OXFORD

INTERNATIONAL
AQA EXAMINATIONS

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

Tuesday 21 January 2020 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.

**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 | |
| 6–35 | |
| **TOTAL** | |

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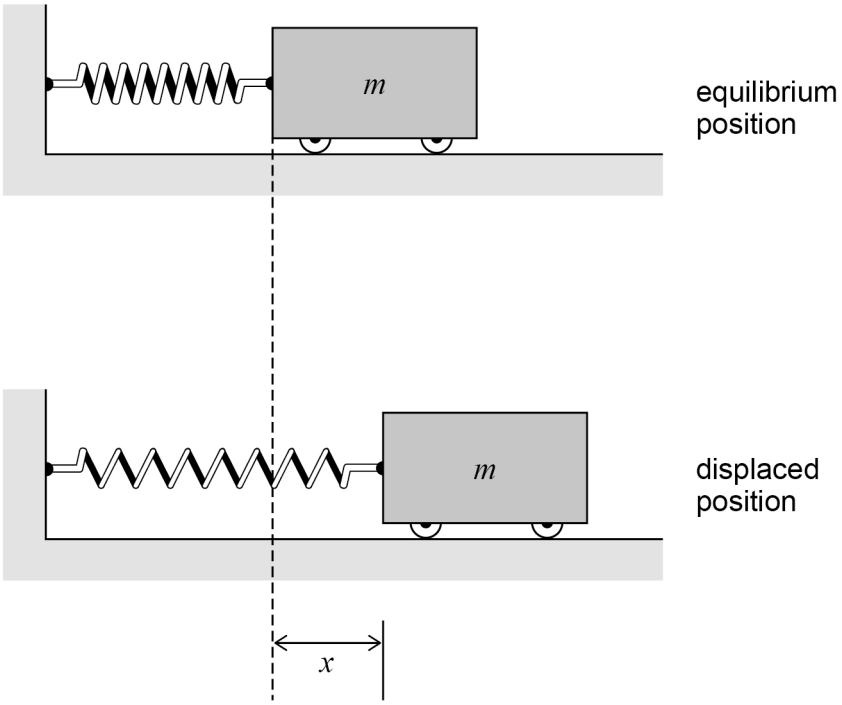
## Section A

Answer **all** questions in this section.

**0 1** A student connects a trolley of mass $m$ to a horizontal spring, as shown in **Figure 1**. The trolley is displaced horizontally from the equilibrium position and oscillates. Any damping of the trolley's motion is negligible.

**Figure 1**




**0 1 . 1** The student uses a stopwatch to determine the time period $T$ of the mass–spring system.

State **two** procedures the student can use to minimise the uncertainty in $T$.

**[2 marks]**

1 _____

_____

_____

_____

2 _____

_____

_____

_____

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**0 1 . 2** The resultant force $F$ on the oscillating trolley varies with its displacement $x$ from the equilibrium position by:

$$F = -kx$$

where $k$ is the spring constant.

Explain the physical significance of the negative sign in this equation.

**[1 mark]**

**0 1 . 3** Show how the equation for the resultant force $F$ on the trolley can be combined with $F = ma$ and other equations to give

$$T = 2\pi\sqrt{\frac{m}{k}}$$

**[4 marks]**

**Turn over for the next question**

7

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**0 2** **Figure 2** shows a capacitor and a switch **S** connected to a parallel combination of two resistors, $\mathbf{R_1}$ and $\mathbf{R_2}$. The initial potential difference across the capacitor is $5.0\ \text{V}$ and the initial charge, in C, on the capacitor is $Q_0$.

