A

Surname _____

Other Names _____

Centre Number _____

Candidate Number _____

For Examiner's Use

Candidate Signature _____

A-level

PHYSICS

Paper 2

7408/2

Friday 8 June 2018 Morning

Time allowed: 2 hours

At the top of the page, write your surname and other names, your centre number, your candidate number and add your signature.

[Turn over]

JUN187408201

For this paper you must have:

- **a pencil and a ruler**
- **a scientific calculator**
- **the Booklet of Diagrams as an insert**
- **a Data and Formulae Booklet.**

INSTRUCTIONS

- **Use black ink or black ball-point pen.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do not write on blank pages.**
- **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.**

DO NOT TURN OVER UNTIL TOLD TO DO SO

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SECTION A

Answer ALL questions in this section.

0 1 . 1

Explain what is meant by specific latent heat of fusion. [2 marks]

0 1 . 2

FIGURE 1, on page 2 of the insert, shows how the temperature of the water is maintained in a hot tub.

The hot tub system has a volume of $4.5\ \mathrm{m}^3$ and is filled with water at a temperature of $28\ ^\circ\mathrm{C}$

The heater transfers thermal energy to the water at a rate of $2.7\ \mathrm{kW}$ while a pump circulates the water.

Assume that no heat is transferred to the surroundings.

Calculate the rise in water temperature that the heater could produce in 1.0 hour.

density of water = $1000\ \mathrm{kg\ m^{-3}}$

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

[3 marks]

temperature rise = _____ K

[Turn over]

0 1 . 3

The pump can circulate the water at different speeds.
When working at higher speeds the rise in temperature is greater.

Explain why.
Again assume that no heat is transferred to the surroundings. [2 marks]

0 2 . 1

Define the electric field strength at a point in an electric field. [2 marks]

0 2 . 2

FIGURE 2, on page 3 of the insert, shows a point charge of $+46\ \mu C$ placed $120\ mm$ from a point charge Q.

Position P is on the line joining the charges at a distance $66\ mm$ from charge Q.
The resultant electric field strength at position P is zero.

Calculate the charge Q. [3 marks]

Q = _____ C

0 2 . 3

Explain, without calculation, whether net work must be done in moving a proton from infinity to position P in FIGURE 2.
[2 marks]

12

0 2 . 4

A small rubber ball coated with a conducting paint carries a positive charge.
The ball is suspended in equilibrium from a vertical wall by an uncharged non-conducting thread of negligible mass.
The wall is positively charged and produces a horizontal uniform electric field perpendicular to the wall along the whole of its length.
FIGURE 3, on page 4 of the insert, shows that the thread makes an angle of $30°$ to the wall.

[Turn over]

The thread breaks.

Explain the motion of the ball. [2 marks]

0 3 . 1

State what is meant by a capacitance of $370\ \mu F$ [2 marks]

0 3 . 2

The charging of a $370\ \mu F$ capacitor is investigated using the circuit shown in FIGURE 4, on page 5 of the insert. Both meters in the circuit are ideal.

The power supply of emf $9.8\ V$ has a negligible internal resistance. The capacitor is initially uncharged. When the switch is closed at time $t = 0$ charge begins to flow through resistor R. The time constant of the charging circuit is $1.0\ s$

Calculate the resistance of R. [1 mark]

resistance of R = _____ Ω

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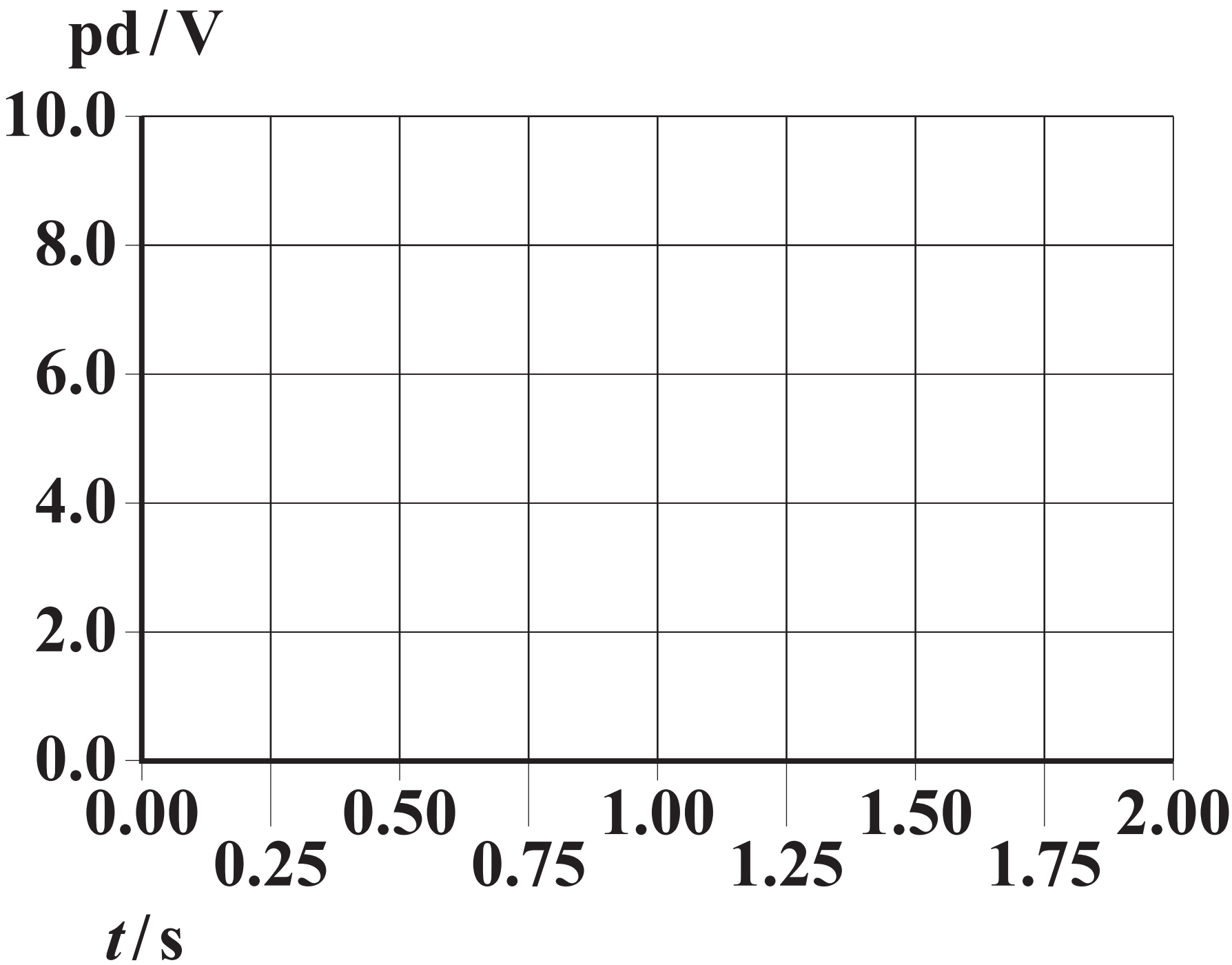
[Turn over]

0 3 . 3

Identify, with the symbol X on FIGURE 5, the potential difference (pd) across the capacitor when the switch has been closed for $2.0\ \text{s}$
Sketch the graph that shows how the pd varies from $t = 0$ to $t = 2.0\ \text{s}$ [2 marks]

FIGURE 5



[Turn over]

0 3 . 4

Calculate the time taken for the charging current to fall to half its initial value.
[1 mark]

time = **s**

0 3 . 5

Calculate the time taken for the charge on the capacitor to reach $3.0\ \mathrm{mC}$
[3 marks]

time = **s**

9

0 4 . 1

State Lenz's law. [1 mark]

0 4 . 2

Lenz’s law can be demonstrated using a bar magnet and a coil of wire connected to a sensitive ammeter as shown in FIGURE 6, on page 6 of the insert.

The bar magnet is moved towards the coil and is then brought to a halt.

State how the reading on the ammeter changes during this process. [1 mark]

0 4 . 3

During the demonstration an induced current is detected by the ammeter. The induced current is in the direction E to F.

Explain how this demonstrates Lenz's law. [2 marks]

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[Turn over]

0 4 . 4

FIGURE 7, on page 7 of the insert, shows an arrangement for investigating induced emf.

As shown, the uniform vertical magnetic field is confined to the gap between the poles of the magnet. The plane of the square coil is horizontal and is made of conducting wire. The coil consists of a single turn and is attached by flexible wire to an oscilloscope.

The oscilloscope gives a reading of $2.9 \times 10^{-4}\ \mathrm{V}$ when the coil is moved at uniform speed from position G outside the field to position H inside the field, as shown in FIGURE 8, on page 8 of the insert.

Calculate the time taken to move the coil from position G to position H. [2 marks]

time = _____ s

[Turn over]

0 4 . 5

The square coil is rotated through $360°$ at a constant angular speed about the horizontal axis shown in FIGURE 9, on page 9 of the insert.

Calculate the angular speed of the coil when the maximum reading on the oscilloscope is $5.1\ \text{mV}$ [2 marks]

angular speed = _____ rad s^{-1}

8

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[Turn over]

0 5 . 1

Suggest, with a reason, which type of radiation is likely to be the most appropriate for the sterilisation of metallic surgical instruments. [1 mark]

0 5 . 2

Explain why the public need not worry that irradiated surgical instruments become radioactive once sterilised.
[1 mark]

0 5 . 3

A student detects the counts from a radioactive source using a G-M radiation detector as shown in FIGURE 10, on page 10 of the insert.

The student measures the count rate for three different distances d. TABLE 1 shows the count rate, in counts per minute, corrected for background for each of these distances.

TABLE 1

d/m	Corrected count rate / counts per minute			
0.20	9013			
0.50	1395			
1.00	242			

Explain, with the aid of suitable calculations, why the data in TABLE 1 are NOT consistent with an inverse-square law. You may use the blank columns for your working. [2 marks]

BLANK PAGE

0 5 . 4

State TWO possible reasons why the results do NOT follow the expected inverse-square law. [2 marks]

Reason 1 _____

Reason 2 _____

[Turn over]

0	6

FIGURE 11, on page 11 of the insert, shows how radioactive decay of one nuclide can be modelled by draining water through a tap from a cylindrical tube.

The water flow-rate is proportional to the pressure of the water. The pressure of the water is proportional to the depth of the water. Therefore the rate at which the depth decreases is proportional to the depth of the water.

Before the tap is opened the depth is 16.0 cm

The tap is opened and the depth is measured at regular intervals. These data are plotted on the graph in FIGURE 12, on page 12 of the insert.

0 6 . 1

Determine the predicted depth of water when the time is 57 s [1 mark]

depth = _____ cm

[Turn over]

0 6 . 2

Suggest how the apparatus in FIGURE 11 may be changed to represent a radioactive sample of the same nuclide with a greater number of nuclei. [1 mark]

0 6 . 3

Suggest how the apparatus in FIGURE 11 may be changed to represent a radioactive sample of a nuclide with a smaller decay constant. [1 mark]

0 6 . 4

The age of the Moon has been estimated from rock samples containing rubidium (Rb) and strontium (Sr), brought back from Moon landings.

$^{87}_{37}$Rb decays to $^{87}_{38}$Sr with a radioactive decay constant of 1.42×10^{-11} year^{-1}

Calculate, in years, the half-life of $^{87}_{37}$Rb.
[1 mark]

half-life = _____ years

[Turn over]

0 6 . 5

A sample of Moon rock contains $1.23\ \text{mg}$ of $^{87}_{37}\text{Rb}$.

Calculate the mass, in g, of $^{87}_{37}\text{Rb}$ that the rock sample contained when it was formed 4.47×10^9 years ago.

Give your answer to an appropriate number of significant figures. [3 marks]

mass = _____ g

0 6 . 6

Calculate the activity of a sample of

$^{87}_{37}$**Rb of mass 1.23 mg**

Give an appropriate unit for your answer.
[3 marks]

activity = _____ unit _____

10

[Turn over]

0 7

A nucleus of polonium Po may decay to the stable isotope of lead $^{208}_{82}Pb$ through a chain of emissions following the sequence α β^- β^- α.

