OXFORD AQA
INTERNATIONAL QUALIFICATIONS

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____
I declare this is my own work.

# INTERNATIONAL A-LEVEL
# PHYSICS

## Unit 3 Fields and their consequences

Wednesday 15 January 2025 | 07:00 GMT | Time allowed: 2 hours

**Materials**
For this paper you must have:
- a Data and Formulae Booklet as a loose insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate
- 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.
- All working must be shown.
- 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.

**Information**
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

| For Examiner's Use | |
|---|---|
| Question | Mark |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8–22 | |
| **TOTAL** | |

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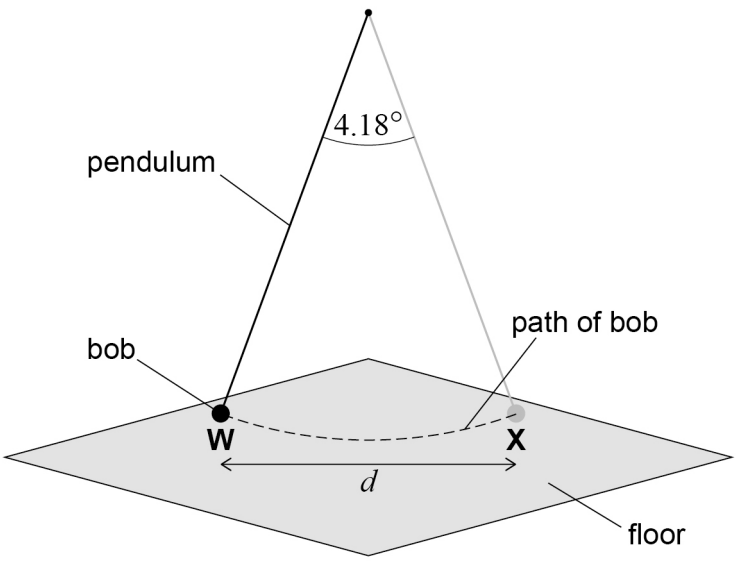
## Section A

Answer **all** questions in this section.

**0 1** **Figure 1** shows a simple pendulum of length $67.7\ \mathrm{m}$.
The pendulum bob is released from position **W** and swings in a vertical plane.

**Figure 1**

**not to scale**




The pendulum swings through an angle of $4.18°$. The bob just reaches position **X**.
The horizontal distance between **W** and **X** is $d$.

Air resistance is negligible.

**0 1 . 1** Calculate $d$.

**[2 marks]**

$d =$ _____ m

Do not write outside the box

**0 1 . 2** Calculate the maximum speed of the bob.

**[3 marks]**

maximum speed = _____ m $s^{-1}$

**Question 1 continues on the next page**

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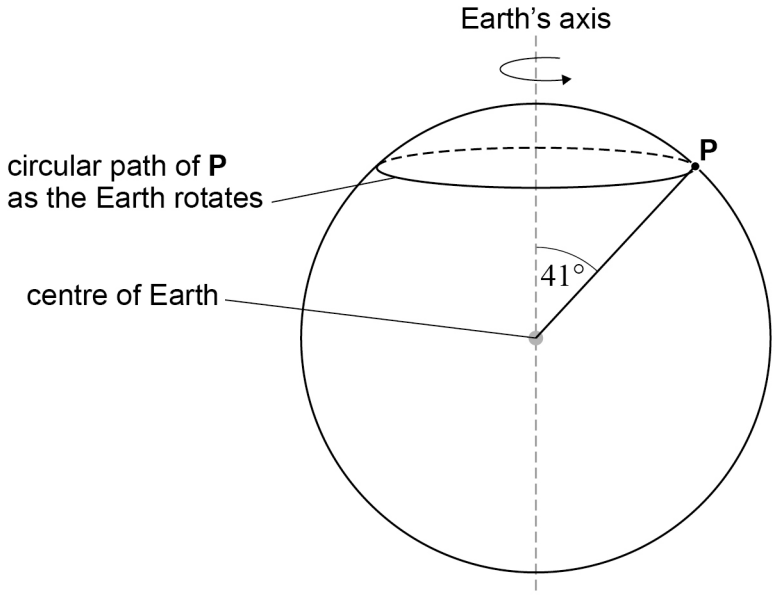
The pendulum is at point **P** on the surface of the Earth.

**0 1 . 3** **Figure 2** shows **P**.

The line joining **P** to the centre of the Earth is at an angle of 41° to the Earth's axis. Due to the Earth's rotation, **P** travels in a circular path about the Earth's axis.

**Figure 2**




Calculate the linear speed of **P** due to the rotation of the Earth.

**[2 marks]**

speed = _____ m s$^{-1}$

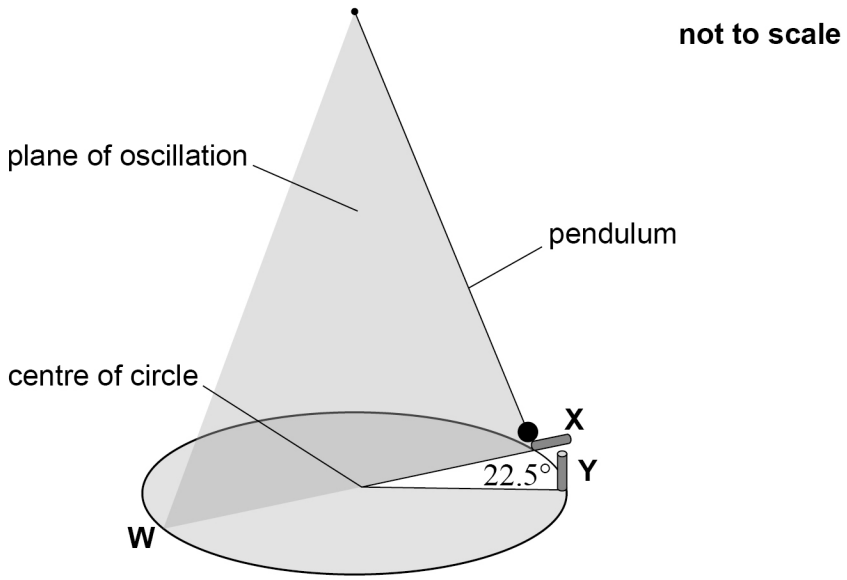
Do not write outside the box

**0 1 . 4** Due to the rotation of the Earth, the plane of oscillation of the pendulum rotates slowly about a vertical axis relative to the floor.
The plane of oscillation rotates through $360°$ in $31.8$ hours.