**Figure 2**

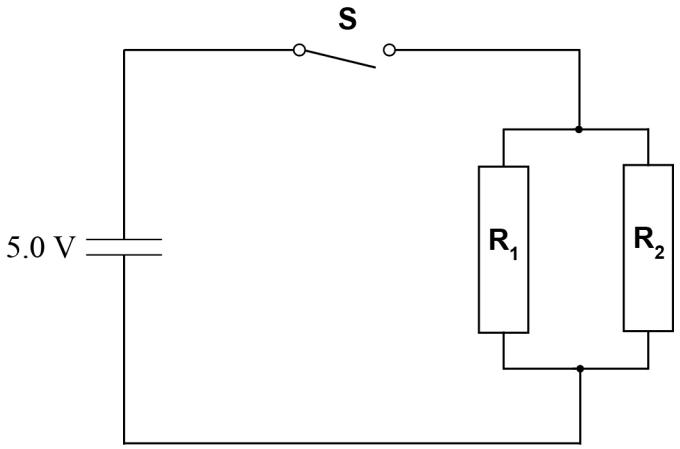
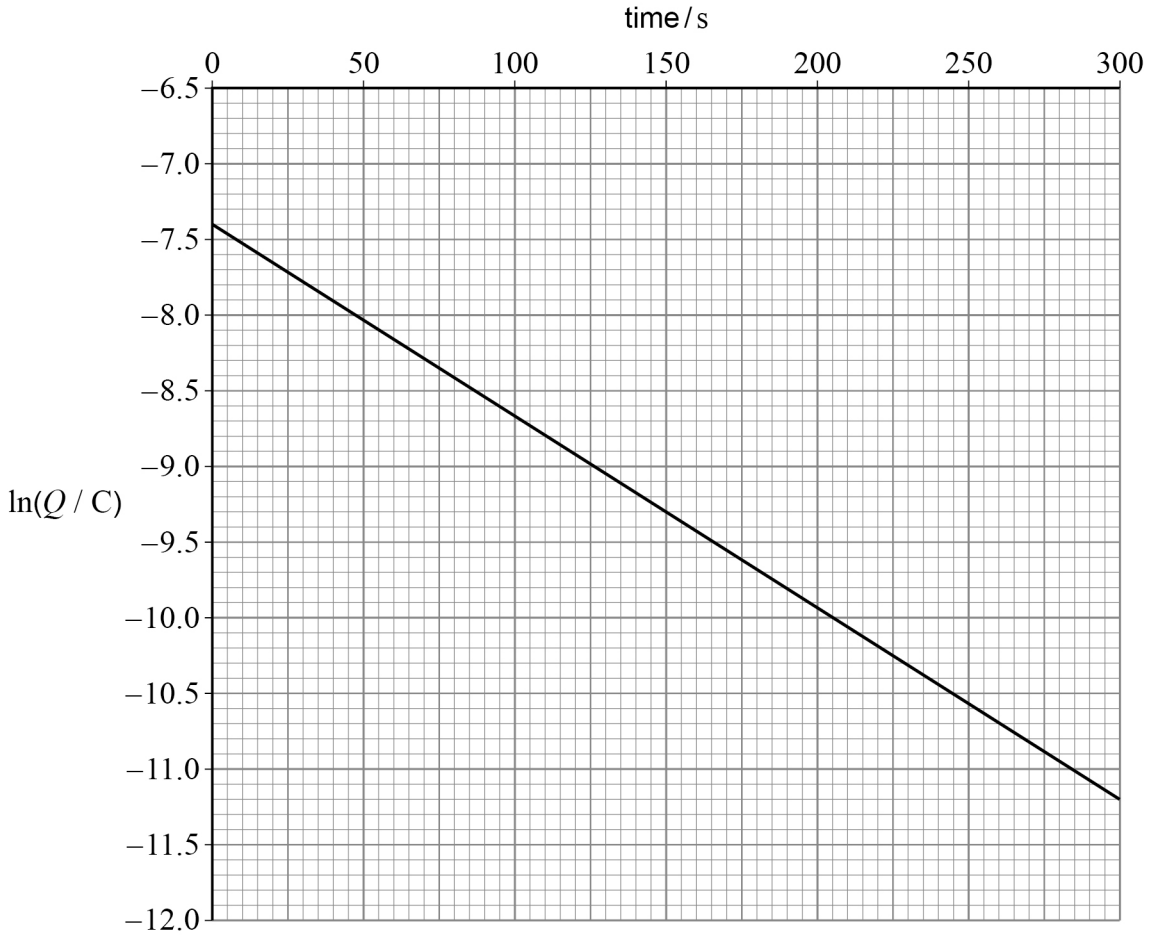



**Figure 3** shows the variation of $\ln(Q / \text{C})$ with time after **S** is closed.

**Figure 3**



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**0 2 . 1** Determine $Q_0$.

