write outside the box

0 3 . 2 Lithium ions travelling at $1.5 \times 10^5 \text{ m s}^{-1}$ pass through the small aperture.

Calculate E.

$B = 0.12 \text{ T}$

[2 marks]

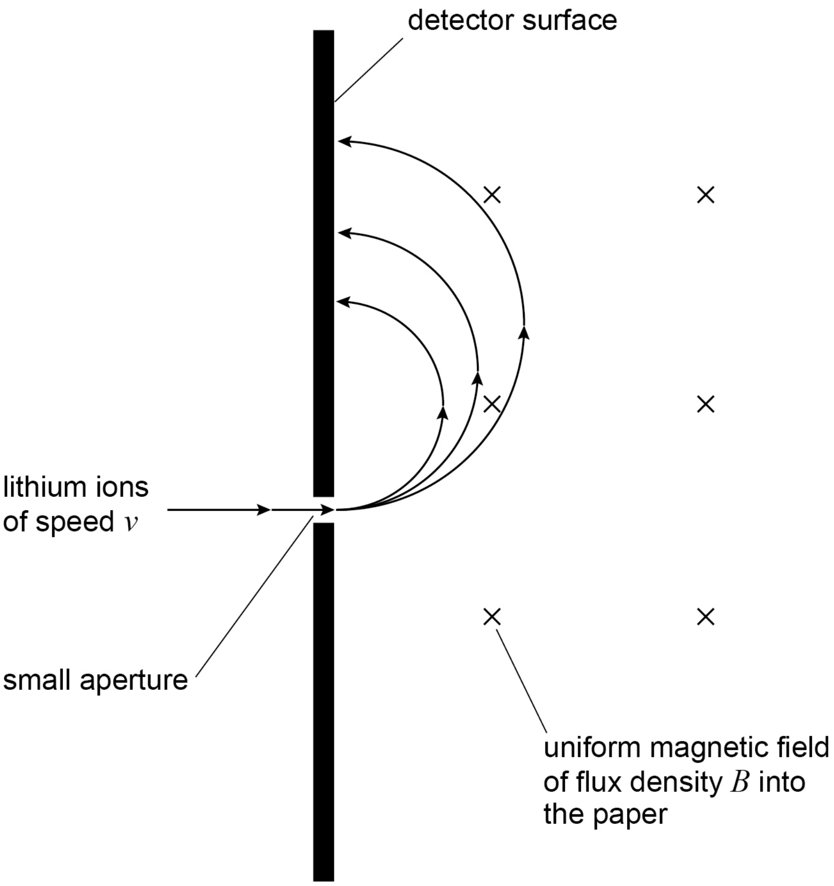
$E =$ ____________________ V m^{-1}

Question 3 continues on the next page

Do not write outside the box

0 3 . 3 Ions that pass through the small aperture enter a second uniform magnetic field of flux density B.
Ions of different mass are separated because they follow different paths as shown in **Figure 4**.

Figure 4



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Ions of mass m and charge q travelling at speed v follow a circular path in the uniform magnetic field.

Show that the radius r of the circular path is given by

$$r = \frac{mv}{Bq}$$

[1 mark]

0 3 . 4 The ions of different mass are deflected and strike the detector surface at different distances from the small aperture as shown in **Figure 4**.

A singly-charged lithium ion ($^{6}_{3}Li^{+}$) passes through the small aperture.

Calculate the distance between the small aperture and the point where this ion strikes the detector surface.

$v = 1.5 \times 10^{5}$ m s^{-1}

$B = 0.12$ T

mass of $^{6}_{3}Li^{+}$ ion $= 1.0 \times 10^{-26}$ kg

[2 marks]

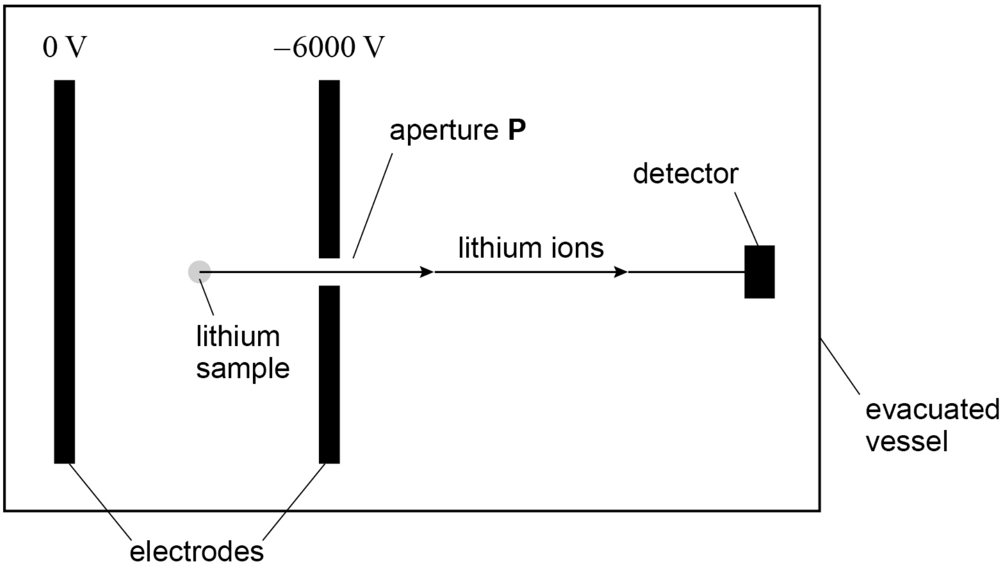
distance = ____________________ m

Question 3 continues on the next page

Do not write outside the box

0 3 . 5 **Figure 5** shows a different type of mass spectrometer working with lithium ions.