Pegs are placed on the floor at positions **X** and **Y** on a circle.
The angle between **X** and **Y**, measured at the centre of the circle, is $22.5°$ as shown in **Figure 3**.

**Figure 3** shows the pendulum just after it knocks over the peg at **X**.

**Figure 3**




The plane of oscillation continues to rotate relative to the floor. The amplitude of oscillation of the pendulum is unchanged.
After knocking over the peg at **X**, the pendulum goes through $n$ oscillations before knocking over the peg at **Y**.

Calculate $n$.

**[3 marks]**

$n =$ _____

10

**Turn over ►**

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**0 2** An unpowered spacecraft **B** orbits the Sun.
The orbit is not circular.
Assume that the only gravitational force on **B** is due to the Sun.

The following data are about **B**:

mass of **B** = 1600 kg
smallest distance between **B** and the centre of the Sun = $4.20 \times 10^{10}$ m
largest distance between **B** and the centre of the Sun = $1.37 \times 10^{11}$ m.

**0 2 . 1** Calculate the maximum gravitational force of the Sun on **B**.

**[2 marks]**

maximum gravitational force = _____ N

**0 2 . 2** The total orbital energy of a satellite is the sum of its kinetic energy and its gravitational potential energy.
The total energy of **B** is $-1.19 \times 10^{12}$ J.

Calculate the minimum speed of **B**.

**[3 marks]**

minimum speed = _____ m s$^{-1}$

Do not write outside the box

An unpowered spacecraft **C** is in a circular orbit of the Sun.
**C** has an orbital period of $1.45 \times 10^7$ s.

**0 2 . 3** Calculate the orbital radius of **C**.

**[3 marks]**

orbital radius = _____ m

**0 2 . 4** Explain which spacecraft, **B** or **C**, is moving on an equipotential.

**[1 mark]**

_____

_____

_____

9

**Turn over for the next question**

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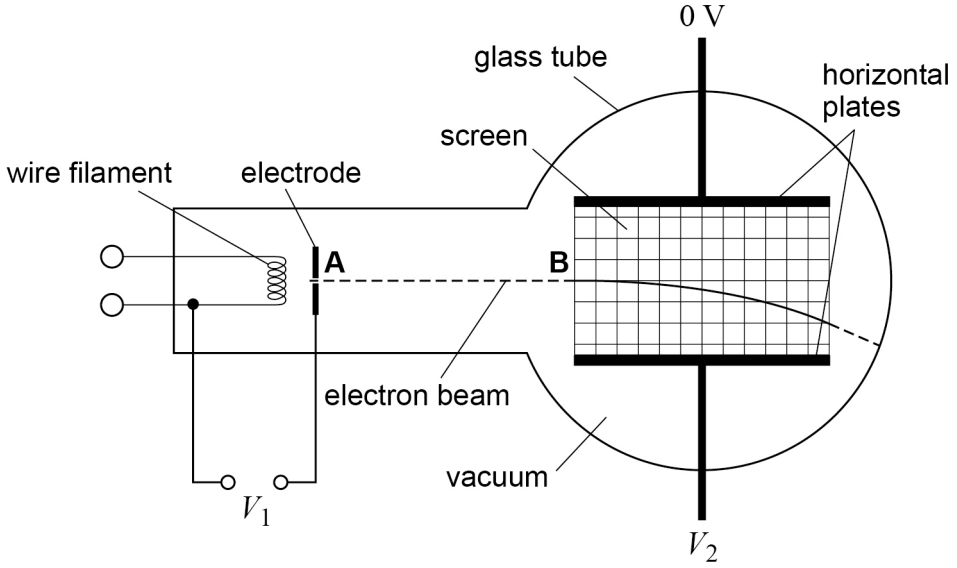
**0 3** **Figure 4** shows an arrangement that is used to investigate the properties of electrons.

**Figure 4**




Electrons are emitted from a wire filament with a negligible initial speed.
The electrons are accelerated through a potential difference $V_1$ towards an electrode.
The electrons that pass through the hole at **A** have a speed of $1.48 \times 10^7$ m s$^{-1}$.

**0 3 . 1** Calculate $V_1$.

**[2 marks]**

$V_1$ = _____ V

Do not write outside the box

**Figure 4** shows the electron beam entering a uniform electric field between two horizontal plates.
At **B**, the electrons are moving horizontally.

The uniform electric field causes the electrons to accelerate.