**[2 marks]**

$Q_0 =$ _____ C

**0 2 . 2** Show that the capacitance of the capacitor is approximately $120\ \mu F$.

**[1 mark]**

**0 2 . 3** Show, using **Figure 3**, that the time constant of the circuit is approximately $80\ s$.

**[3 marks]**

**Question 2 continues on the next page**

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**0 2 . 4** The resistance of $\mathbf{R_1}$ is $3.2\ \text{M}\Omega$.

Calculate, in $\text{M}\Omega$, the resistance of $\mathbf{R_2}$.

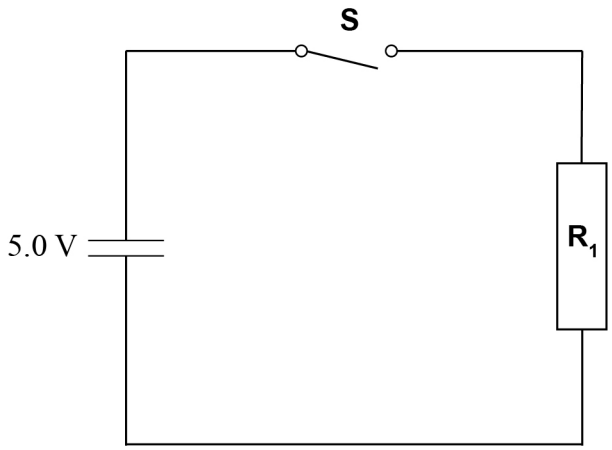
**[3 marks]**

resistance of $\mathbf{R_2}$ = _____ $\text{M}\Omega$

Do not write outside the box

**0 2 . 5** **Figure 4** shows the circuit with **S** open and $R_2$ removed.

**Figure 4**




The capacitor is recharged so that the initial potential difference across the capacitor is 5.0 V.
**S** is now closed.

Compare the initial rate of discharge of the capacitor in **Figure 4** with the initial rate of discharge of the capacitor in **Figure 3**.

**[3 marks]**

12

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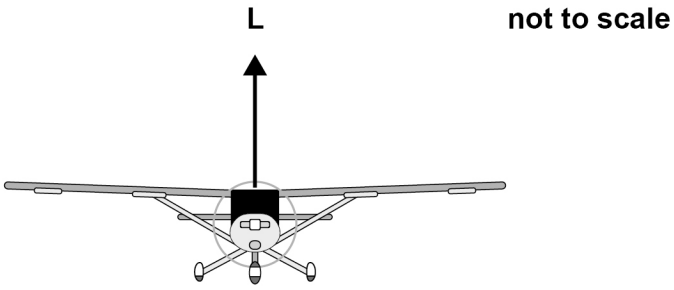
**0 3** **Figure 5** shows an aircraft flying at a constant height. A lift force **L** acts at right angles to the aircraft's wings. The magnitude of **L** depends on the speed of the aircraft.

**Figure 5**




The mass of the aircraft is 1100 kg.

**0 3 . 1** Calculate the magnitude of **L**.

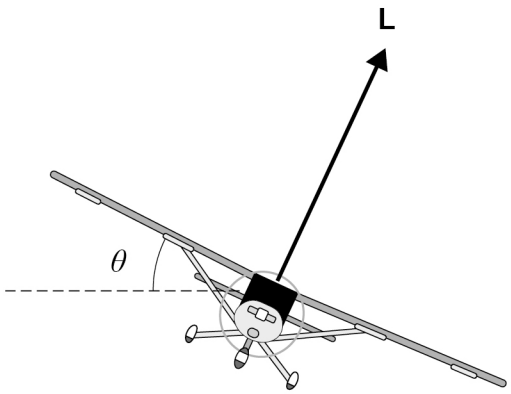
**[1 mark]**

magnitude of **L** = _____ N

*Do not write outside the box*

**0 3 . 2** **Figure 6** shows the aircraft travelling at an increased speed with its wings making an angle $\theta$ to the horizontal.
The magnitude of **L** has increased. The aircraft moves in a horizontal circle at a constant speed.