Figure 5



A stationary $^{7}_{3}\mathrm{Li}^{+}$ ion in the lithium sample is at the mid-point between the parallel electrodes. The $^{7}_{3}\mathrm{Li}^{+}$ ion accelerates towards aperture **P**.

Determine the speed of the ion when it emerges through aperture **P**.

mass of $^{7}_{3}\mathrm{Li}^{+}$ ion $= 1.2 \times 10^{-26}$ kg

[3 marks]

speed = ______________________ $\mathrm{m\ s^{-1}}$

Do not write outside the box

0 3 . 6 ${}^{6}_{3}\mathrm{Li}^{+}$ and ${}^{7}_{3}\mathrm{Li}^{+}$ ions are produced in the sample simultaneously and travel a distance L from aperture **P** to the detector.
For each type of ion, the time interval between production and detection is measured.

Discuss how the masses of the ions can be deduced from the measurement of these time intervals.

[2 marks]

11

Turn over for the next question

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There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED

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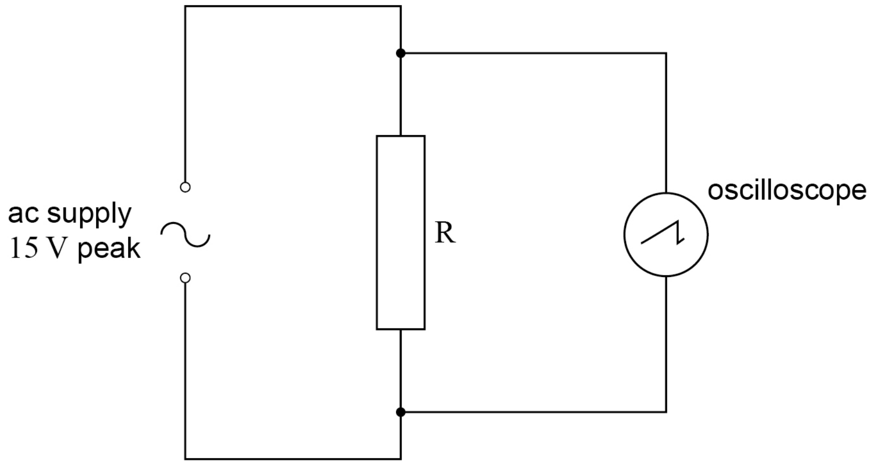
0 4 **Figure 6** shows an oscilloscope connected across resistor R which is in series with an ac supply. The supply provides a sinusoidal output of peak voltage 15 V.

Figure 6



0 4 . 1 Calculate the rms voltage of the supply.

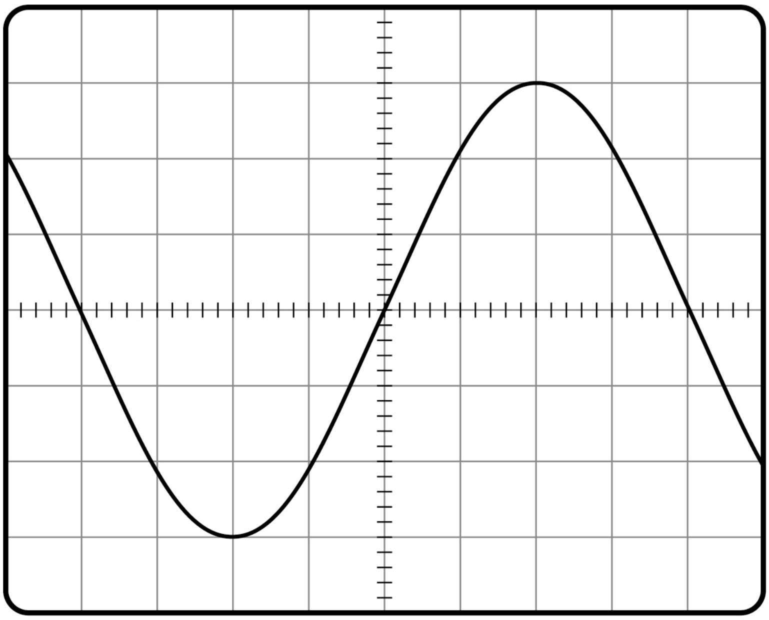
[1 mark]

rms voltage = ____________________ V

Question 4 continues on the next page

Figure 7 shows the trace of the waveform displayed on the oscilloscope.

Figure 7



0 4 . 2 Determine the y-voltage gain of the oscilloscope used for **Figure 7**.