**0 3 . 2** Describe this acceleration.
Explain your answer.

**[3 marks]**

**Question 3 continues on the next page**

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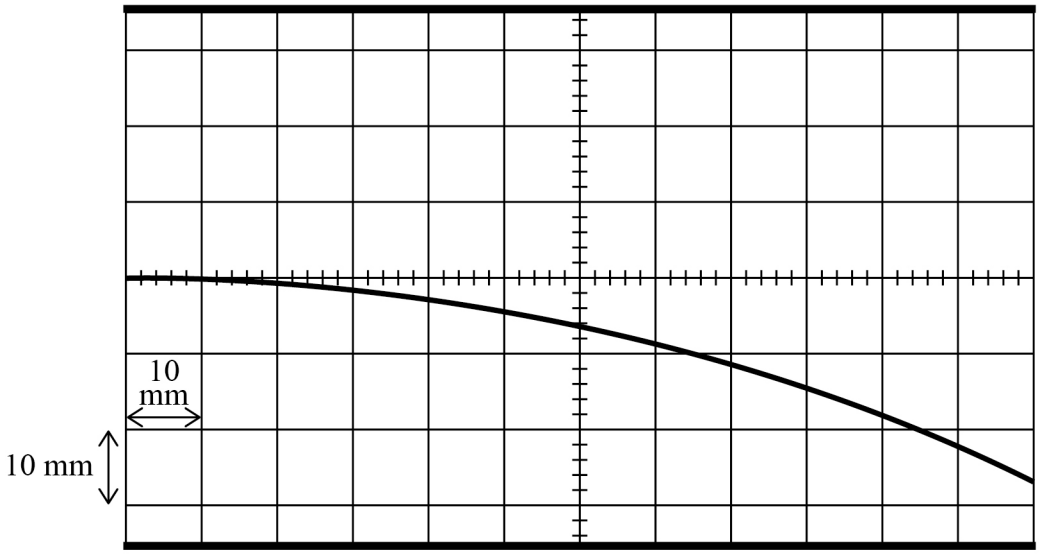
The curved line on **Figure 5** shows the path of electrons on the fluorescent screen between the horizontal plates.

**Figure 5**

**to scale**




Each square on the screen measures 10 mm by 10 mm.

**0 3 . 3** The horizontal component of an electron's velocity is $1.48 \times 10^7$ m s$^{-1}$.

Show that the time taken for the electron to cross the screen is about 8 ns.

**[1 mark]**

Do not write outside the box

**0 3 . 4** The potential difference across the plates is equal to $V_2$.

Determine $V_2$.

**[4 marks]**

$V_2 =$ _____ V

**0 3 . 5** The apparatus is enclosed in a glass tube.
Initially there is no air in the glass tube.
A fault occurs and some air leaks into the tube.

Explain **two** effects on the curved line seen on the screen.

**[2 marks]**

1 _____

_____

_____

2 _____

_____

_____

12

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**ANSWER IN THE SPACES PROVIDED**

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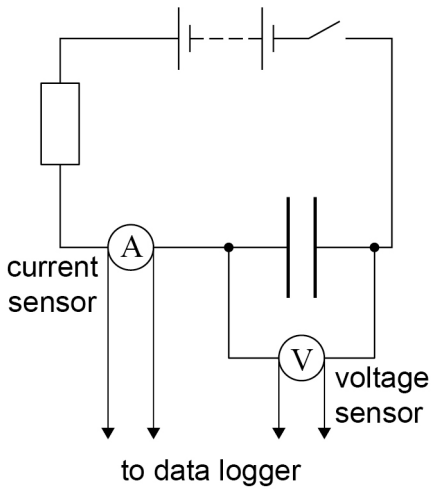
**0 4** **Figure 6** shows an arrangement for collecting data from a circuit that is used to charge a capacitor.
A data logger is connected to a current sensor and to a voltage sensor. The data are analysed.

**Figure 6**




The battery has an emf $\varepsilon$ and negligible internal resistance. The resistance of the resistor is $R$ and the capacitance of the capacitor is $C$.

The capacitor is initially uncharged.
The switch is then closed and the voltage $V_c$ across the capacitor and the current $I$ are recorded. Further readings of $V_c$ and $I$ are recorded at regular time intervals.

It can be shown that:

$$V_c = \varepsilon - IR$$

**Question 4 continues on the next page**

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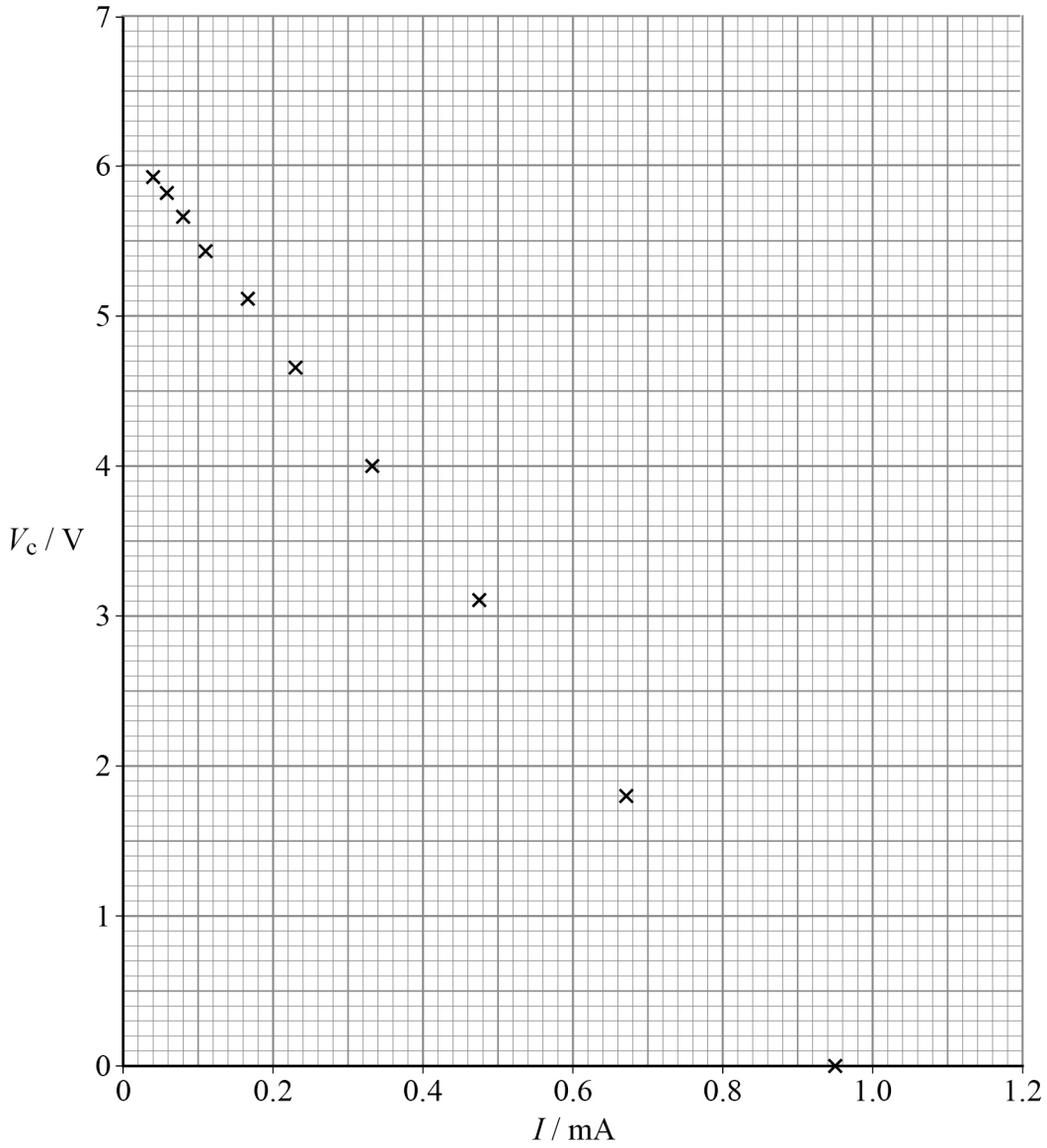
**Figure 7** shows the plot of $V_c$ against $I$.