**Figure 6**




**not to scale**

A resultant force **R** acts on the aircraft in **Figure 6**. **R** is produced by the weight **W** of the aircraft and **L**.

Draw, in the space below, a vector diagram to show how the addition of **W** and **L** produces **R**.

**[2 marks]**

**Question 3 continues on the next page**

*Do not write outside the box*

**0 3 . 3** In **Figure 6**, $\theta = 25°$.

Show that **L** is approximately $12\ \text{kN}$.

**[2 marks]**

**0 3 . 4** When $\theta = 25°$, the radius of the circle is $900\ \text{m}$.

Calculate the speed of the aircraft.

**[3 marks]**

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

Do not write outside the box

**0 3 . 5** The angle $\theta$ is increased to more than $25°$. The speed of the aircraft does not change from the speed in Question **03.4**.

State and explain the changes in the motion of the aircraft.

**[4 marks]**

12

**Turn over for the next question**

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**0 4** This question is about the gravitational fields of the Earth and its satellites.

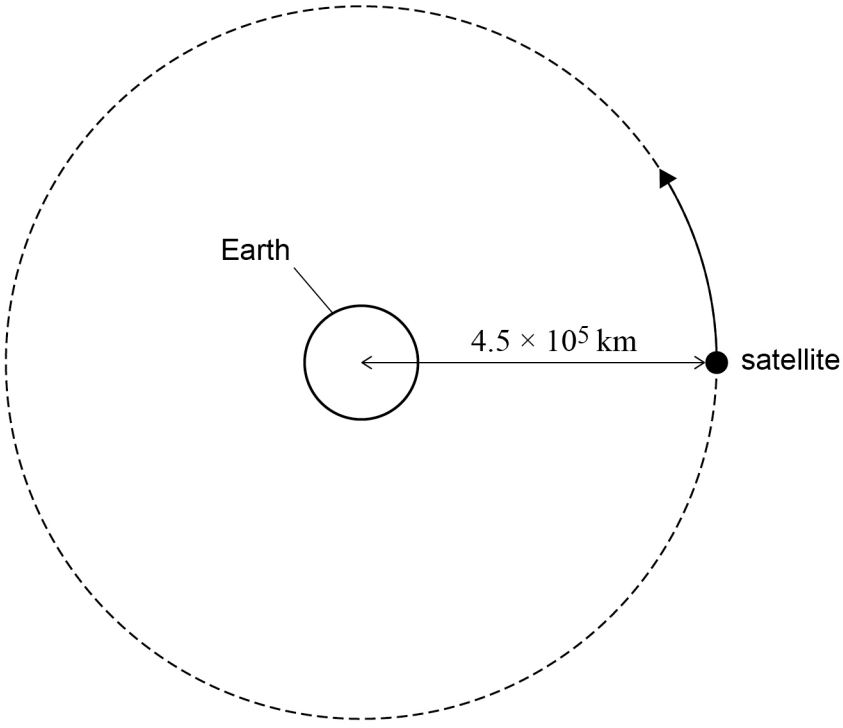
**0 4 . 1** The Moon orbits the Earth with a time period of $27.3$ days.

Show that the angular speed of the Moon is approximately $2.7 \times 10^{-6}$ rad s$^{-1}$.

**[2 marks]**

**0 4 . 2** **Figure 7** shows an artificial satellite in a circular orbit of radius $4.5 \times 10^5$ km from the centre of the Earth.

**Figure 7**



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Calculate the gravitational field strength of the Earth at this radius.

**[2 marks]**

gravitational field strength = _____ $\mathrm{N\ kg^{-1}}$

**0 4 . 3** The satellite and the Moon orbit the Earth at the same angular speed.

Calculate the centripetal acceleration of the satellite.