[1 mark]

y-voltage gain = ______________________ $\mathrm{V\ div^{-1}}$

0 4 . 3 A dc supply gives the same rate of energy dissipation in R as the ac supply in **Figure 6**.

Draw the trace of the output of the dc supply on **Figure 7**.
The oscilloscope settings remain the same.

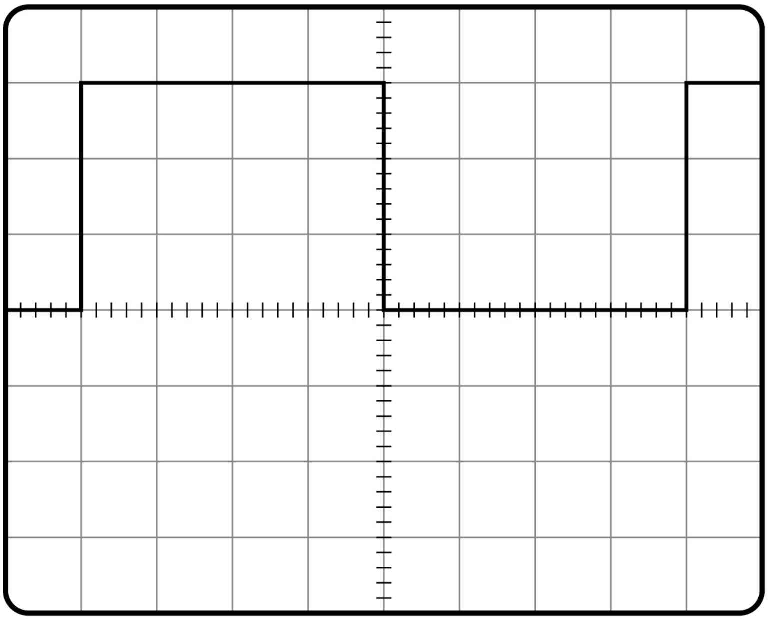
[1 mark]

Do not write outside the box

0 4 . 4 The ac supply shown in **Figure 6** is replaced with a square-wave generator operating between 0 and $+15$ V.

Figure 8 shows the trace of the new waveform displayed on the oscilloscope.
The time-base is set to 5.0×10^{-4} s div^{-1}.

Figure 8



Calculate the frequency of the square waves.

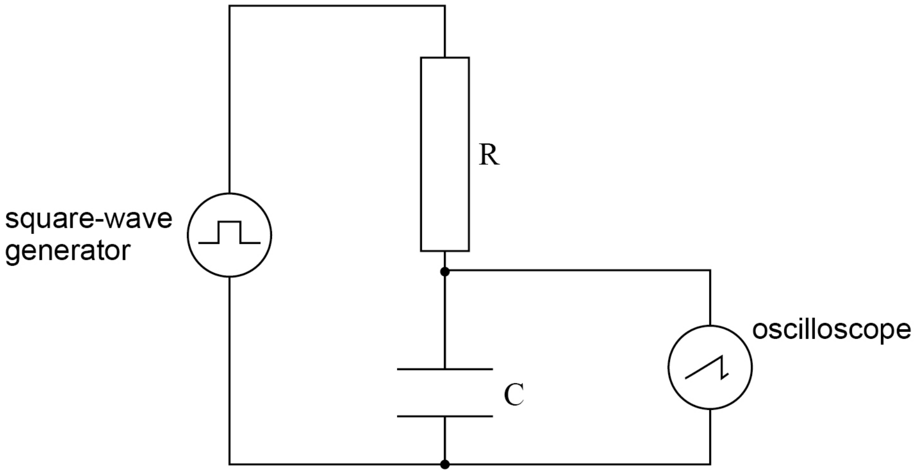
[1 mark]

frequency = ____________________ Hz

Question 4 continues on the next page

0 4 . 5 **Figure 9** shows the arrangement with the square-wave generator connected to an RC circuit.
A capacitor C is placed in series with the resistor R.
The oscilloscope is connected across the capacitor C.

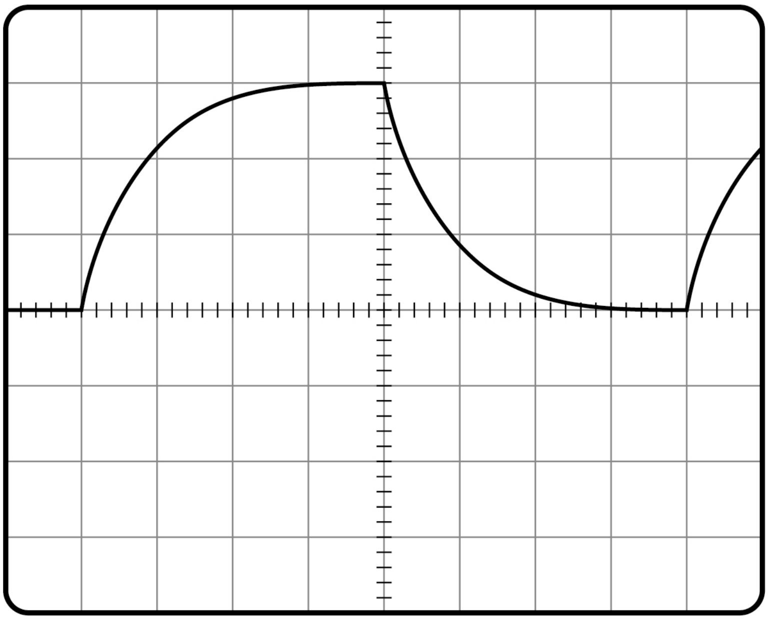
Figure 9



The capacitor charges and discharges.