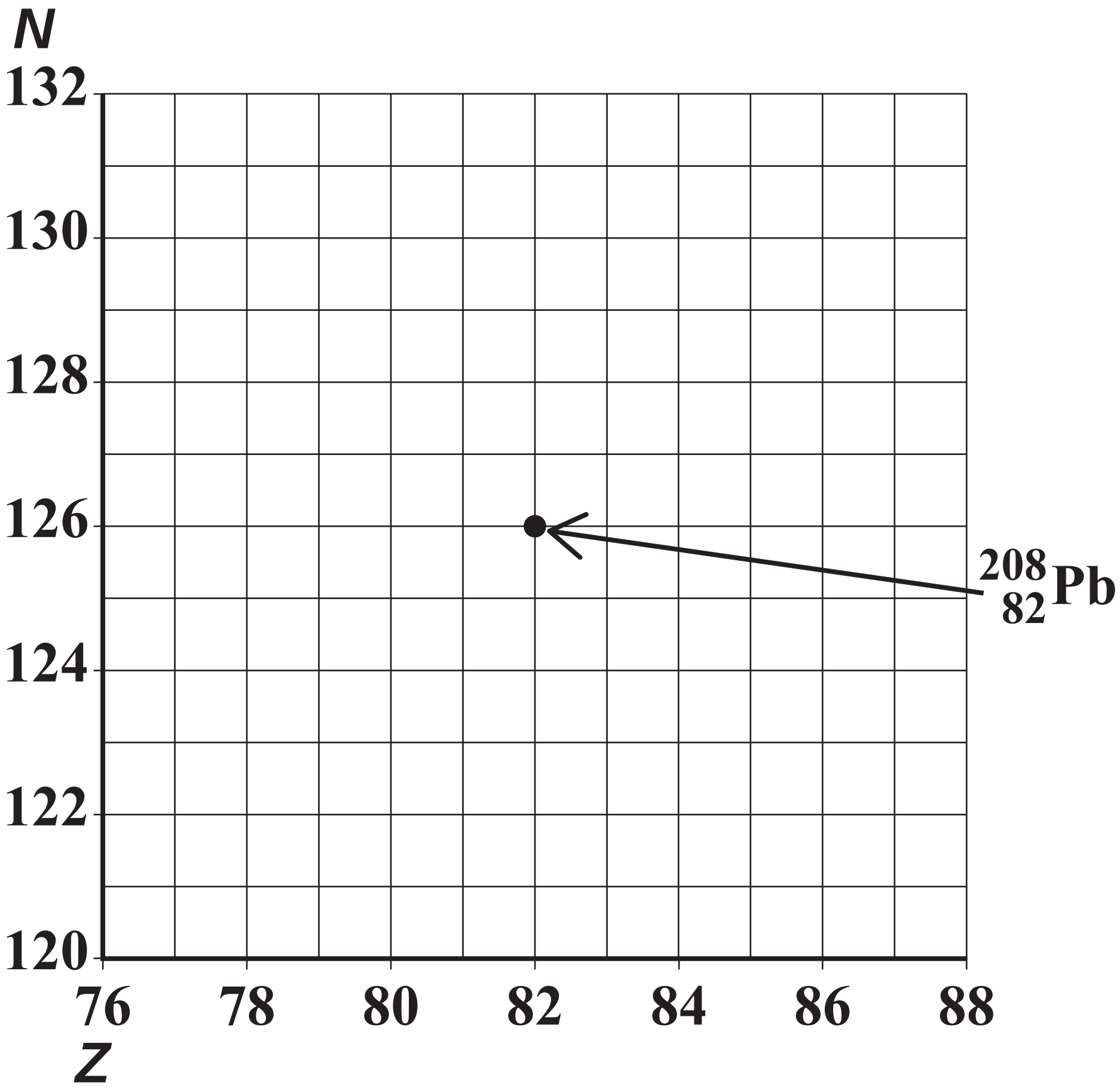
FIGURE 13 shows

the position of the isotope $^{208}_{82}Pb$ on a grid of neutron number *N* against proton number *Z*.

0 7 . 1

Draw FOUR arrows on FIGURE 13 to show the sequence of changes to *N* and *Z* that occur as the polonium nucleus is transformed into $^{208}_{82}Pb$. [2 marks]

FIGURE 13



[Turn over]

0 7 . 2

A nucleus of the stable isotope $^{208}_{82}\mathrm{Pb}$ has more neutrons than protons.

Explain why there is this imbalance between proton and neutron numbers by referring to the forces that operate within the nucleus.
Your explanation should include the range of the forces and which particles are affected by the forces. [4 marks]

[Turn over]

0 7 . 3

Many, but not all, isotopes of lead are stable. For example, $^{205}_{82}\mathrm{Pb}$ decays by electron capture to become an isotope of thallium, Tl.

Write the equation to represent this decay, including the isotope of thallium produced. [1 mark]

0 7 . 4

The thallium nucleus is formed in an excited state. Electromagnetic radiation is emitted from the thallium atom following its formation.

Explain the origin and location of TWO sources of this radiation. [2 marks]

Source 1 _____

_____

_____

_____

_____

Source 2

[Turn over]

0 7 . 5

Other nuclides also emit electromagnetic radiation.

Explain why the metastable form of the isotope of technetium $^{99}_{43}\mathrm{Tc}$ is a radioactive source suitable for use in medical diagnosis. [2 marks]

END OF SECTION A

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[Turn over]

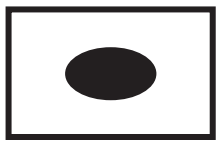
SECTION B

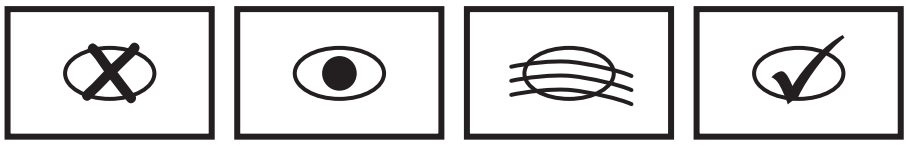
Each of Questions 08 to 32 is followed by four responses, A, B, C and D.

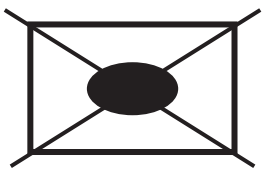
For each question select the best response.

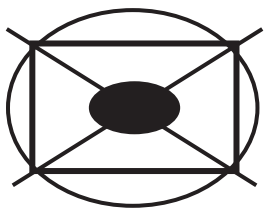
Only ONE answer per question is allowed.

For each answer 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.

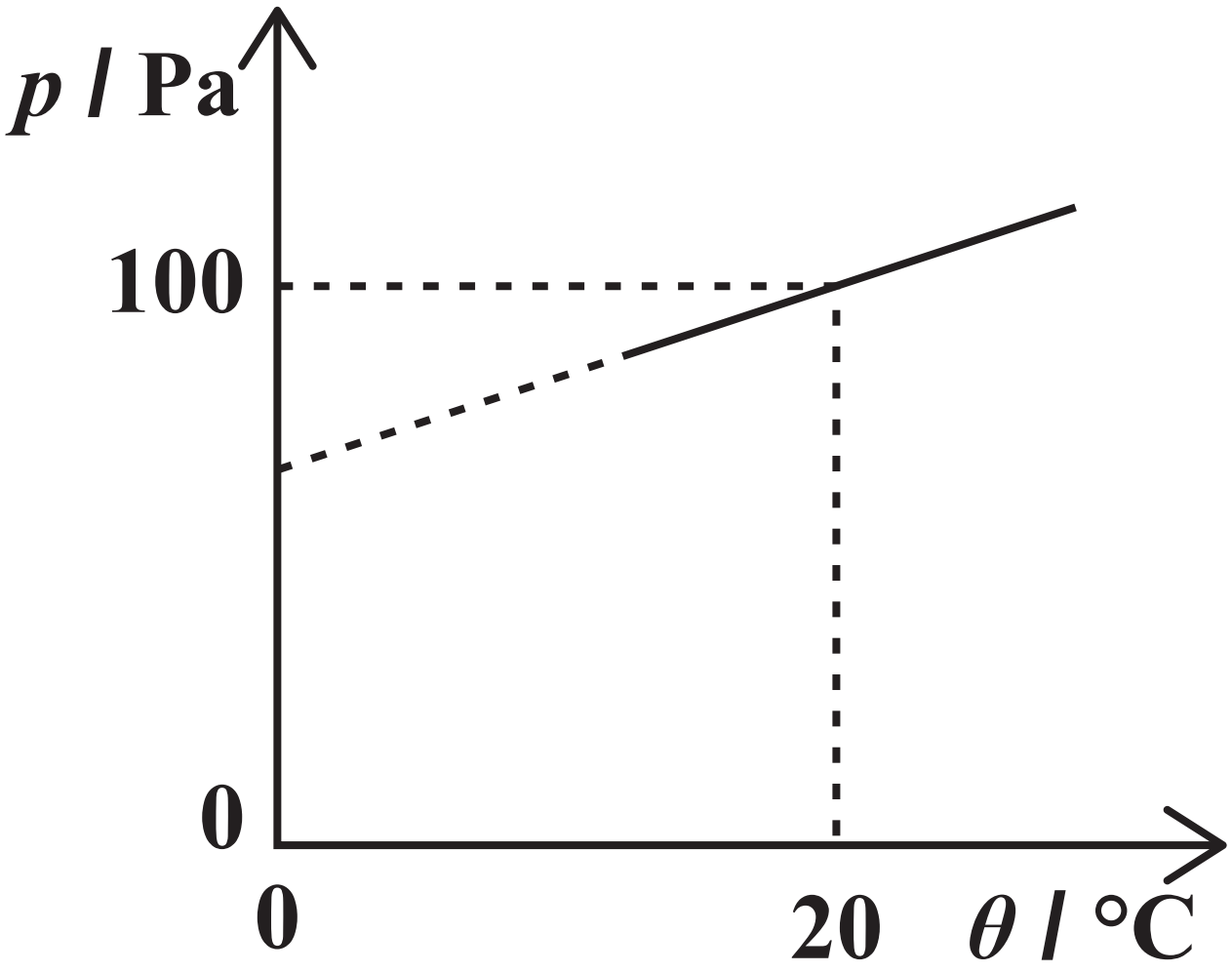
Do NOT use additional sheets for this working.

[Turn over]

0 8

The graph shows the variation of pressure p with temperature θ for a fixed mass of an ideal gas at constant volume.

What is the gradient of the graph?
[1 mark]



- **A** **0.341**
- **B** **0.395**
- **C** **2.93**
- **D** **5.00**

0 9

Two flasks X and Y are filled with an ideal gas and are connected by a tube of negligible volume compared to that of the flasks.
The volume of X is twice the volume of Y.
X is held at a temperature of $150\ \mathrm{K}$ and Y is held at a temperature of $300\ \mathrm{K}$

What is the ratio $\frac{\text{mass of gas in X}}{\text{mass of gas in Y}}$?

[1 mark]

- ⬭ **A** 0.125
- ⬭ **B** 0.25
- ⬭ **C** 4
- ⬭ **D** 8

[Turn over]

1	0

The average mass of an air molecule is 4.8×10^{-26} kg

What is the mean square speed of an air molecule at 750 K? [1 mark]

- ⬭ **A** 3.3×10^5 m^2 s^{-2}
- ⬭ **B** 4.3×10^5 m^2 s^{-2}
- ⬭ **C** 6.5×10^5 m^2 s^{-2}
- ⬭ **D** 8.7×10^5 m^2 s^{-2}

1	1

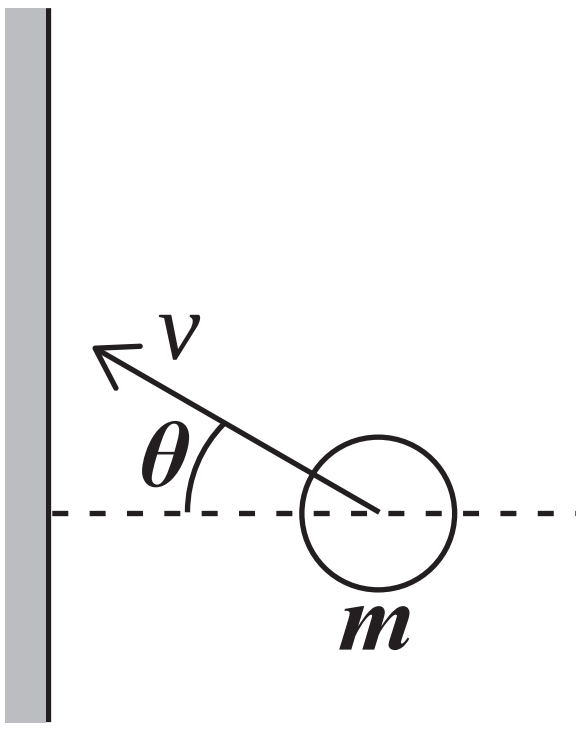
**A transparent illuminated box contains small smoke particles and air.
The smoke particles are observed to move randomly when viewed through a microscope.**

What is the cause of this observation of Brownian motion? [1 mark]

- ⬭ **A** Smoke particles gaining kinetic energy by the absorption of light
- ⬭ **B** Collisions between smoke particles and air molecules
- ⬭ **C** Smoke particles moving in convection currents caused by the air being heated by the light
- ⬭ **D** The smoke particles moving randomly due to their temperature

1	2

The diagram shows a gas particle about to collide elastically with a wall.