**[2 marks]**

centripetal acceleration = _____ $\mathrm{m\ s^{-2}}$

**Question 4 continues on the next page**

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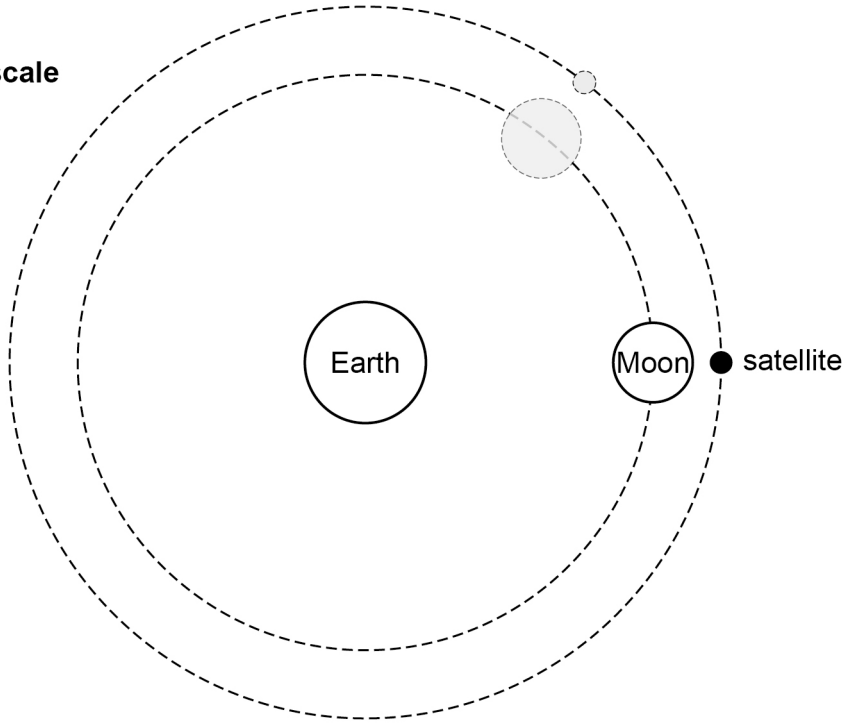
**0 4 . 4** **Figure 8** shows two positions of the satellite and the Moon as they orbit the Earth. The orbital radius of the satellite is greater than the orbital radius of the Moon but their orbital periods are the same.

**Figure 8**

**not to scale**




Explain how this satellite orbit is possible.

**[2 marks]**

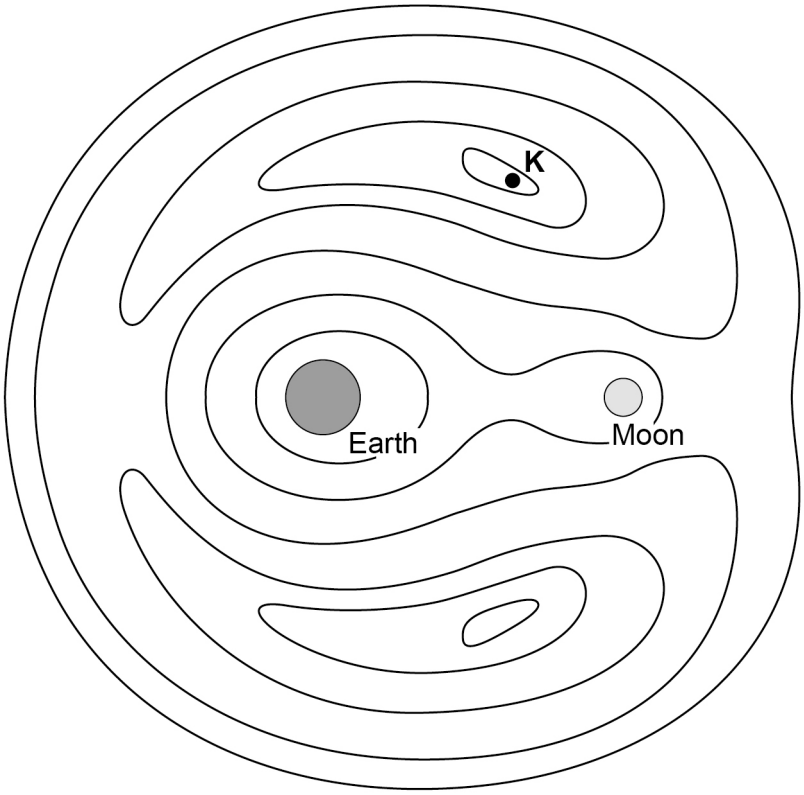
*Do not write outside the box*

**0 4 . 5** **Figure 9** shows some resultant gravitational equipotential lines for the Earth and Moon system.

Draw, on **Figure 9**, **one** gravitational field line from the Moon to **K**.