Figure 10 shows the trace of the waveform displayed on the oscilloscope.
The settings of the oscilloscope remain the same as in Question **04.4**.

Figure 10



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Deduce the time constant for the RC circuit, explaining each step of your method.

[3 marks]

time constant = ______________________ s

0 4 . 6 State and explain a change to **one** control setting on the oscilloscope that would reduce the uncertainty in the value of the time constant.

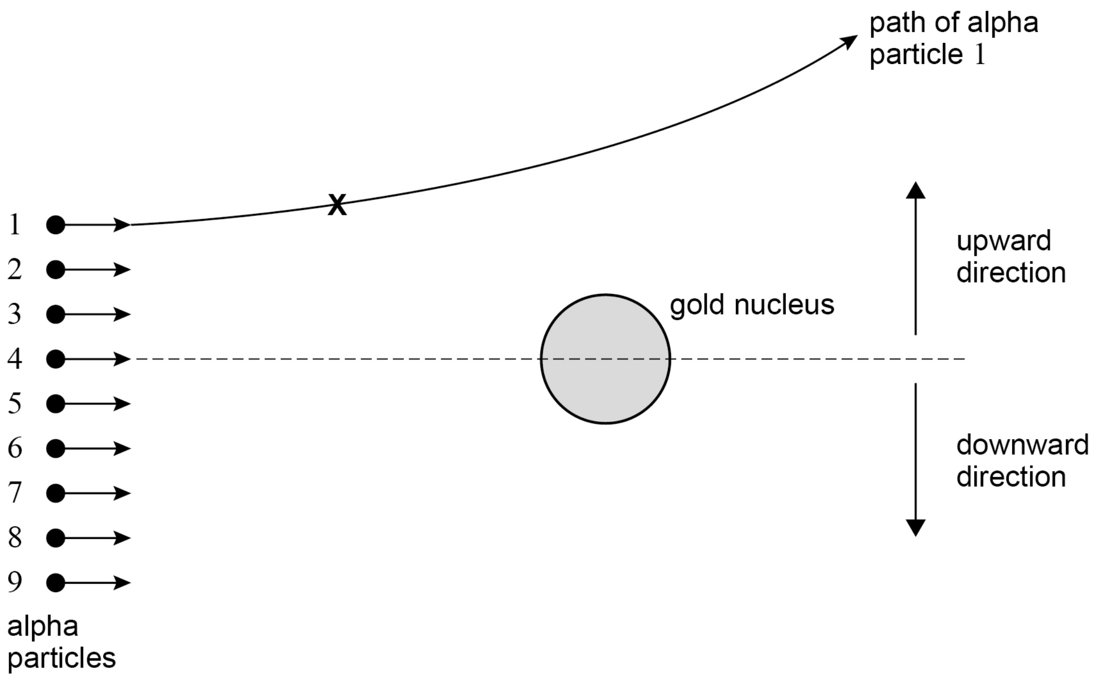
[2 marks]

9

Do not write outside the box

0 5 **Figure 11** shows alpha particles all travelling in the same direction at the same speed. The alpha particles are scattered by a gold ($^{197}_{79}\mathrm{Au}$) nucleus.
The path of alpha particle **1** is shown.

Figure 11



0 5 . 1 State the fundamental force involved when alpha particle **1** is scattered by the nucleus in **Figure 11**.

[1 mark]

---

0 5 . 2 Draw an arrow at position **X** on **Figure 11** to show the direction of the rate of change in momentum of alpha particle **1**

[1 mark]

Do not write outside the box

0 5 . 3 Suggest **one** of the alpha particles in **Figure 11** which may be deflected downwards with a scattering angle of $90°$

Justify your answer.

[2 marks]

alpha particle number = ____________________

____

____

____

____

0 5 . 4 Alpha particle **4** comes to rest at a distance of 5.5×10^{-14} m from the centre of the $^{197}_{79}\mathrm{Au}$ nucleus.

Calculate the speed of alpha particle **4** when it is at a large distance from the nucleus. Ignore relativistic effects.

mass of alpha particle = 6.8×10^{-27} kg

[3 marks]

speed = ____________________ $\mathrm{m\ s^{-1}}$

Question 5 continues on the next page

Do not write outside the box

0 5 . 5 The nuclear radius of $^{197}_{79}\mathrm{Au}$ is 6.98×10^{-15} m.

Calculate the nuclear radius of $^{107}_{47}\mathrm{Ag}$.

[2 marks]

radius = ______________________ m

0 5 . 6 All nuclei have approximately the same density.