**Figure 7**




**0 4 . 1** Determine $\varepsilon$.

**[1 mark]**

$\varepsilon =$ _____ V

**0 4 . 2** Determine $R$.

**[2 marks]**

$R =$ _____ Ω

Do not write outside the box

The data shown on **Figure 7** were recorded at time intervals of $5.0\ \text{ms}$.

**0 4 . 3** Explain why the plotted points on **Figure 7** become closer together as $V_c$ increases.

**[1 mark]**

_____

_____

_____

**0 4 . 4** Determine the time constant for the circuit in **Figure 6** on page 13.
Go on to calculate $C$.

**[5 marks]**

time constant = _____ s

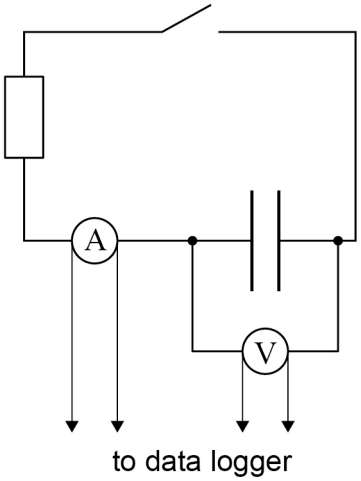
$C$ = _____ F

**Question 4 continues on the next page**

Do not write outside the box

**0 4 . 5** When the capacitor is fully charged the switch is opened. The battery is then removed from the circuit.
**Figure 8** shows the new circuit for the charged capacitor.

**Figure 8**




The switch is then closed and the capacitor discharges through the resistor.

Draw, on **Figure 9**, a line showing the variation of the magnitude of $V_c$ with the magnitude of $I$ for this experiment.

**[2 marks]**

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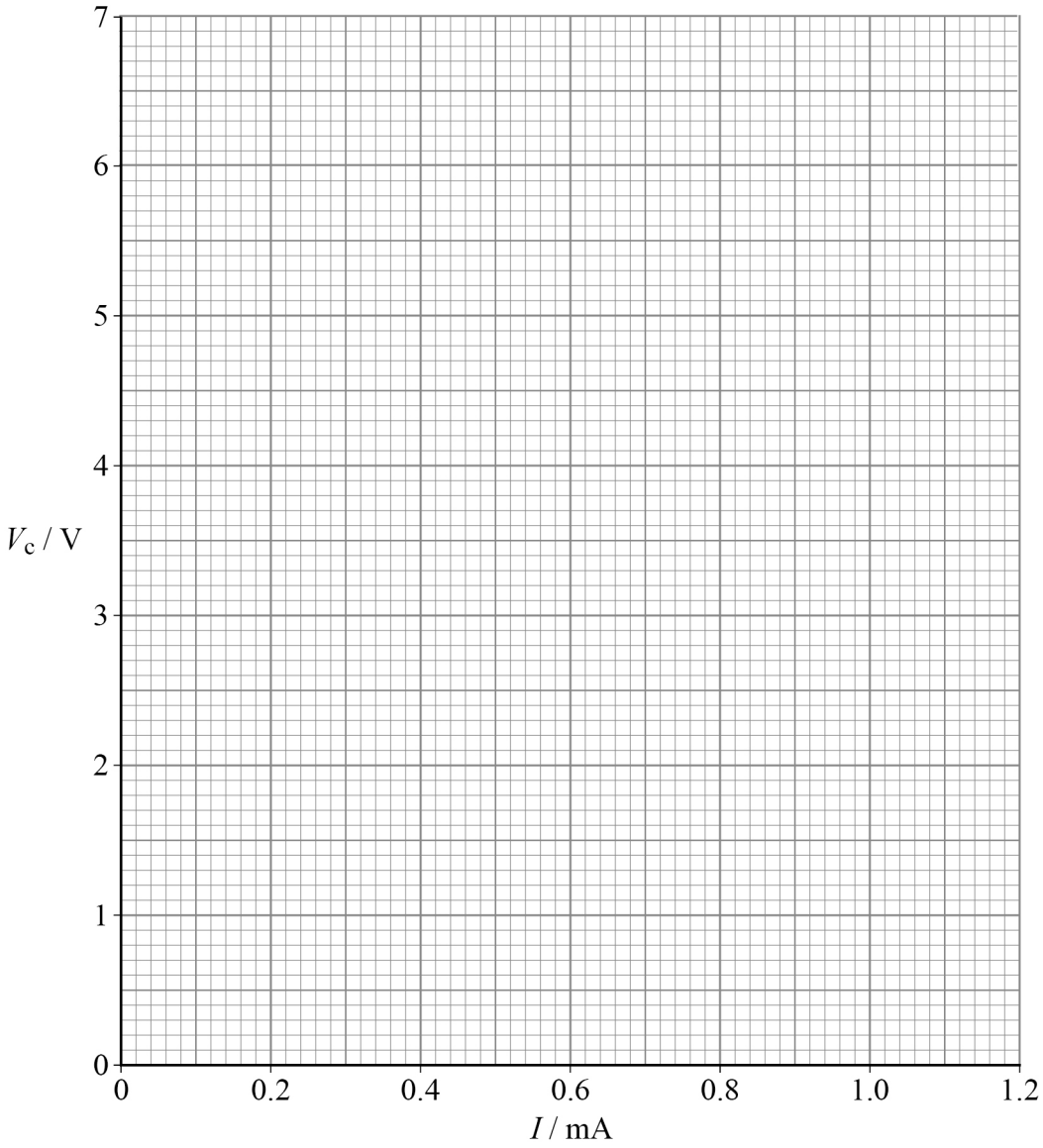
**Figure 9**