**[1 mark]**

**Figure 9**




9

**Turn over for the next question**

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**ANSWER IN THE SPACES PROVIDED**

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**0 5** **Figure 10** shows apparatus used to investigate the motion of a trolley down a ramp. The trolley has a magnet attached to it. When released from point **X**, the trolley moves down the ramp at a **constant speed**.

An emf is induced in a circular coil of wire as the trolley and magnet pass under the coil. The coil is connected to a datalogger that records the induced emf.

**Figure 10**

**not to scale**

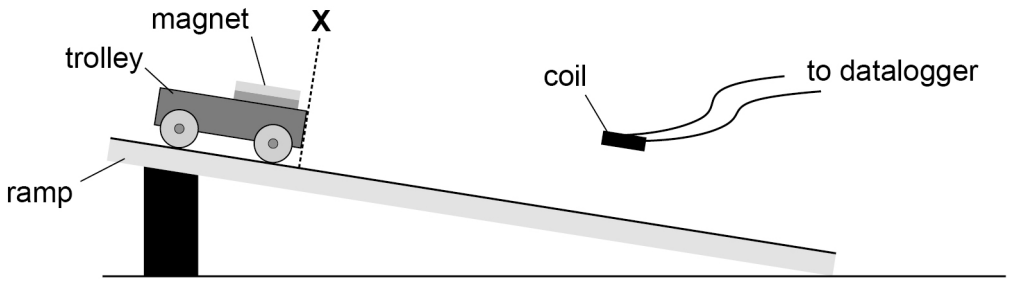
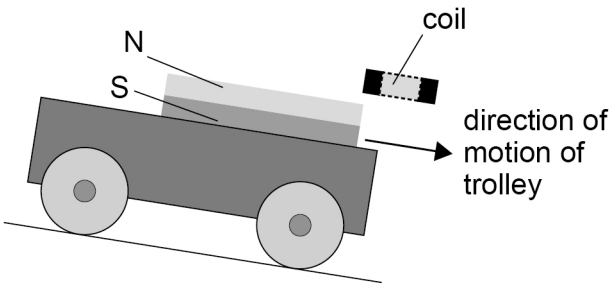



**Figure 11** shows expanded views of the magnet passing under the coil. Two positions are shown as the magnet moves down the ramp.

Position **A** is when the front edge of the magnet reaches the left-hand side of the coil. Position **B** is when the trailing edge of the magnet leaves the right-hand side of the coil.

**Figure 11**

Magnet at position **A**




Magnet at position **B**

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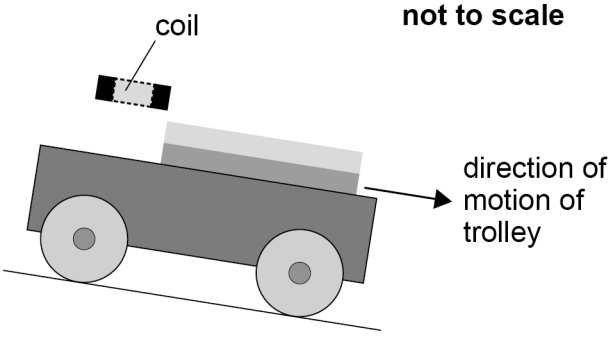