State **one** conclusion about the nucleons in a nucleus that can be deduced from this fact.

[1 mark]

____

____

____

____

10

Do not write outside the box

0 6 A thermal nuclear reactor uses enriched uranium as its fuel.
This is fuel in which the ratio of U-235 to U-238 has been artificially increased from that found in naturally-occurring ore.

0 6 . 1 Describe what happens when neutrons interact with U-235 and U-238 nuclei in a thermal nuclear reactor.

[3 marks]

0 6 . 2 The amounts of U-235 and U-238 in the ore decrease due to radioactive decay at different rates.

A sample of uranium ore today contains 993 g of U-238
The mass of U-238 in this sample was greater 2.00×10^{9} years ago.

Show that the mass of U-238 in this sample at that time was about 1.4 kg.

decay constant of U-238 = 1.54×10^{-10} year^{-1}

[2 marks]

Question 6 continues on the next page

Turn over ►

Do not write outside the box

06.3 A thermal nuclear reactor requires a minimum of 3.0% of its uranium mass to be U-235

The ratio of U-235 to U-238 in the ore has changed over time.
2.00×10^9 years ago, the sample in Question **06.2** contained 52 g of U-235

Deduce whether the sample had a high enough U-235 content to be used in a reactor 2.00×10^9 years ago.

[1 mark]

6

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 When an ideal gas at a temperature of $27\ ^\circ\mathrm{C}$ is suddenly compressed to one quarter of its volume, the pressure increases by a factor of 7

What is the new temperature of the gas?

[1 mark]

A $15\ ^\circ\mathrm{C}$ ○

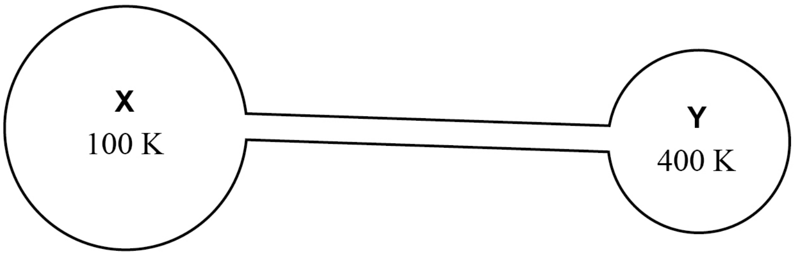
B $47\ ^\circ\mathrm{C}$ ○

C $171\ ^\circ\mathrm{C}$ ○

D $252\ ^\circ\mathrm{C}$ ○

Turn over for the next question

0 8 The diagram shows two flasks **X** and **Y** connected by a thin tube of negligible volume.



The flasks contain an ideal gas.

The volume of **X** is twice the volume of **Y**. When **X** is at a temperature of $100\ \mathrm{K}$ and **Y** is at a temperature of $400\ \mathrm{K}$ there is no net transfer of particles between the flasks.

X contains gas of mass m.

What is the mass of gas in **Y**?

[1 mark]

A $\frac{m}{8}$ ☐

B $\frac{m}{2}$ ☐

C $2m$ ☐

D $8m$ ☐

0 9 A sample **P** of an ideal gas contains 1 mol at an absolute temperature T.

A second sample **Q** of an ideal gas contains $\frac{2}{3} \text{ mol}$ at an absolute temperature $2T$.

The total molecular kinetic energy of **P** is E.

What is the total molecular kinetic energy of **Q**?

[1 mark]

A $\frac{2}{3}E$

B $\frac{3}{4}E$

C $\frac{4}{3}E$

D $\frac{3}{2}E$

1 0 An ideal gas is contained in a cubical box of side length a.
The gas has N molecules each of mass m.

What is the pressure exerted by the gas on the walls of the box?

[1 mark]

A $\frac{mNa^3}{2} \times c_{\text{rms}}^2$

B $\frac{mNa^2}{2} \times c_{\text{rms}}^2$

C $\frac{mN}{3a^2} \times c_{\text{rms}}^2$

D $\frac{mN}{3a^3} \times c_{\text{rms}}^2$

Do not write outside the box

1 1 Which statement is true about an experiment where Brownian motion is demonstrated using smoke particles in air?

[1 mark]

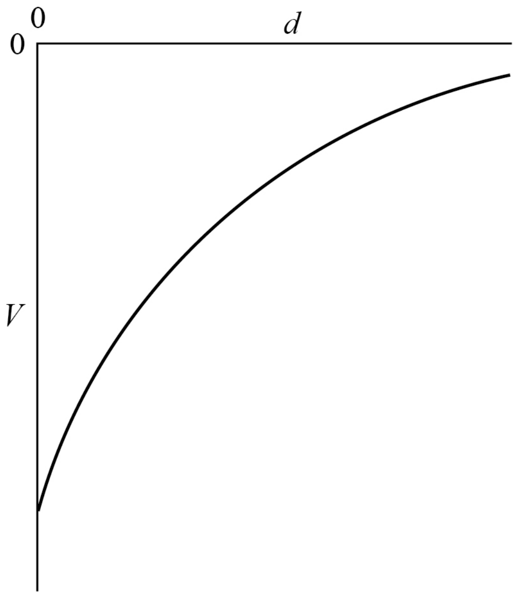
A The experiment makes it possible to see the motion of air molecules. ⬭

B The motion is caused by the collisions of smoke particles with each other. ⬭

C The motion is caused by collisions between air molecules and smoke particles. ⬭

D The motion occurs because air is a mixture of gases and the molecules have different masses. ⬭

1 2 The graph shows how the gravitational potential V varies with the vertical distance d from the surface of the Earth.