Which diagram, on the opposite page, shows the correct change in momentum Δmv that occurs during the collision? [1 mark]

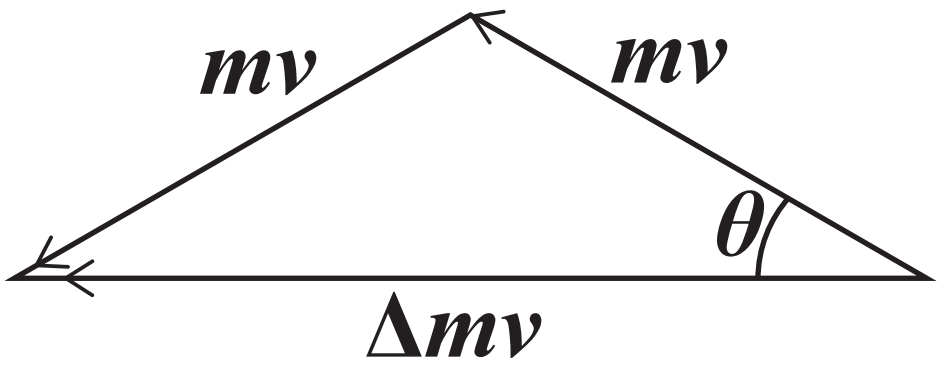
○ **A**

○ **B**

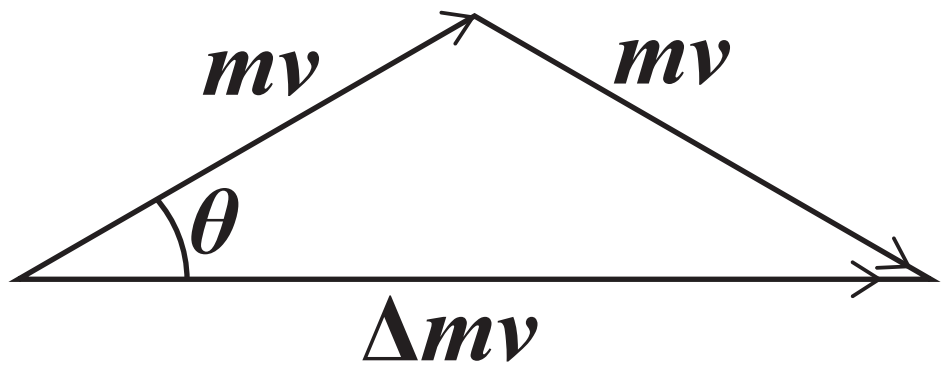
○ **C**

○ **D**

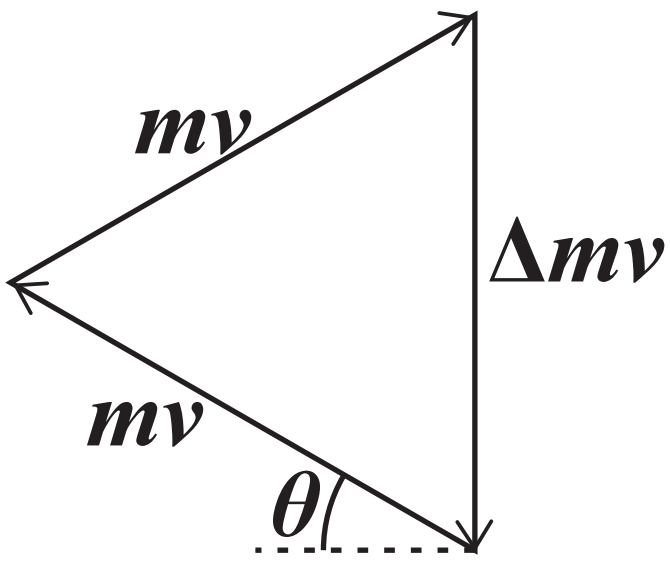
A



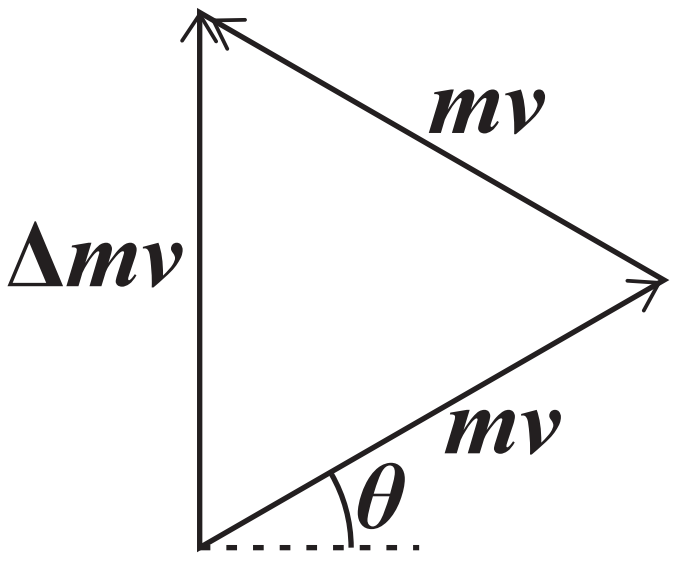
B



C



D



[Turn over]

1	3

The distance between the Sun and the Earth is 1.5×10^{11} m

What is the gravitational force exerted on the Sun by the Earth? [1 mark]

- ⬭ **A** 3.5×10^{22} N
- ⬭ **B** 1.7×10^{26} N
- ⬭ **C** 5.3×10^{33} N
- ⬭ **D** 8.9×10^{50} N

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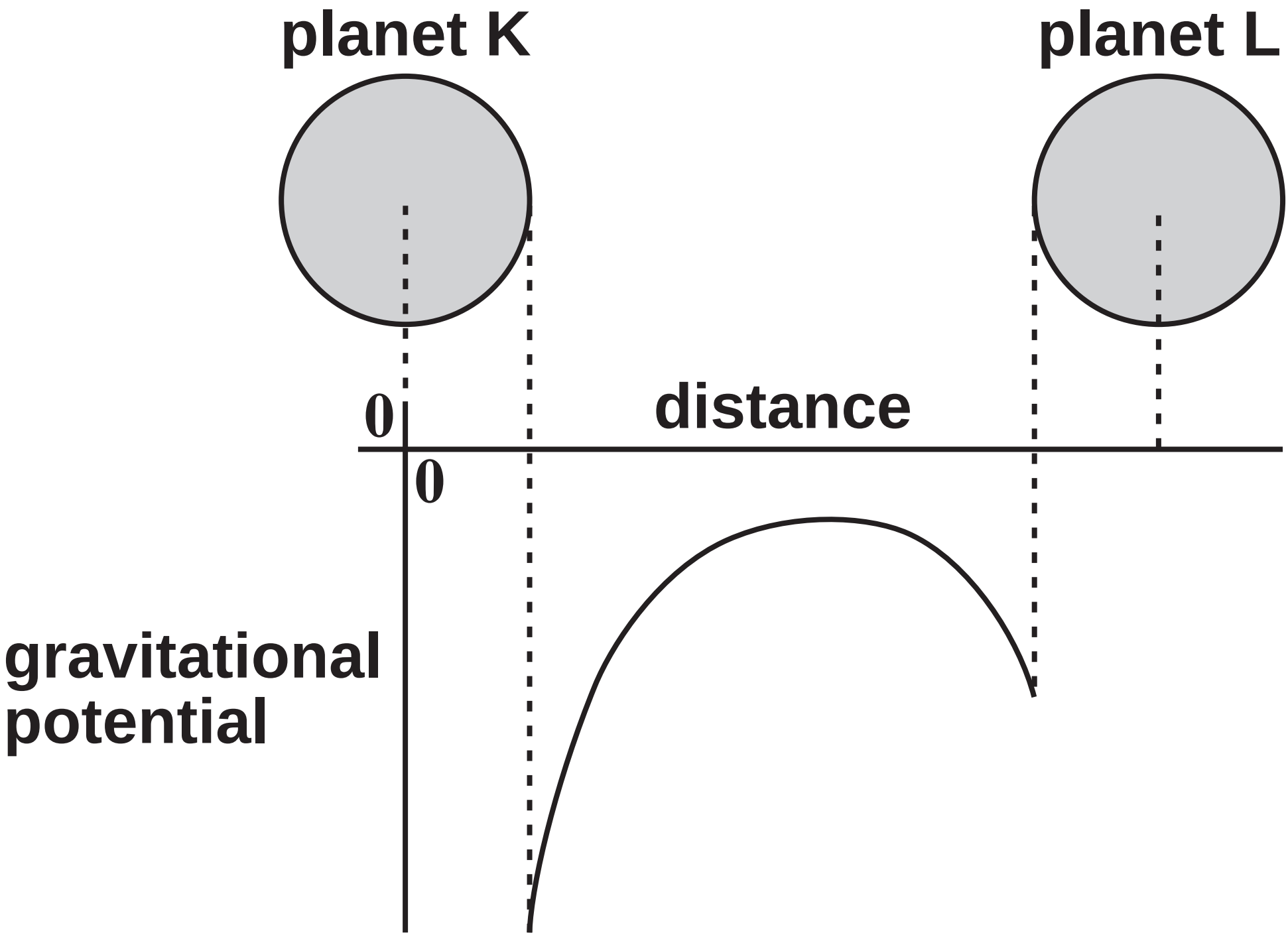
[Turn over]

1	4

The graph shows how the gravitational potential varies with distance between two planets, K and L, that have the same radius.

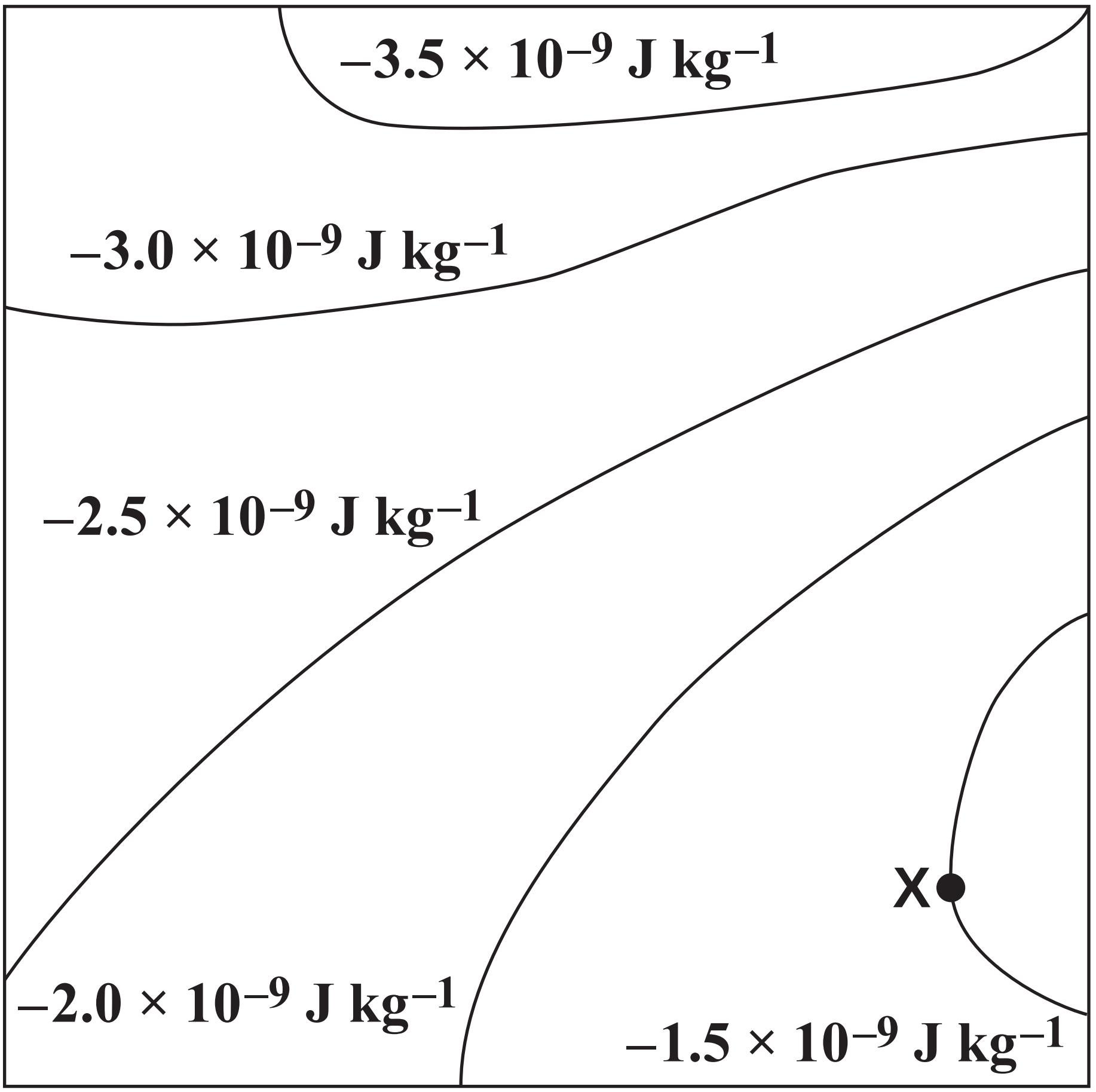


Which statement is correct? [1 mark]

- ⬭ **A** The mass of L is greater than the mass of K.
- ⬭ **B** The gravitational field strength at the surface of L is greater than that at the surface of K.
- ⬭ **C** The escape velocity from planet L is greater than that from planet K.
- ⬭ **D** More work must be done to move a mass of $1\ \text{kg}$ from the surface of K to a distant point, than $1\ \text{kg}$ from the surface of L.