**Question 5 continues on the next page**

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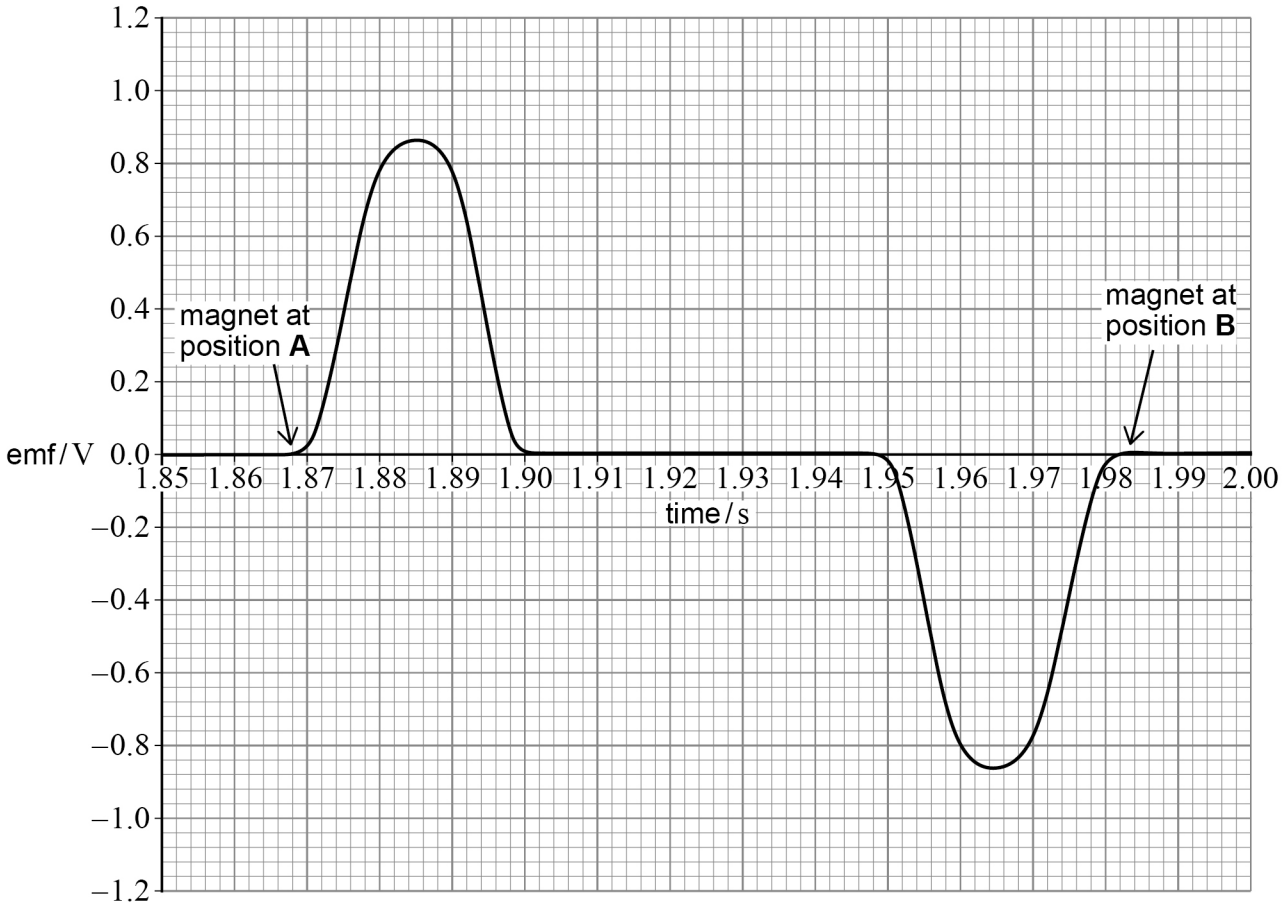
**Figure 12** shows how the induced emf in the coil varies with time after the trolley is released from point **X**.

**Figure 12**




**0 5 . 1** Determine the maximum rate of change of flux linkage in the coil.

**[1 mark]**

maximum rate of change of flux linkage = _____ Wb $s^{-1}$

*Do not write outside the box*

**0 5 . 2** Explain the shape of the graph in **Figure 12**.

**[3 marks]**

**0 5 . 3** The length of the magnet is $4.0\ \text{cm}$ and the diameter of the coil is $1.5\ \text{cm}$.

Estimate, using **Figure 12**, the speed of the trolley between positions **A** and **B**.