What does the gradient of the graph represent at the surface of the Earth?

[1 mark]

A potential energy ⬭

B mass of the Earth ⬭

C magnitude of the gravitational constant ⬭

D magnitude of the gravitational field strength ⬭

Do not write outside the box

1 3 What is the angular speed of a satellite in a geostationary orbit around the Earth?

[1 mark]

A 1.2×10^{-5} rad s^{-1} ⬭

B 7.3×10^{-5} rad s^{-1} ⬭

C 4.4×10^{-3} rad s^{-1} ⬭

D 2.6×10^{-1} rad s^{-1} ⬭

1 4 Two fixed charges of magnitude $+Q$ and $+3Q$ repel each other with a force F.
An additional charge of $-2Q$ is given to each charge.

What are the magnitude and the direction of the force between the charges?

[1 mark]

	Magnitude of force	**Direction of force**	
A	$\frac{F}{3}$	repulsive	⬭
B	$5F$	attractive	⬭
C	$5F$	repulsive	⬭
D	$\frac{F}{3}$	attractive	⬭

Turn over for the next question

Do not write outside the box

1 5 At a distance L from a fixed point charge, the electric field strength is E and the electric potential is V.

What are the electric field strength and the electric potential at a distance $3L$ from the charge?

[1 mark]

	Electric field strength	Electric potential	
A	$\frac{E}{3}$	$\frac{V}{9}$	⬭
B	$\frac{E}{3}$	$\frac{V}{3}$	⬭
C	$\frac{E}{9}$	$\frac{V}{3}$	⬭
D	$\frac{E}{9}$	$\frac{V}{9}$	⬭

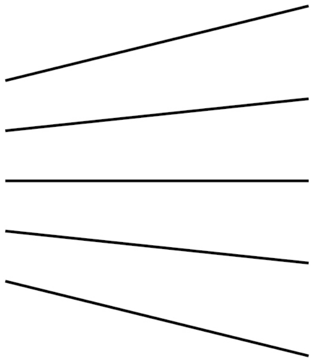
Do not write outside the box

1 6 Which diagram shows lines of equipotential in steps of equal potential difference near an isolated point charge?

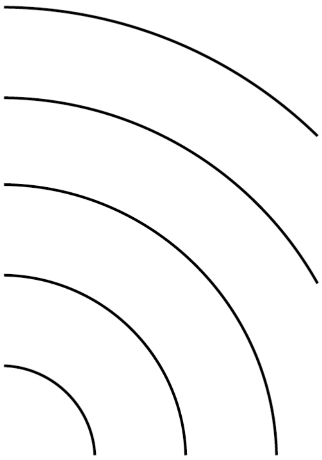
[1 mark]

A

B



C



D

A ⬭

B ⬭

C ⬭

D ⬭

Turn over ►

1 7 A positive charge of 2.0×10^{-4} C is placed in an electric field at a point where the potential is +500 V.

What is the potential energy of the system?

[1 mark]

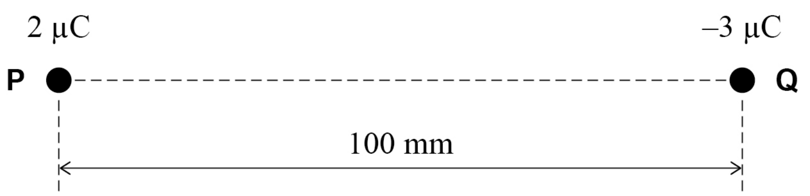
A 1.0×10^{-1} J ○

B 1.0×10^{-1} J C^{-1} ○

C 4.0×10^{-7} J ○

D 4.0×10^{-7} J C^{-1} ○

1 8 Two charges **P** and **Q** are 100 mm apart.
X is a point on the line between **P** and **Q** where the electric potential is 0 V.



What is the distance from **P** to **X**?

[1 mark]

A 33 mm ○

B 40 mm ○

C 60 mm ○

D 67 mm ○

1 9 An uncharged capacitor is connected to a power supply which supplies a constant current of $10\ \mu A$.

After $100\ ms$, the potential difference across the capacitor is $5.0\ kV$.

What is the capacitance of the capacitor?

[1 mark]

A 2.0×10^{-10} F

B 4.0×10^{-10} F

C 2.5×10^{9} F

D 5.0×10^{9} F

2 0 When a parallel-plate capacitor is connected across a battery, the energy stored in the capacitor is W.

The battery remains connected as the distance between the capacitor plates is halved.

What is the energy now stored in the capacitor?