**0 4 . 6** Suggest why a data logger and sensors were used in these experiments rather than an ammeter, a voltmeter and a stopwatch.

**[1 mark]**

_____

_____

12

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**0 5** Cobalt-60 ($^{60}Co$) is a radioactive isotope used in some school laboratories.

A school has a sealed $^{60}Co$ source with an activity of 62 kBq.

half-life of $^{60}Co$ = $1.66 \times 10^{8}$ s
molar mass of $^{60}Co$ = 60.0 g $mol^{-1}$

**0 5 . 1** Calculate, in g, the mass of $^{60}Co$ in the sealed source.

**[3 marks]**

mass = _____ g

**0 5 . 2** The school plans to replace the source when the activity of the $^{60}Co$ has decreased to 9.0 kBq.

Calculate, in years, the time before the source needs to be replaced.

**[3 marks]**

time = _____ years

6

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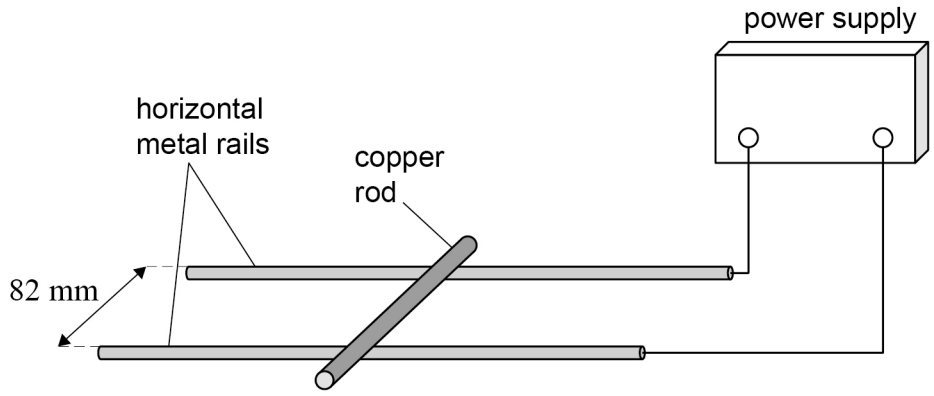
**0 6 . 1** Define the tesla.

**[1 mark]**

For all parts of **Question 6**, assume that the Earth's magnetic flux density is negligible.

**0 6 . 2** **Figure 10** shows a dc power supply connected to two horizontal metal rails. A copper rod rests on the rails, completing the circuit. Initially the power supply is off.

**Figure 10**




A uniform magnetic field is applied vertically downwards between the two rails. When the power supply is switched on, the copper rod rolls to the left.

Label with a + sign the positive terminal of the power supply in **Figure 10**.
Explain your answer.

**[2 marks]**

**Question 6 continues on the next page**

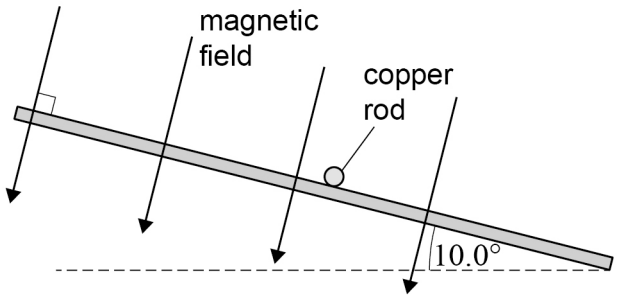
Do not write outside the box

**0 6 . 3** The power supply is switched off.
The rails are tilted at an angle of $10.0°$ to the horizontal.
The direction of the magnetic field is changed so that it remains at $90°$ to the rails.
The power supply is switched on and the rod is placed on the rails. The combination of magnetic and gravitational forces acting on the rod keep it stationary.

**Figure 11** shows a side view of the arrangement.

**Figure 11**

**side view**




The current in the rod is $2.75\ \mathrm{A}$ and the magnetic flux density is $0.11\ \mathrm{T}$.
The distance between the rails is $82\ \mathrm{mm}$.

Calculate the mass of the rod.

**[3 marks]**

mass = _____ kg

Do not write outside the box

**0 6 . 4** The connections to the power supply are removed.

The rails remain tilted at an angle of $10.0°$ to the horizontal and the magnetic field is unchanged.
The rod is placed on the rails and released.
The rod accelerates down the rails.

State and explain what happens to the emf induced across the rod.