1	5

The diagram shows equipotential lines near a group of asteroids.



Which arrow shows the direction of the gravitational field at X? [1 mark]

[Turn over]

1	6

Planet N has a gravitational potential $-V$ at its surface. Planet M has double the density and double the radius of planet N. Both planets are spherical and have uniform density.

What is the gravitational potential at the surface of planet M? [1 mark]

- ⬭ **A** $-16V$
- ⬭ **B** $-8V$
- ⬭ **C** $-4V$
- ⬭ **D** $-0.2V$

1	7

A spacecraft of mass 1.0×10^6 kg is in orbit around the Sun at a radius of 1.1×10^{11} m
The spacecraft moves into a new orbit of radius 2.5×10^{11} m around the Sun.

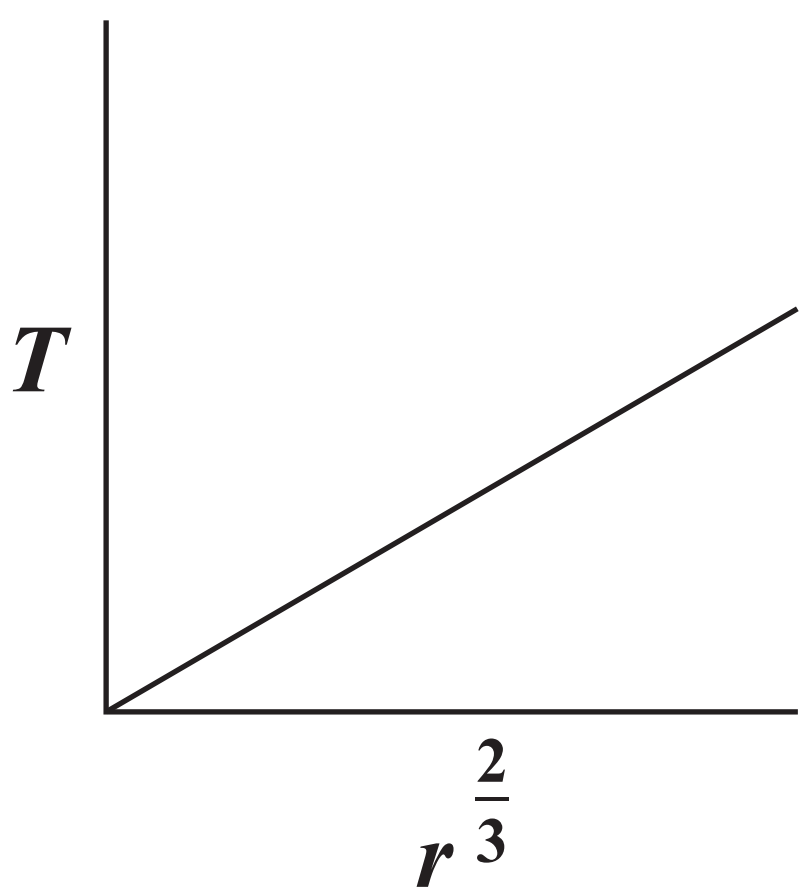
What is the total change in gravitational potential energy of the spacecraft?
[1 mark]

- ⬭ **A** -6.76×10^{14} J
- ⬭ **B** -3.38×10^{14} J
- ⬭ **C** 3.38×10^{14} J
- ⬭ **D** 6.76×10^{14} J

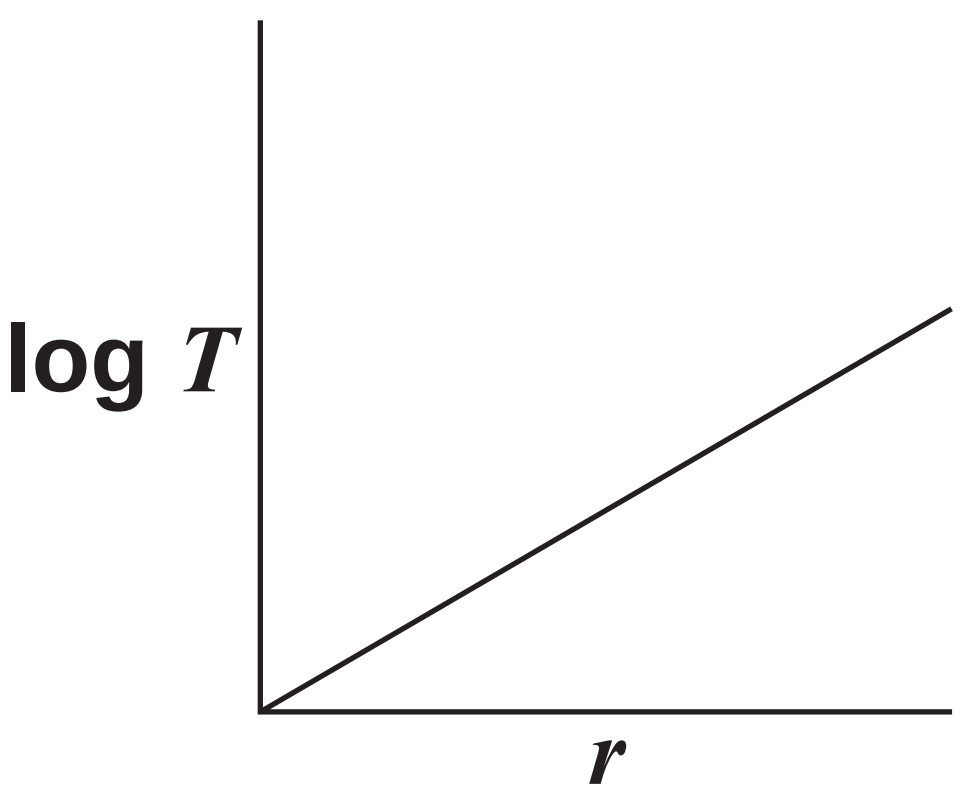
1	8

Which graph on the opposite page shows the relationship between the time period T and the orbital radius r of a planet in orbit around the Sun? [1 mark]

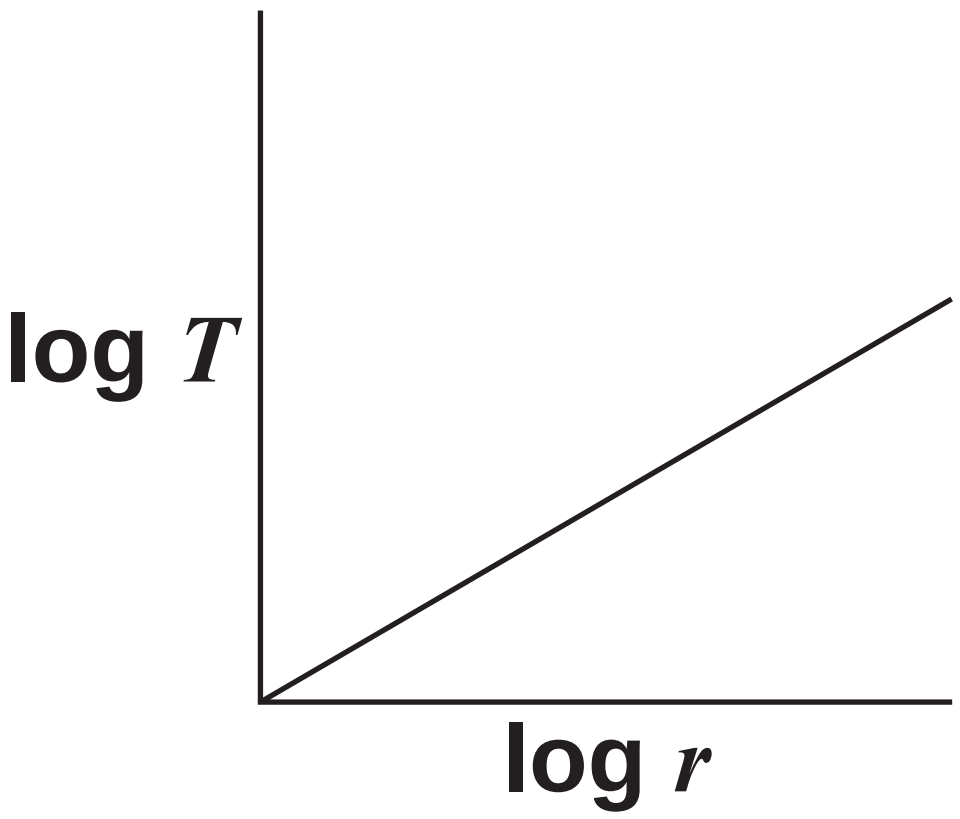
A



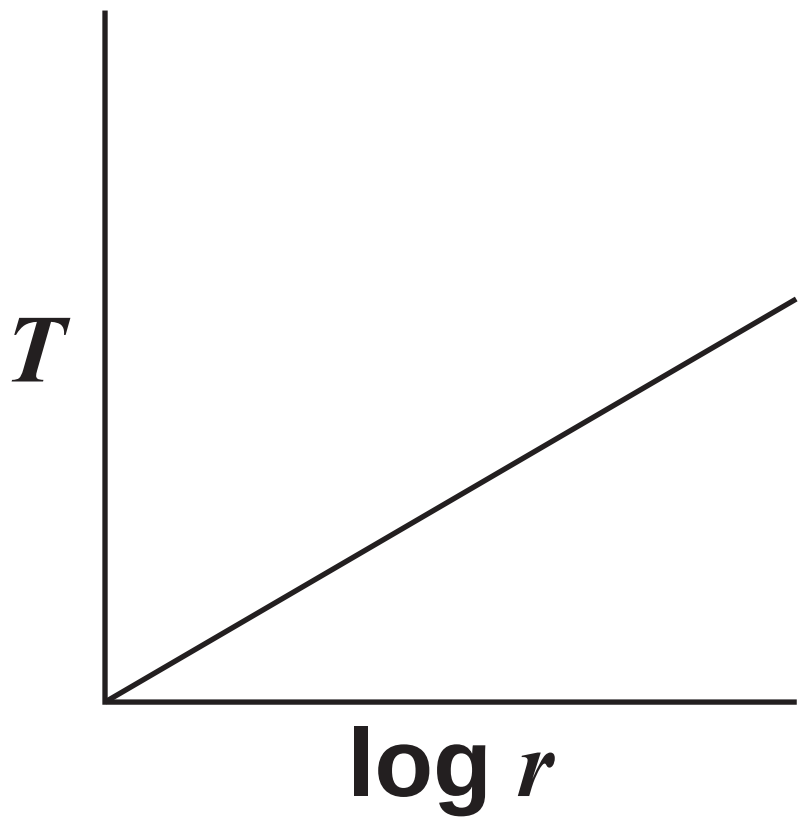
B



C



D



[Turn over]

1	9

The Earth can be assumed to be a uniform sphere of radius R.