[1 mark]

A $0.5W$

B W

C $2W$

D $4W$

Turn over for the next question

Turn over ►

Do not write outside the box

2 1 A parallel-plate capacitor is made using a sheet of dielectric material between, and in contact with, two plates.
The properties of four sheets of dielectric material are shown.

Which sheet will produce the maximum capacitance?

[1 mark]

Sheet	Relative permittivity	Thickness / mm
A	2	0.40
B	3	0.90
C	4	1.0
D	6	1.6

2 2 A $10\ \mu F$ capacitor stores $4.5\ mJ$ of energy.
It then discharges through a $25\ \Omega$ resistor.

What is the maximum current during the discharge of the capacitor?

[1 mark]

A 1.2 A

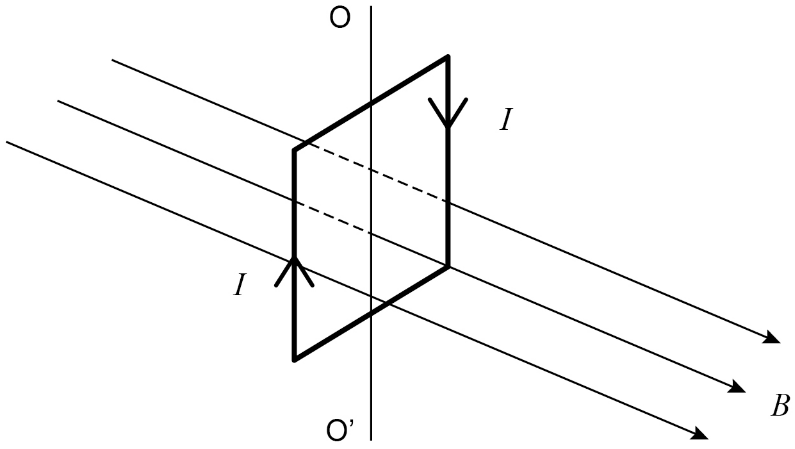
B 18 A

C 30 A

D 36 A

Do not write outside the box

2 3 The diagram shows a current I in a vertical square coil.
The coil can rotate about an axis OO'.
The plane of the coil is at right angles to a uniform horizontal magnetic field of flux density B.



Which statement is correct?

[1 mark]

A The forces on the vertical sides of the coil are equal in magnitude and opposite in direction. ⬭

B A non-zero couple acts on the coil. ⬭

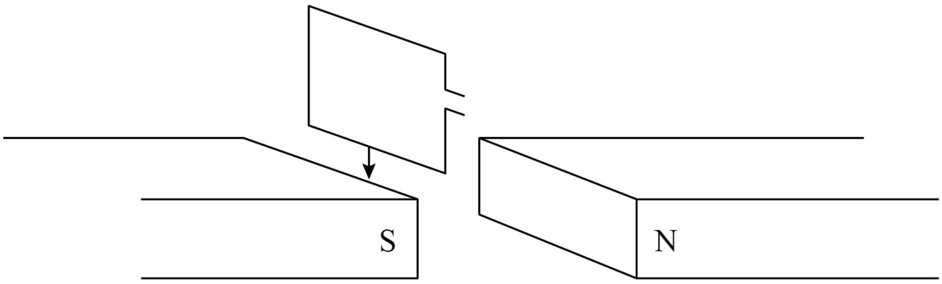
C No forces act on the horizontal sides of the coil. ⬭

D The forces on all sides of the coil act toward the centre of the coil. ⬭

Turn over for the next question

Do not write outside the box

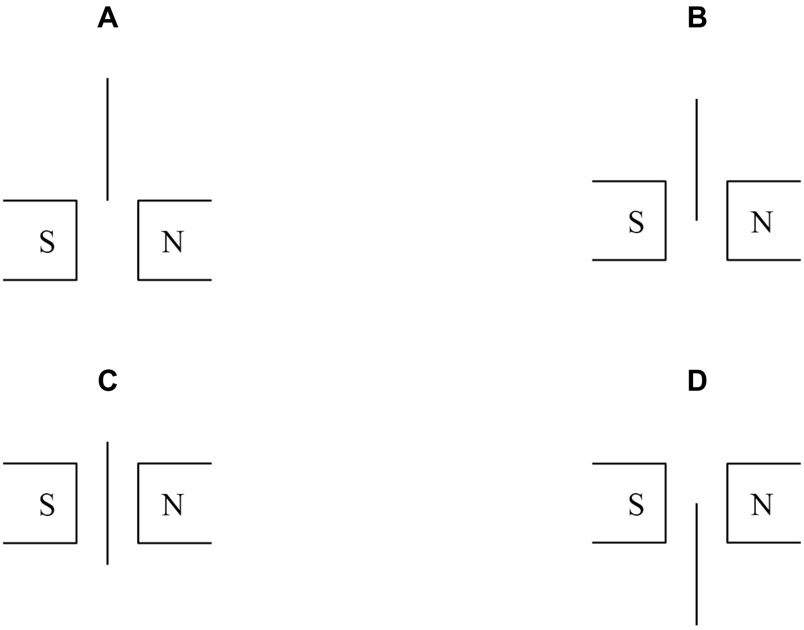
2 4 The diagram shows a small rectangular coil falling between two magnetic poles.