**[2 marks]**

_____

_____

_____

_____

_____

_____

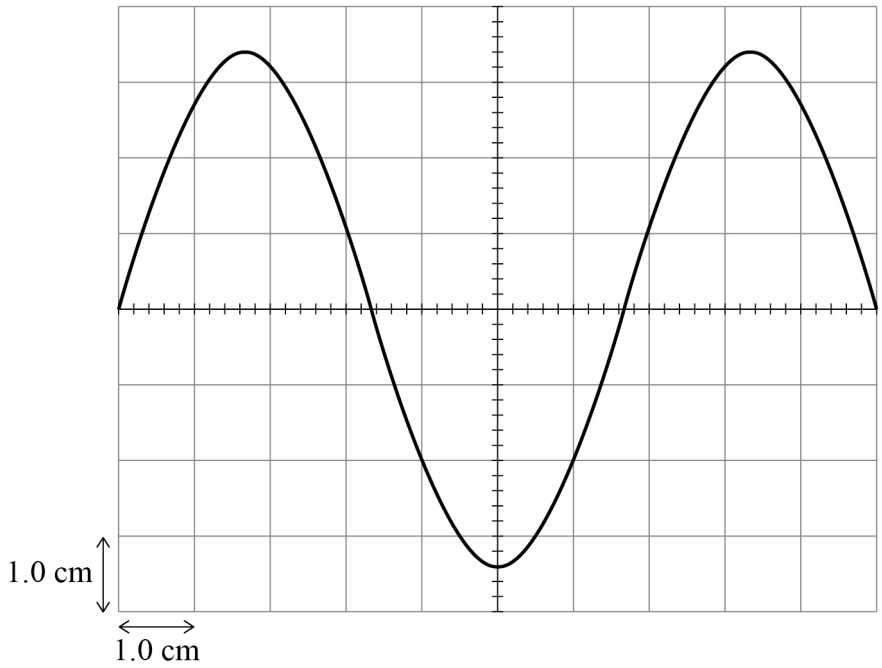
8

**Turn over for the next question**

Do not write outside the box

**0 7** **Figure 12** shows the oscilloscope trace of the output of an ac power supply.

**Figure 12**




The root mean square (rms) voltage is 12.0 V and the frequency is 60.0 Hz.

**0 7 . 1** Determine:

- the $y$-gain setting in $\mathrm{V\ cm^{-1}}$
- the time-base setting in $\mathrm{ms\ cm^{-1}}$.

**[4 marks]**

$y$-gain = _____ $\mathrm{V\ cm^{-1}}$

time-base = _____ $\mathrm{ms\ cm^{-1}}$

Do not write outside the box

**0 7 . 2** The output of the power supply is connected to the primary coil of a transformer.
The rms voltage output of the transformer is 3.0 V.
The number of turns on the secondary coil of the transformer is 4500

Calculate the number of turns on the primary coil.

**[1 mark]**

number of turns = _____

**0 7 . 3** A resistor **R** is connected across the secondary coil.
The rms voltage across **R** is measured.

State the other measurements needed to determine the efficiency of the transformer.

**[1 mark]**

_____

_____

_____

**0 7 . 4** State **two** causes of inefficiency in a transformer.

**[2 marks]**

1 _____

_____

2 _____

_____

8

**END OF SECTION A**

Do not write outside the box

## Section B

Each of the questions in this section 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 pages for this working.

**0 8** A bob on the end of a light string is rotated in a vertical circle at a constant angular speed of $5.5\ \text{rad s}^{-1}$.
The bob has a mass of $0.20\ \text{kg}$ and the circle has a radius of $0.75\ \text{m}$.

What is the **minimum** tension in the string?

**[1 mark]**

**A** $2.0\ \text{N}$

**B** $2.6\ \text{N}$

**C** $6.1\ \text{N}$

**D** $6.5\ \text{N}$

Do not write outside the box

**0 9** A car is travelling on a circular track.
The car completes four revolutions of the track in one minute.

What is the average angular speed of the car?

**[1 mark]**

**A** $0.030\ \text{rad s}^{-1}$

**B** $0.10\ \text{rad s}^{-1}$

**C** $0.42\ \text{rad s}^{-1}$

**D** $1.6\ \text{rad s}^{-1}$

**1 0** A charged particle is moving with a velocity $v$ at right angles to a magnetic field of flux density $B$.
The acceleration of the particle due to the magnetic field is $a$.

What is the specific charge of the particle?

**[1 mark]**

**A** $\dfrac{Bv^2}{a}$

**B** $\dfrac{Bv}{a}$

**C** $\dfrac{a}{Bv}$

**D** $\dfrac{a}{Bv^2}$

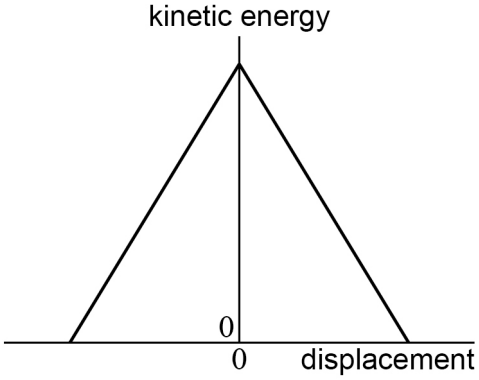
Do not write outside the box

**1 1** A mass on a spring undergoes simple harmonic motion.

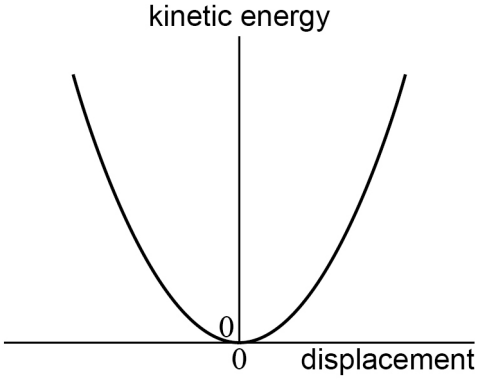
Which graph shows the variation with displacement of the kinetic energy of the oscillating system?