What is the mean density of the Earth?
[1 mark]

A $\frac{3g}{4\pi RG}$

B $\frac{3RG}{4\pi g}$

C $\frac{3G}{4\pi Rg}$

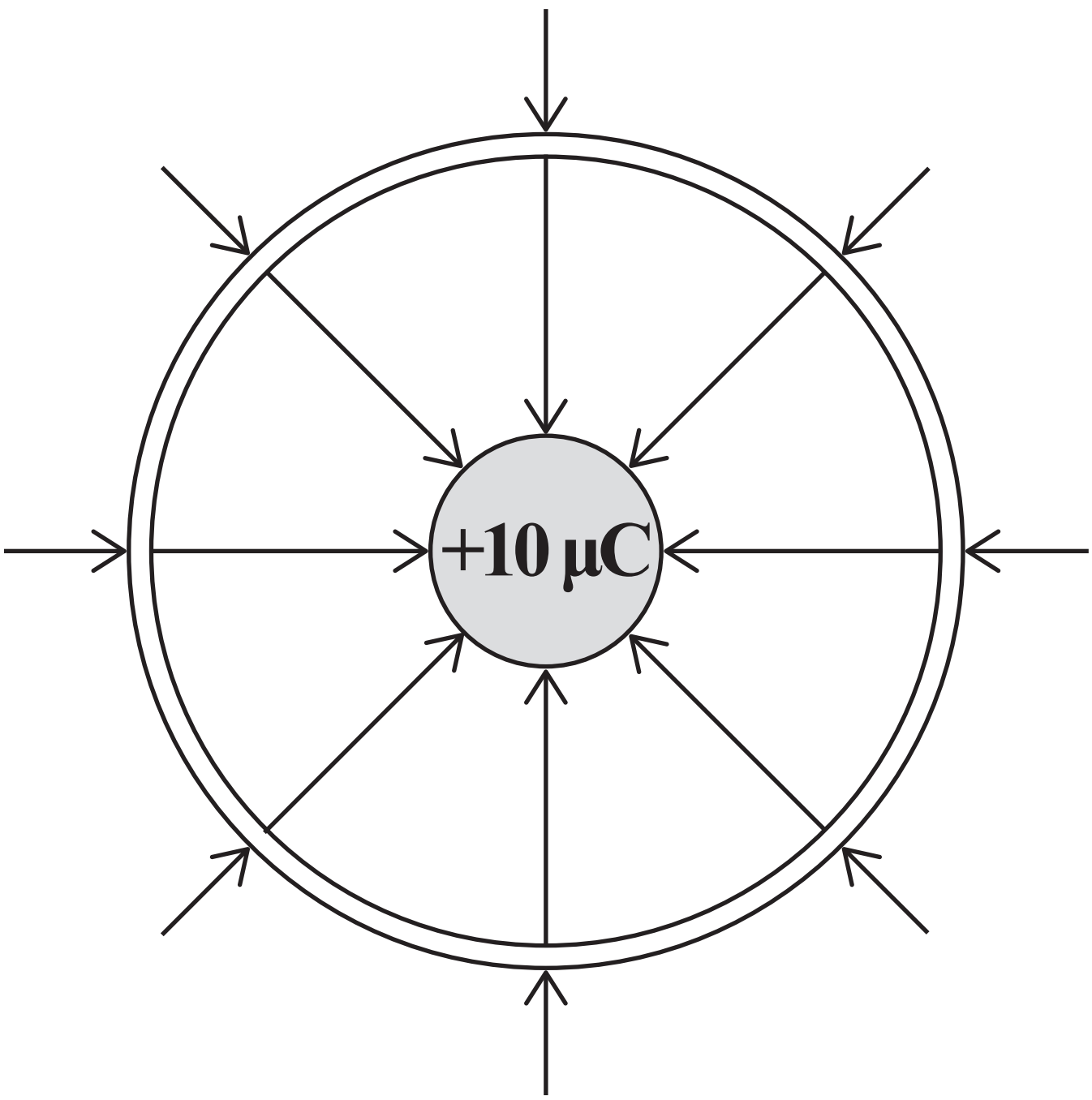
D $\frac{3Rg}{4\pi G}$

2	0

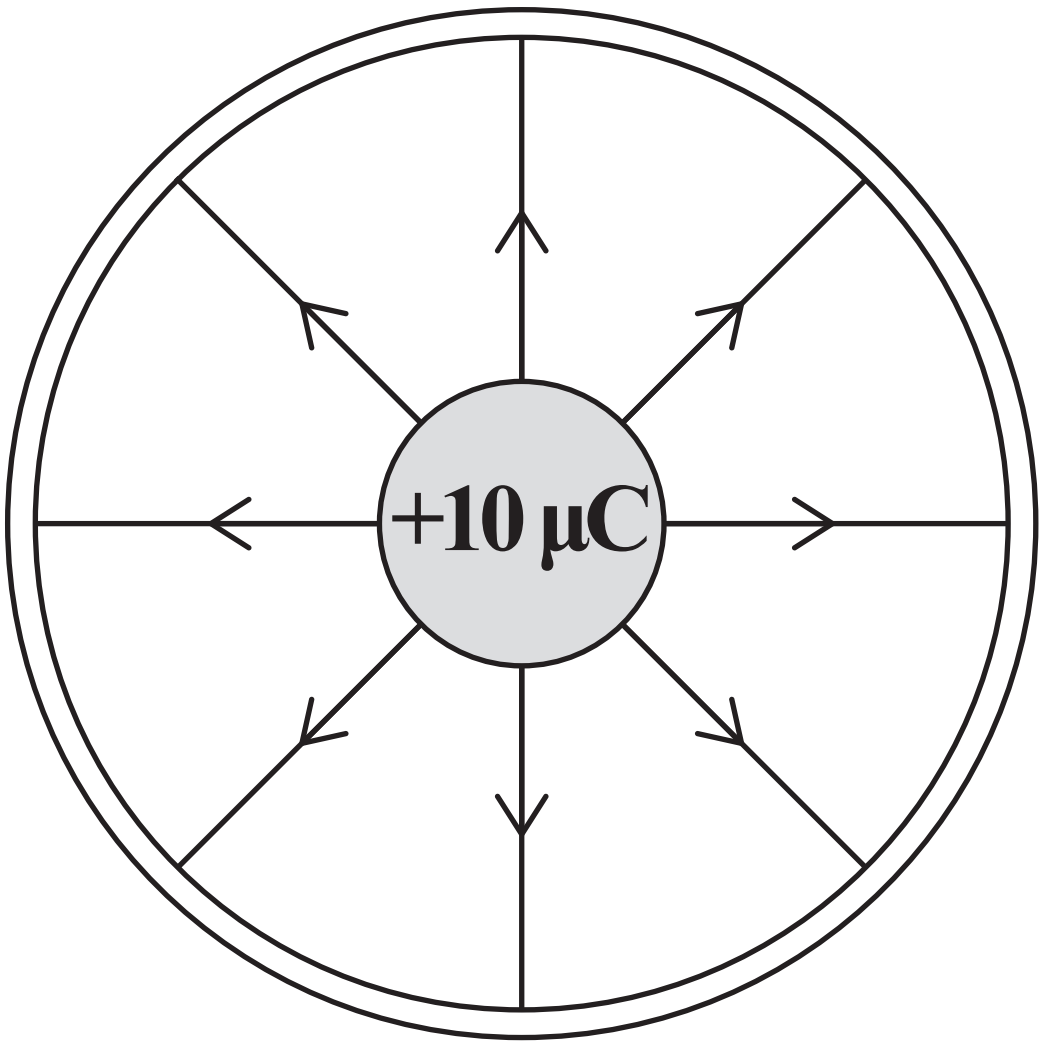
A conducting sphere holding a charge of $+10\ \mu C$ is placed centrally inside a second uncharged conducting sphere.

Which diagram, on pages 71, 72, 73 and 74, shows the electric field lines for the system? [1 mark]