The coil is shown at four instants as it passes through the magnetic field.

At which instant will the induced emf be a maximum?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

Do not write outside the box

2 5 An alternating emf is induced in a coil rotating in a magnetic field.

What is the phase difference between the magnetic flux linkage through the coil and the emf?

[1 mark]

A 0 ⬭

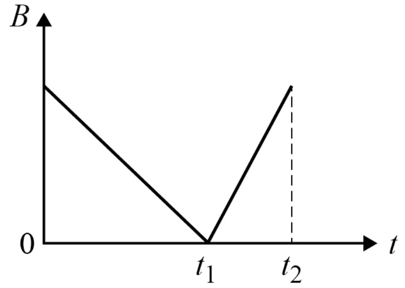
B $\frac{\pi}{3}$ rad ⬭

C $\frac{\pi}{2}$ rad ⬭

D π rad ⬭

Turn over for the next question

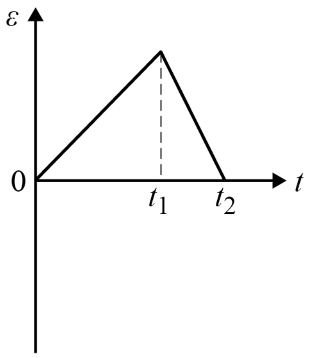
2 6 The diagram shows the variation with time t of the magnetic flux density B of the field linking a coil.



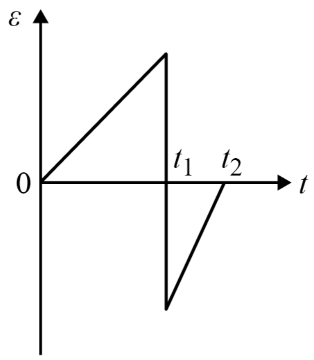
Which graph shows the variation of induced emf ε in the coil during this time interval?

[1 mark]

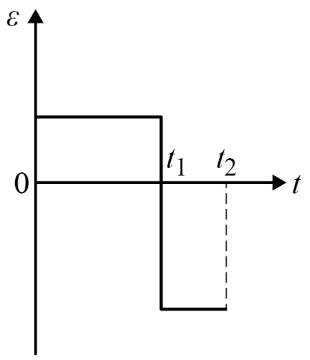
A



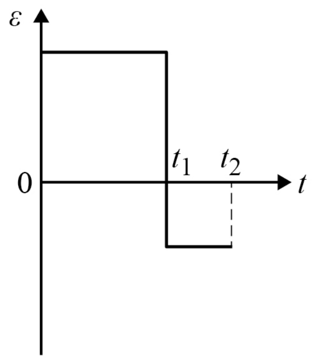
B



C



D



A ☐

B ☐

C ☐

D ☐

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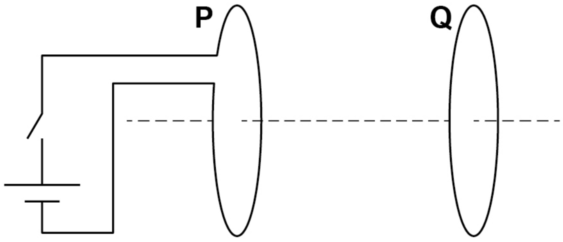
2 7 A coil **P** is connected to a cell and a switch.
A closed coil **Q** is parallel to **P** and is arranged on the same axis.



Which describes the force acting on **Q** after the switch is closed?

[1 mark]

A steady and directed to the left

B steady and directed to the right

C short-lived and directed to the left

D short-lived and directed to the right

2 8 A point source emits gamma radiation. The intensity I of the radiation is measured at different distances d from the source.

Which graph will show a straight line through the origin?

[1 mark]

A I plotted against d

B I plotted against d^2

C I plotted against d^{-1}

D I plotted against d^{-2}

Turn over for the next question

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2 9 The number of parent nuclei in a sample of a radioactive element is N at time t.
The radioactive element has a half-life $t_{\frac{1}{2}}$

The rate of decay is proportional to

[1 mark]

A N ⬭

B t ⬭

C $\frac{1}{t}$ ⬭

D $t_{\frac{1}{2}}$ ⬭

3 0 The table shows the masses of three particles.

Particle	**Mass / u**
proton	1.00728
neutron	1.00867
nucleus of lithium $^{7}_{3}\mathrm{Li}$	7.01436

What is the mass difference of a $^{7}_{3}\mathrm{Li}$ nucleus?

[1 mark]

A 4.99841 u ⬭

B 0.04216 u ⬭

C 0.04147 u ⬭

D 0.04077 u ⬭

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3 1 The mass of the fuel in a fission reactor decreases at a rate of 6.0×10^{-6} kg hour^{-1}.

What is the maximum possible power output of the reactor?

[1 mark]

A 75 MW ⬭

B 150 MW ⬭

C 300 MW ⬭

D 9000 MW ⬭

25

END OF QUESTIONS

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