**[1 mark]**

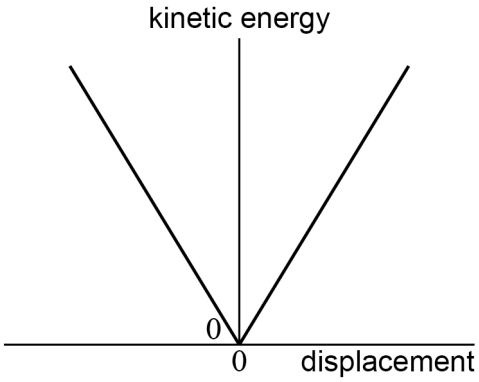
**A**



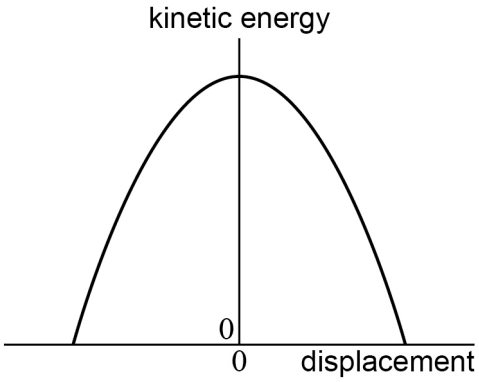

**B**




**C**




**D**




**A** ⬭

**B** ⬭

**C** ⬭

**D** ⬭

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**1 2** A satellite is in a circular orbit of radius $R$ around a planet of mass $M$.
The orbital radius of the satellite is increased by a small distance $\Delta r$,
where $\Delta r \ll R$.

The difference between the gravitational potentials of the two orbits is $\Delta V$.

What is an approximation for $\Delta V$?

**[1 mark]**

**A** $\dfrac{GM\Delta r}{R^2}$ ⬭

**B** $\dfrac{GM\Delta r}{R}$ ⬭

**C** $\dfrac{GM}{R + \Delta r}$ ⬭

**D** $\dfrac{GM}{\Delta r}$ ⬭

**1 3** A capacitor consists of two parallel plates with a dielectric between the plates.
The capacitor is connected to a battery and becomes fully charged.
The dielectric is then removed from between the plates without disconnecting the battery.

What happens to the charge on the plates and the energy stored on the capacitor?

**[1 mark]**

| | **Charge** | **Energy stored** | |
|---|---|---|---|
| **A** | decreases | increases | ⬭ |
| **B** | increases | decreases | ⬭ |
| **C** | increases | increases | ⬭ |
| **D** | decreases | decreases | ⬭ |

Do not write outside the box

**1 4** A charge of $1.5\ \text{mC}$ is stored on a capacitor of capacitance $22\ \text{mF}$.
The capacitor is discharged until the pd across the capacitor is halved.

What is the change in the energy stored by the capacitor?

**[1 mark]**

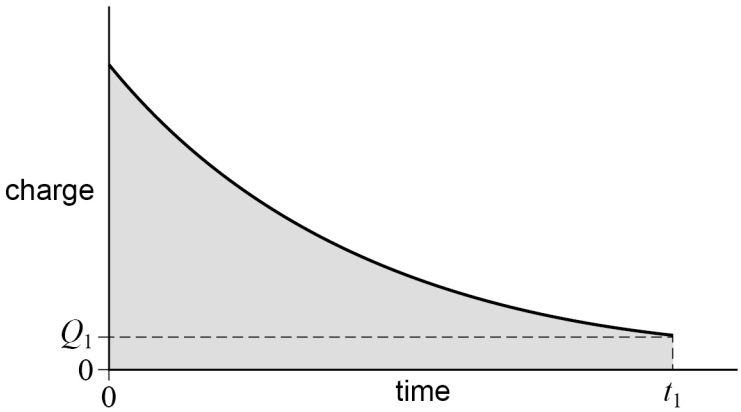
**A** $13\ \mu\text{J}$

**B** $26\ \mu\text{J}$

**C** $38\ \mu\text{J}$

**D** $78\ \mu\text{J}$

**1 5** A charged capacitor is discharged through a resistor of resistance $R$.
A graph is plotted of the charge on the capacitor against time.




After time $t_1$ the charge on the capacitor is $Q_1$.

What is the capacitance of the capacitor?

**[1 mark]**

**A** $\dfrac{t_1}{R}$

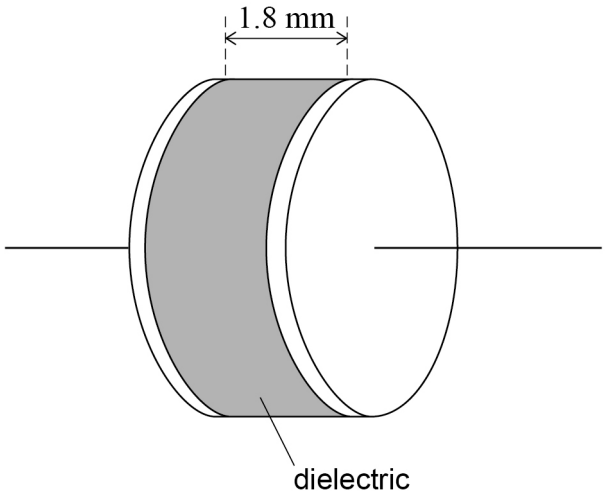
**B** $\dfrac{\text{area under the graph}}{RQ_1}$

**C** $-\dfrac{\text{area under the graph}}{R \times \text{gradient at } (t_1, Q_1) \times t_1}$

**D** $-\dfrac{Q_1}{R \times \text{gradient at } (t_1, Q_1)}$

Do not write outside the box

**1 6** A parallel-plate capacitor is made from two identical circular discs that completely overlap.




A sheet of dielectric material of thickness 1.8 mm fills the space between the plates.
The material has a relative permittivity of 2.4
The capacitance of the capacitor is 2.2 nF.

What is the diameter of the discs?

**[1 mark]**

**A** 0.24 m

**B** 0.49 m

**C** 0.58 m

**D** 1.17 m

**Turn over for the next question**

Do not write outside the box

**1 7** At a distance $y$ from an isolated point charge, the electric potential is $V$ and the electric field strength is $E$.

What are the electric potential and the electric field strength at a distance $2y$ from the charge?