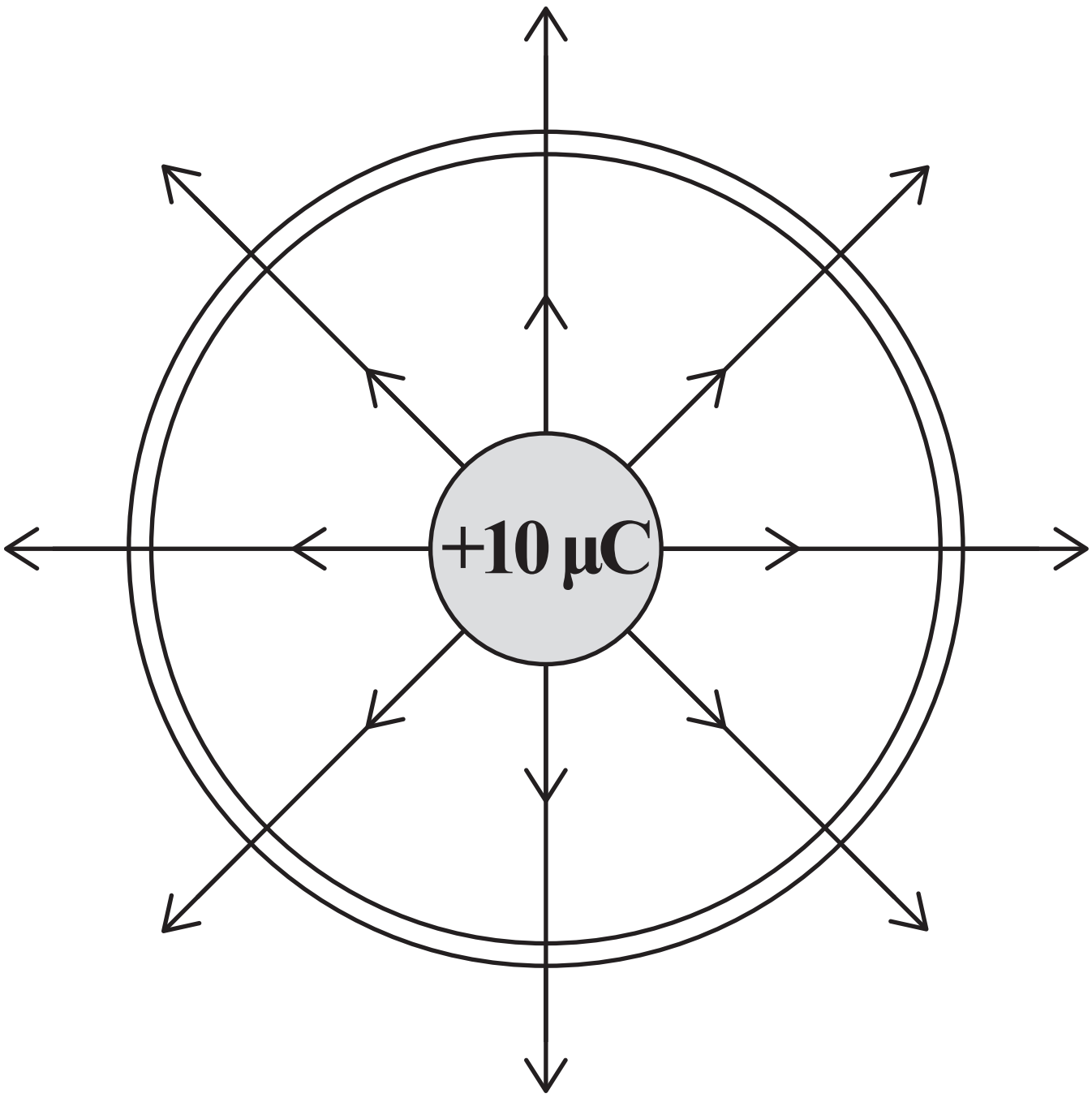
A



B

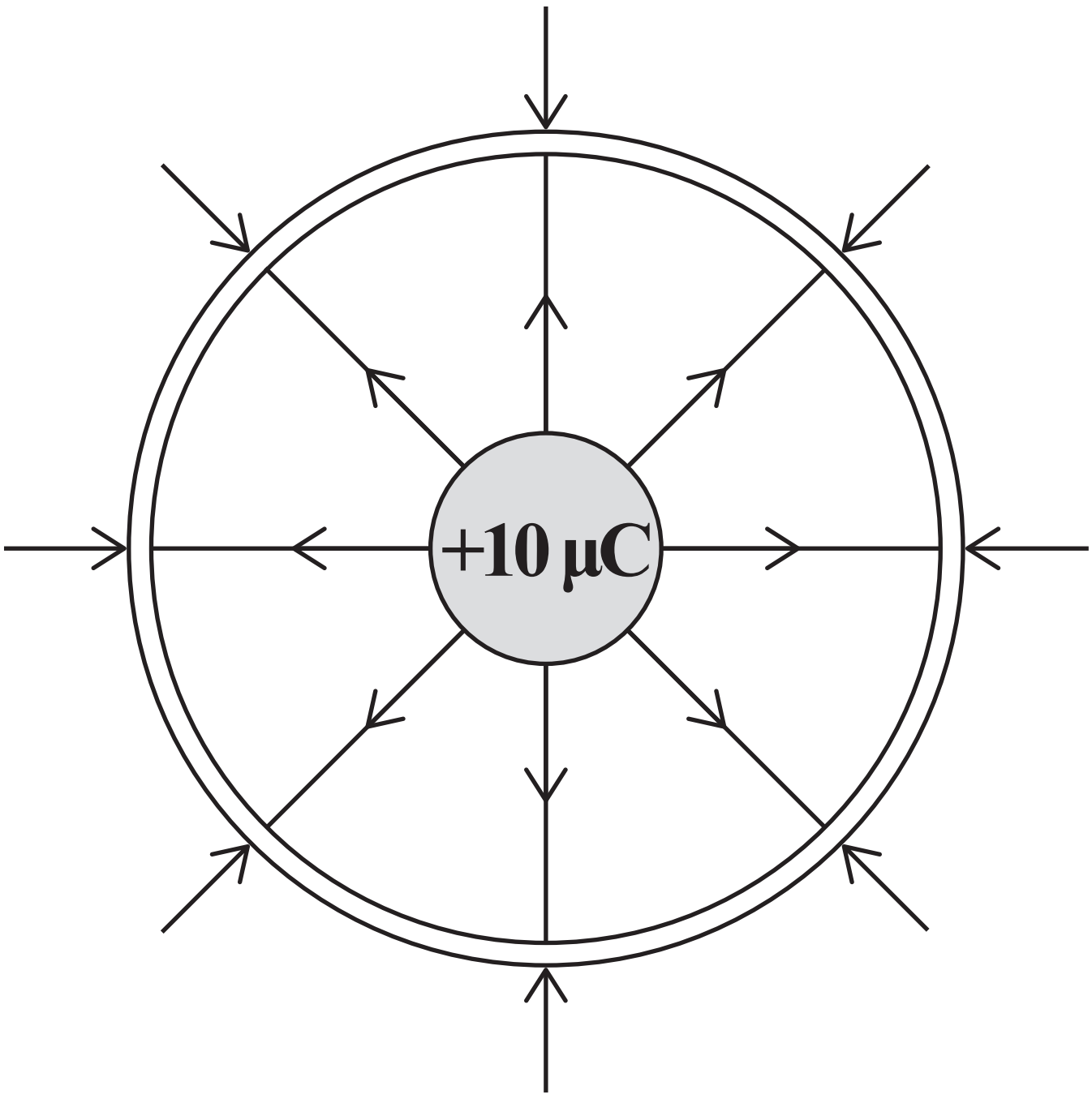


C



[Turn over]

D



2 1

A charged spherical conductor has a radius r.
An electric field of strength E exists at the surface due to the charge.

What is the potential of the spherical conductor? [1 mark]

A r^2E

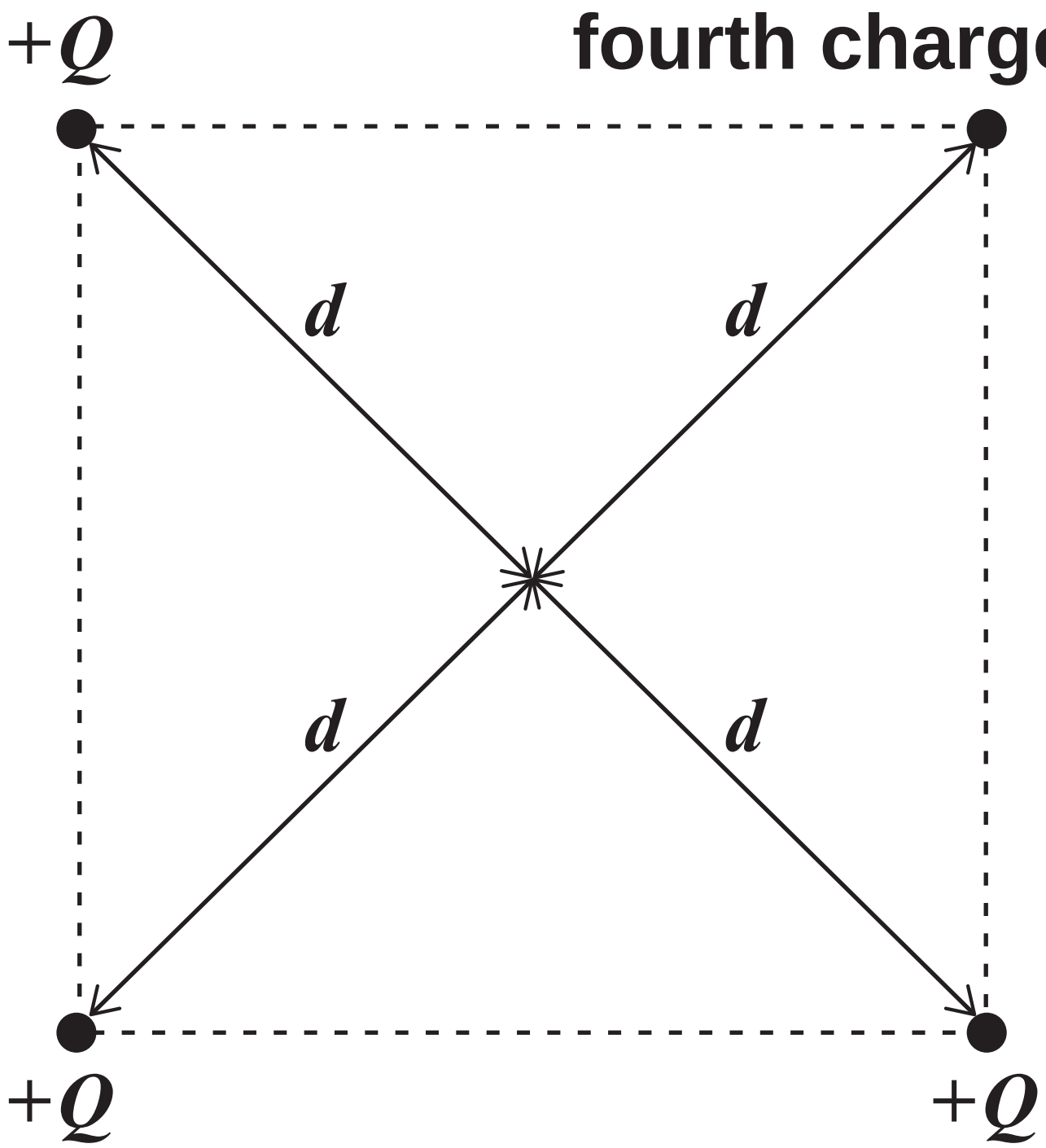
B rE^2

C $\frac{E}{r}$

D rE

2	2

Four positive charges are fixed at the corners of a square as shown.



The total potential at the centre of the square, a distance d from each charge, is $\frac{5Q}{4\pi\varepsilon_0 d}$.

Three of the charges have a charge of $+Q$.

What is the magnitude of the fourth charge? [1 mark]

A $-\frac{7Q}{4}$

B Q

C $\sqrt{2}Q$

D $2Q$

2	3

An air-filled parallel-plate capacitor is charged from a source of emf. The electric field has a strength E between the plates. The capacitor is disconnected from the source of emf and the separation between the isolated plates is doubled.

What is the final electric field between the plates? [1 mark]

○ **A** $2E$

○ **B** E

○ **C** $\frac{E}{2}$

○ **D** $\frac{E}{4}$

2 4

A parallel-plate capacitor has square plates of length l separated by distance d and is filled with a dielectric.

A second capacitor has square plates of length $2l$ separated by distance $2d$ and has air as its dielectric.

Both capacitors have the same capacitance.

What is the relative permittivity of the dielectric in the first capacitor? [1 mark]

○ **A** $\frac{1}{2}$

○ **B** 1

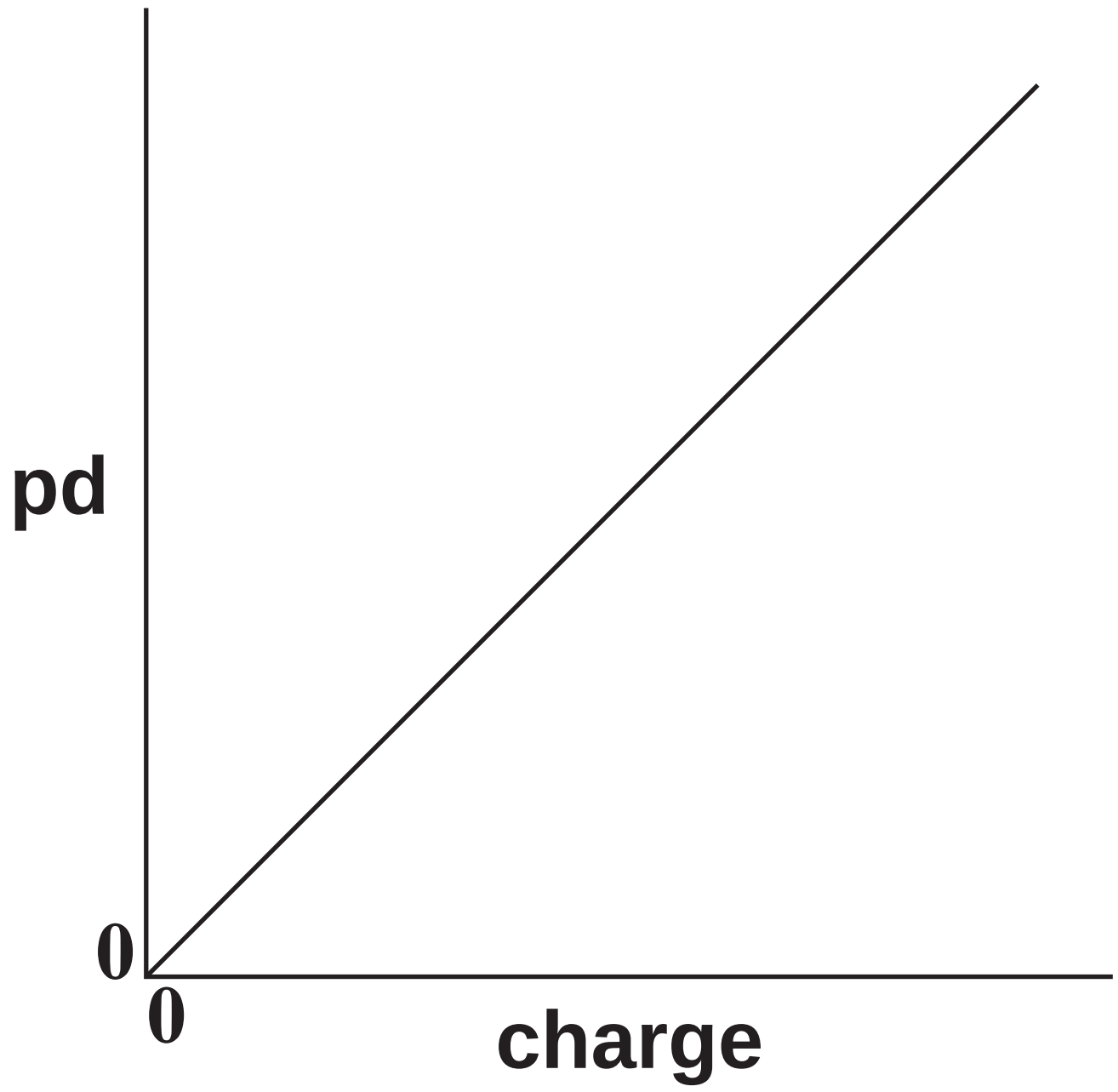
○ **C** 2

○ **D** 8

[Turn over]

2	5

The graph shows the variation of potential difference (pd) with charge for a capacitor while it is charging.



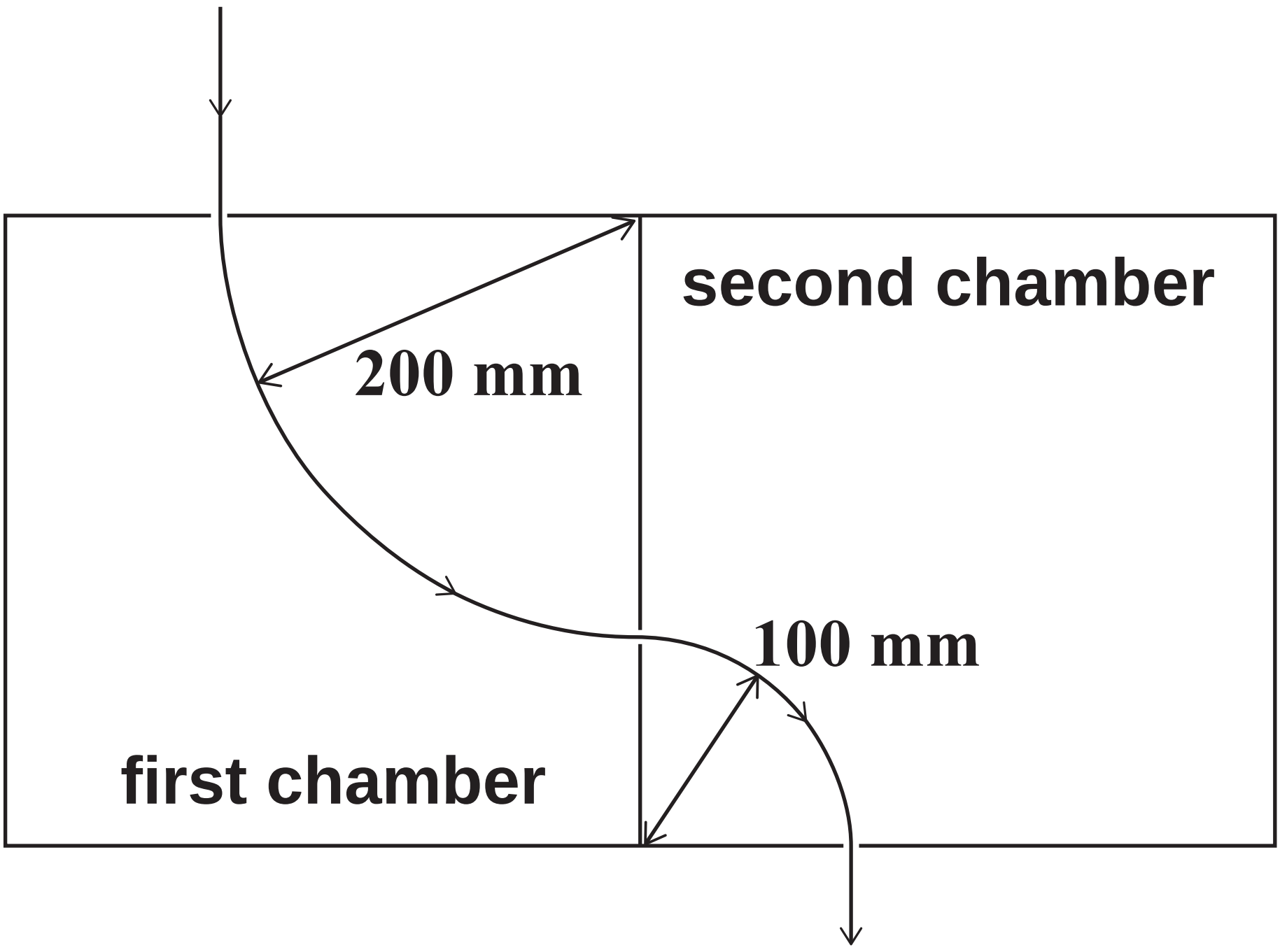
Which statement can be deduced from the graph? [1 mark]

- ⬭ **A** The charging current is constant.
- ⬭ **B** The energy stored in the capacitor increases uniformly with time.
- ⬭ **C** The capacitance of the capacitor is constant.
- ⬭ **D** The power supply used to charge the capacitor had a constant terminal pd.

[Turn over]

2	6

Different magnetic fields are present in the two chambers shown. A particle enters the first chamber at a velocity of $80\ \mathrm{m\ s^{-1}}$ and is deflected into a circular path of radius $200\ \mathrm{mm}$
In the second chamber it follows a circular path of radius 100 mm



The particle leaves the second chamber at a speed of

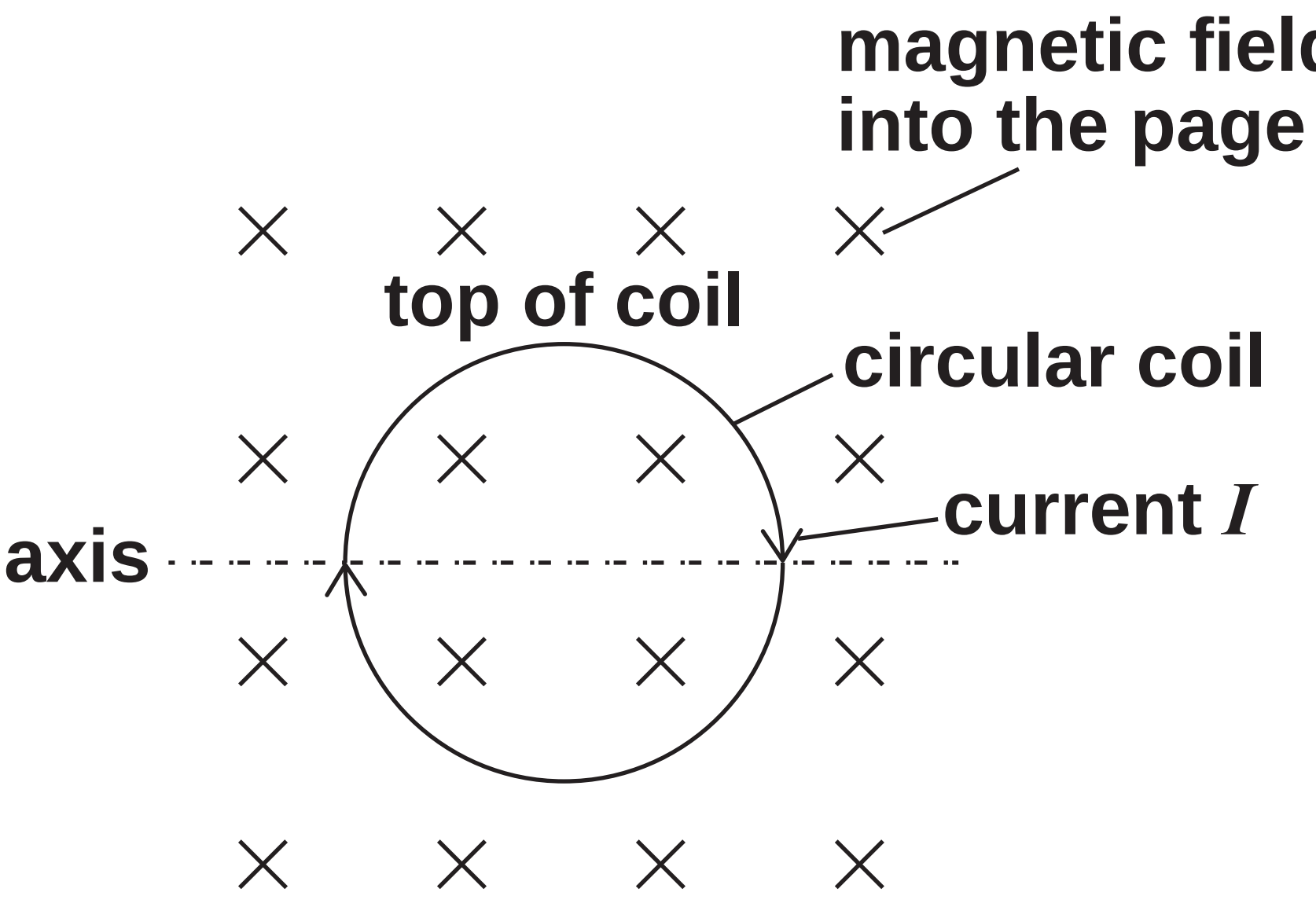
[1 mark]

- ⬭ **A** $20\ \mathrm{m\ s^{-1}}$
- ⬭ **B** $40\ \mathrm{m\ s^{-1}}$
- ⬭ **C** $80\ \mathrm{m\ s^{-1}}$
- ⬭ **D** $160\ \mathrm{m\ s^{-1}}$

[Turn over]

2	7

The diagram shows a clockwise current I in a circular coil placed in a uniform magnetic field B with the plane of the coil perpendicular to the magnetic field.



What is the effect on the coil of the interaction between the current and the magnetic field? [1 mark]

- A It rotates about the axis with the top moving out of the page.
- B It rotates about the axis with the top moving into the page.
- C It causes an increase in the diameter of the coil.
- D It causes a decrease in the diameter of the coil.

2	8

A transformer has an efficiency of 80%. It has 7000 turns on its primary coil and 175 turns on its secondary coil. When the primary of the transformer is connected to a 240 V ac supply, the secondary current is 8.0 A

What are the primary current and secondary voltage? [1 mark]

	Primary current / mA	Secondary voltage / V
A	250	6.0
B	160	6.0
C	250	9600
D	160	9600

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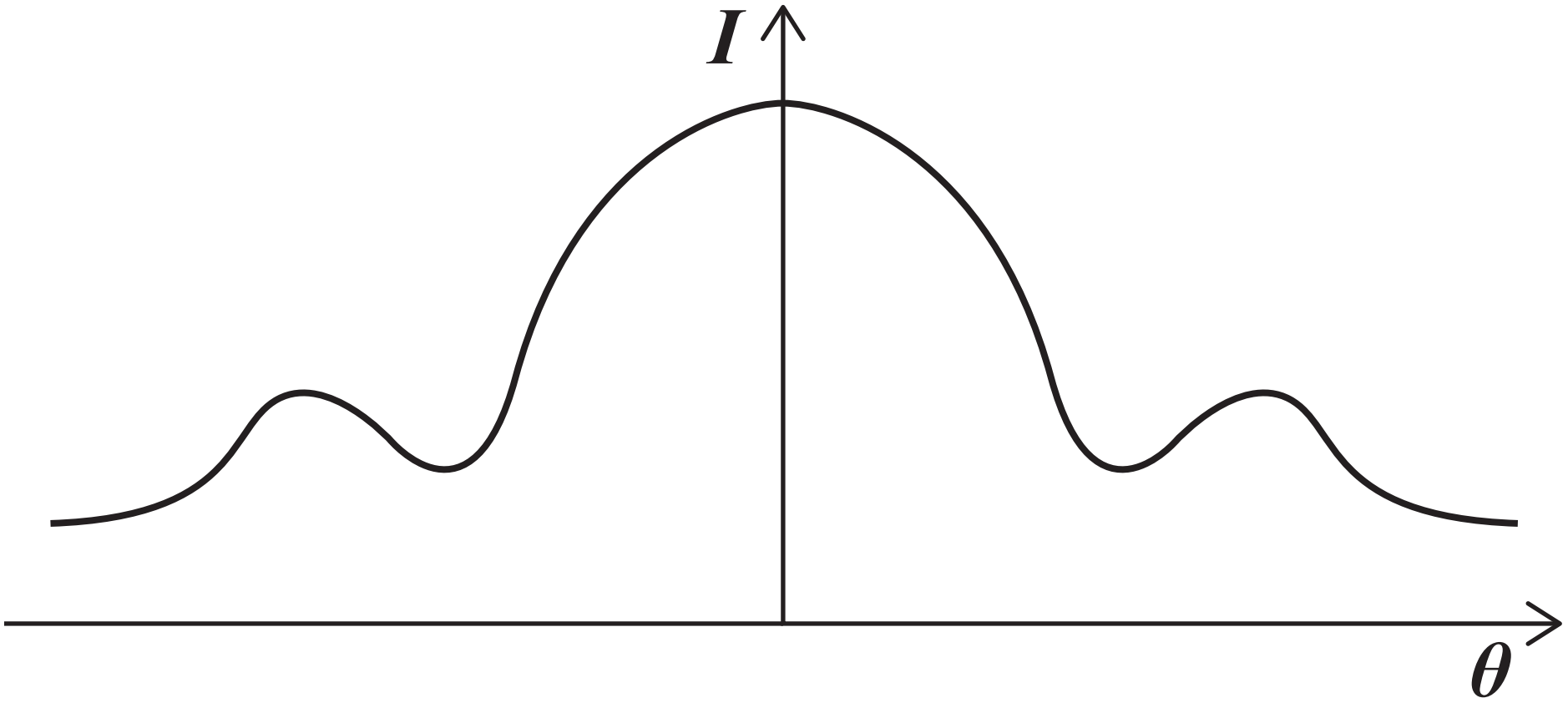
[Turn over]