**[1 mark]**

| | Electric potential | Electric field strength | |
|---|---|---|---|
| **A** | $\frac{V}{2}$ | $\frac{E}{2}$ | ⬭ |
| **B** | $\frac{V}{2}$ | $\frac{E}{4}$ | ⬭ |
| **C** | $\frac{V}{4}$ | $\frac{E}{2}$ | ⬭ |
| **D** | $\frac{V}{4}$ | $\frac{E}{4}$ | ⬭ |

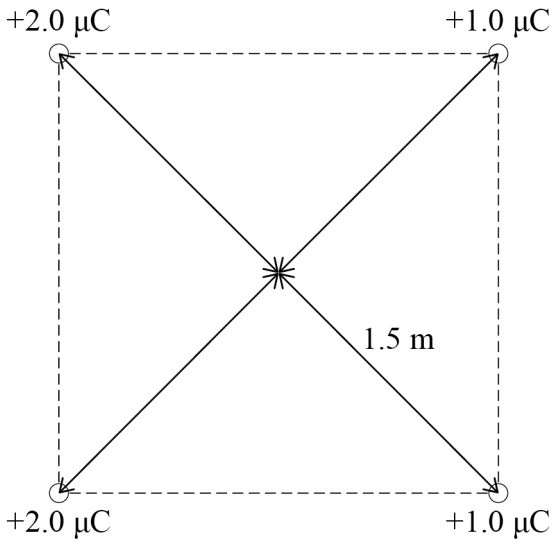
**1 8** Which row identifies a vector quantity and a scalar quantity?

**[1 mark]**

| | Vector | Scalar | |
|---|---|---|---|
| **A** | gravitational field strength | electric potential | ⬭ |
| **B** | gravitational field strength | electric field strength | ⬭ |
| **C** | gravitational potential | electric potential | ⬭ |
| **D** | electric potential | gravitational field strength | ⬭ |

Do not write outside the box

**1 9** Four point charges are at the corners of a square.




What is the electric potential at the centre of the square?

**[1 mark]**

**A** $1.2 \times 10^4$ V

**B** $2.4 \times 10^4$ V

**C** $3.6 \times 10^4$ V

**D** $4.0 \times 10^4$ V

**Turn over for the next question**

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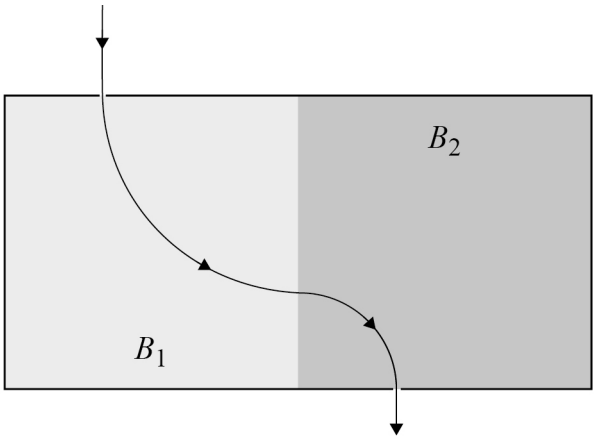
**2 0** A proton passes through two evacuated chambers.
The chambers contain uniform magnetic fields of magnetic flux density $B_1$ and $B_2$.
The path of the proton is at right angles to the magnetic field in each chamber.
The diagram shows the path of the proton from above.




$$x = \frac{\text{speed in second chamber}}{\text{speed in first chamber}}$$

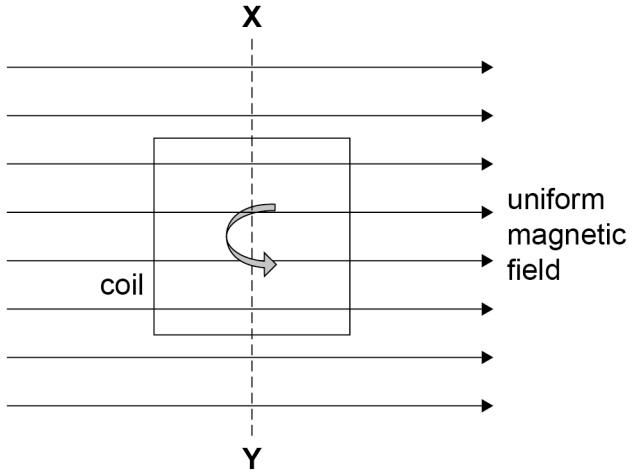
Which row describes $x$ and the directions of $B_1$ and $B_2$?

**[1 mark]**

| | $x$ | Direction of $B_1$ | Direction of $B_2$ | |
|---|---|---|---|---|
| **A** | >1 | out of the page | into the page | ⬭ |
| **B** | 1 | into the page | out of the page | ⬭ |
| **C** | 1 | out of the page | into the page | ⬭ |
| **D** | >1 | into the page | out of the page | ⬭ |

The following information is for Questions **21** and **22**.

A square coil of side $0.12\ \mathrm{m}$ has $20$ turns.
The coil rotates with a frequency of $75\ \mathrm{Hz}$ in a uniform magnetic field.
The magnetic flux density is $45\ \mathrm{mT}$.
The axis of rotation of the coil **XY** is at right angles to the magnetic field.




**2 1** What is the maximum emf induced in the coil?

**[1 mark]**

**A** $0.30\ \mathrm{V}$ ⬭

**B** $1.0\ \mathrm{V}$ ⬭

**C** $6.1\ \mathrm{V}$ ⬭

**D** $51\ \mathrm{V}$ ⬭

**2 2** What is the flux linkage at the instant when the minimum emf is induced in the coil?

**[1 mark]**

**A** $0$ ⬭

**B** $0.65\ \mathrm{mWb}$ ⬭

**C** $13\ \mathrm{mWb}$ ⬭

**D** $110\ \mathrm{mWb}$ ⬭

15

**END OF QUESTIONS**

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**There are no questions printed on this page**

**DO NOT WRITE ON THIS PAGE**
**ANSWER IN THE SPACES PROVIDED**

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