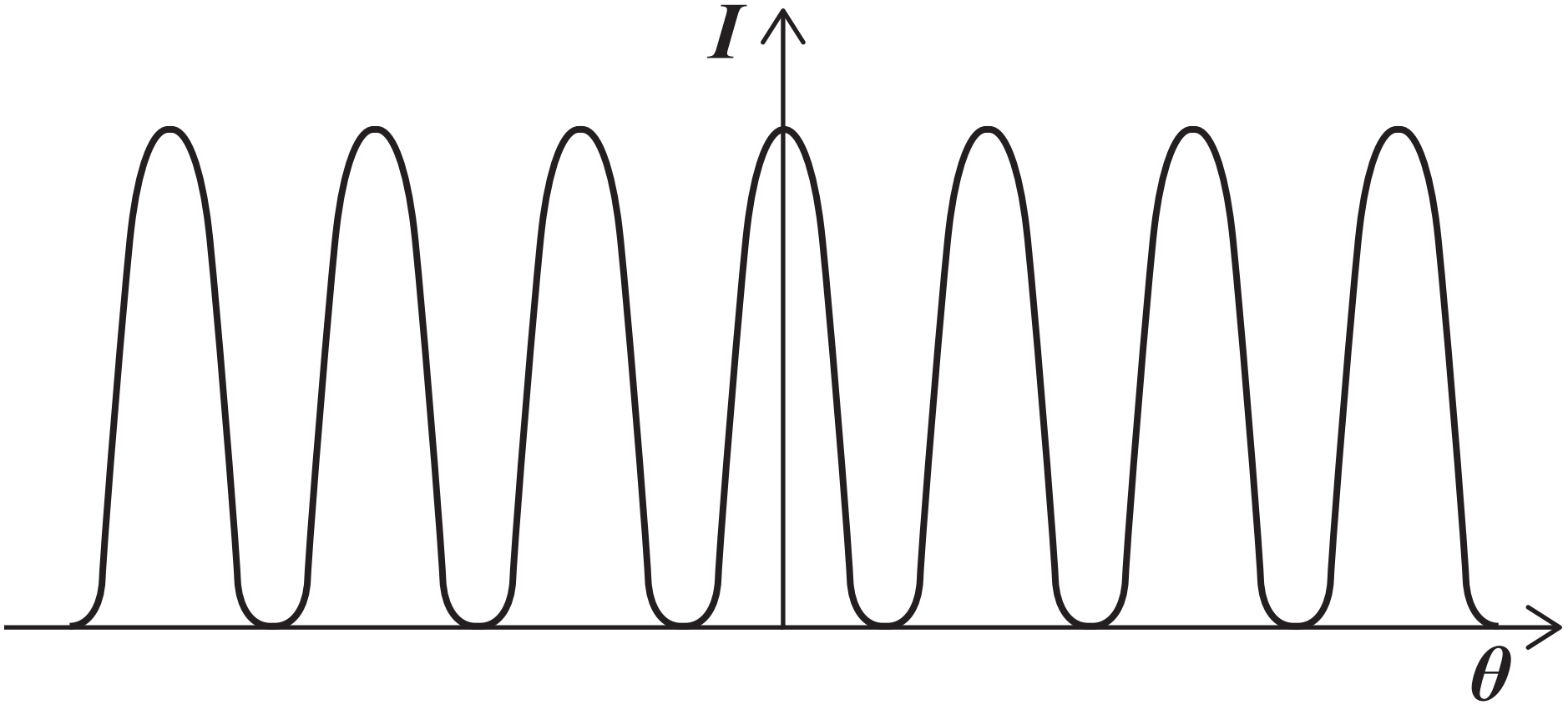
2 9

Which graph shows how intensity I varies with angle θ when electrons are diffracted by a nucleus? [1 mark]

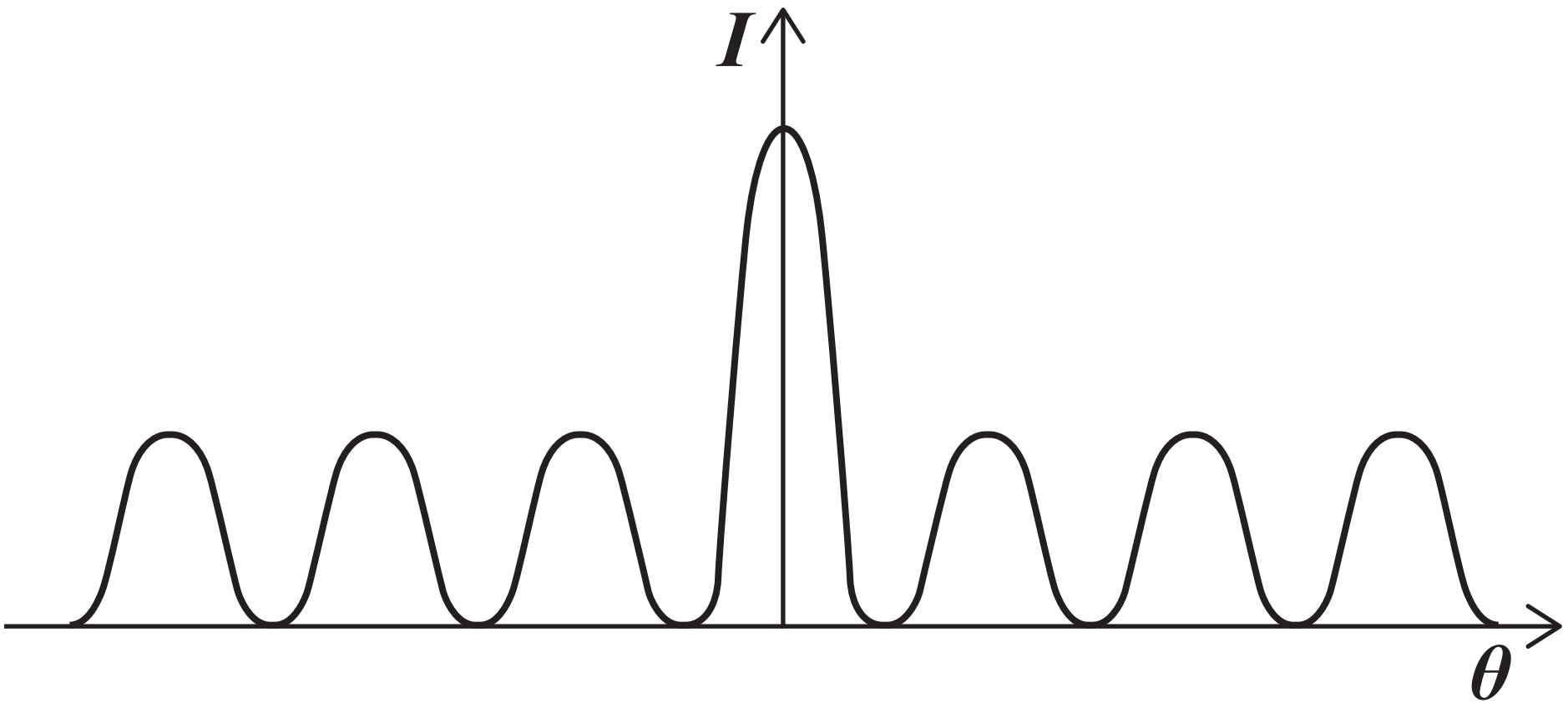
A



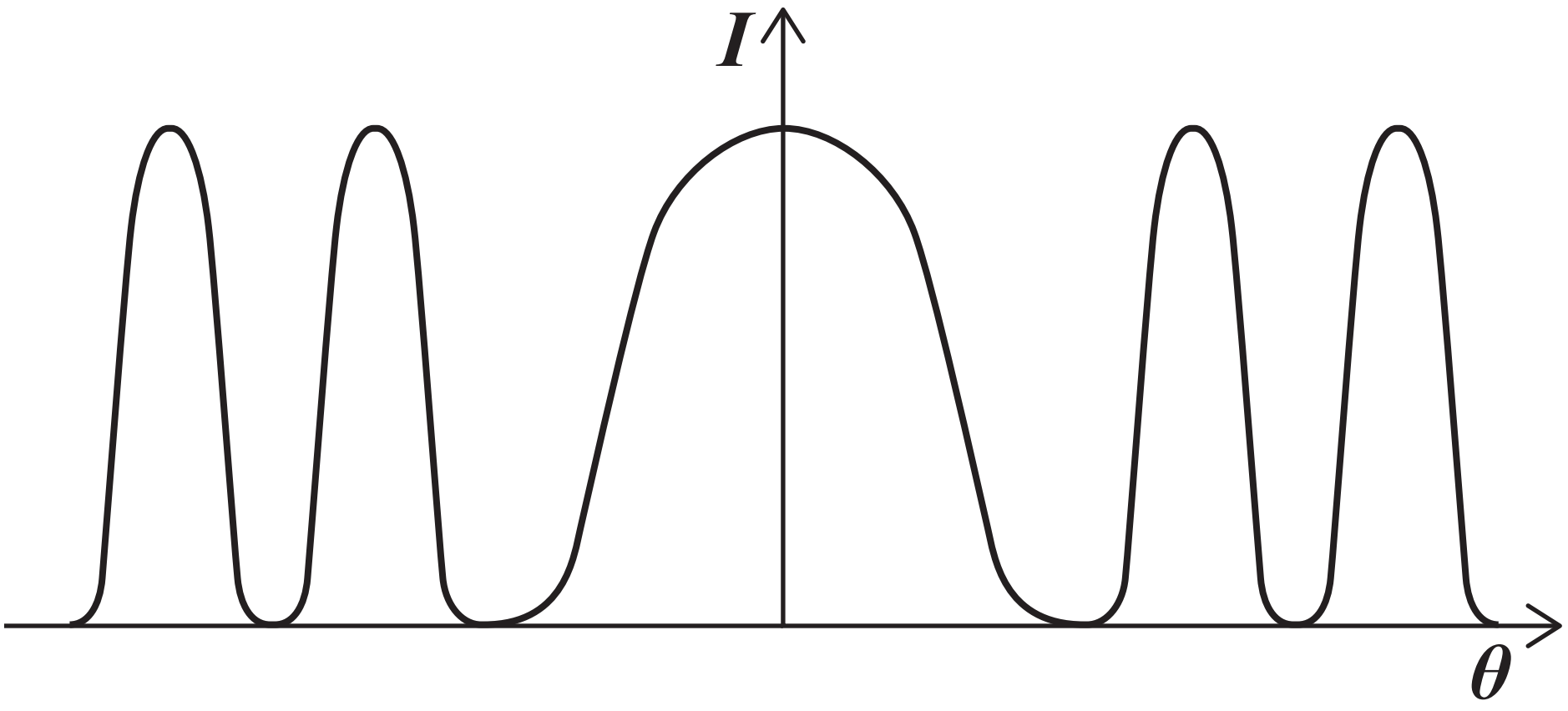
B



C



D



[Turn over]

3	0

The radius of a uranium $^{238}_{92}\mathrm{U}$ nucleus is 7.75×10^{-15} m

What is the radius of a $^{12}_{6}\mathrm{C}$ nucleus?

[1 mark]

- ⬭ **A** 1.10×10^{-18} m
- ⬭ **B** 3.91×10^{-16} m
- ⬭ **C** 2.86×10^{-15} m
- ⬭ **D** 3.12×10^{-15} m

3	1

During a single fission event of uranium-235 in a nuclear reactor the total mass lost is 0.23 u.
The reactor is 25% efficient.

How many events per second are required to generate 900 MW of power?
[1 mark]

- ⬭ **A** 1.1×10^{14}
- ⬭ **B** 6.6×10^{18}
- ⬭ **C** 1.1×10^{20}
- ⬭ **D** 4.4×10^{20}

[Turn over]

3 2

Which of the following substances can be used as a moderator in a nuclear reactor? [1 mark]

- ⬭ **A Boron**
- ⬭ **B Concrete**
- ⬭ **C Uranium-238**
- ⬭ **D Water**

25

END OF QUESTIONS

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For Examiner's Use	
Question	Mark
1	
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8–32	
TOTAL	