**[2 marks]**

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

**Question 5 continues on the next page**

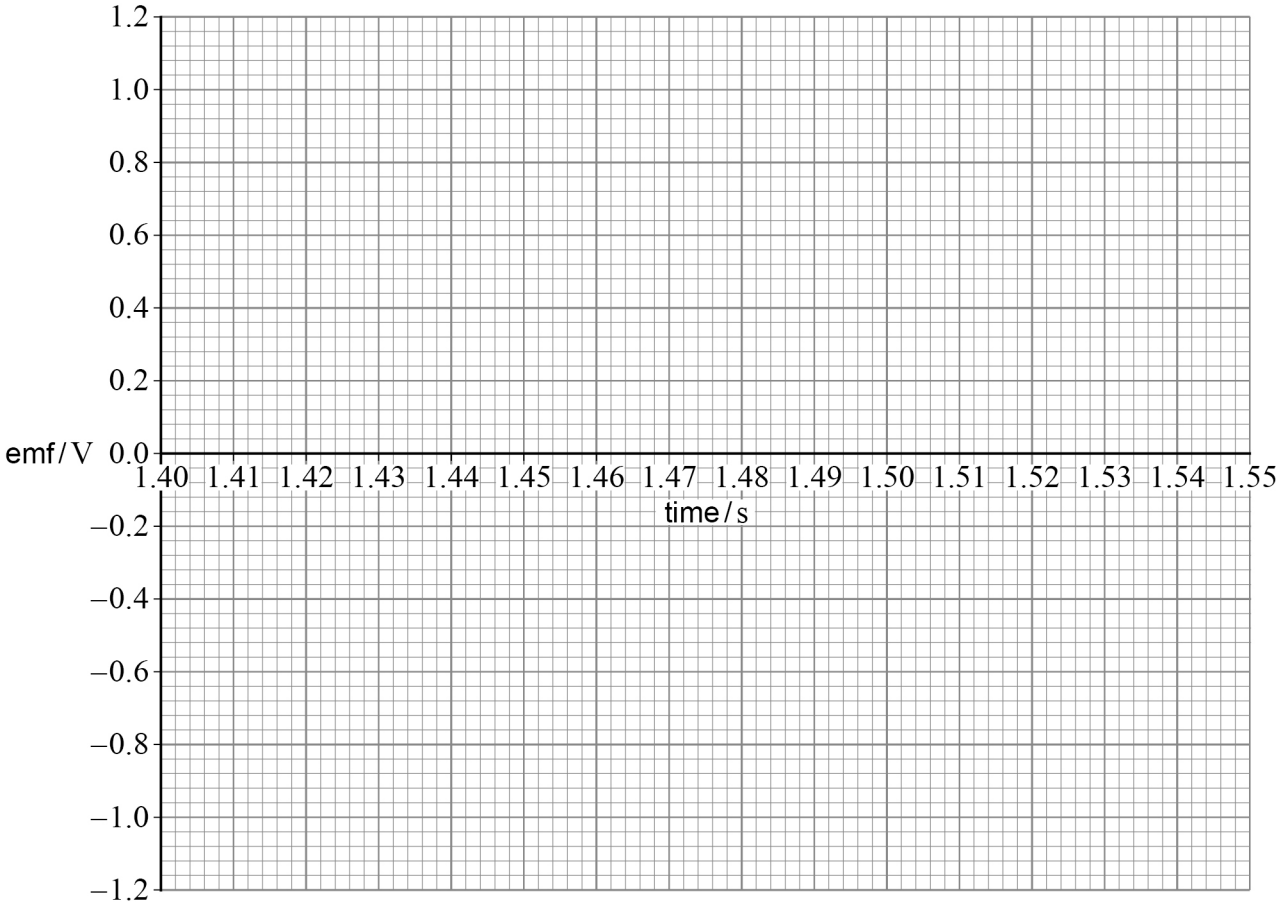
*Do not write outside the box*

**0 5 . 4** The angle of the ramp is increased and the trolley is again released from point **X**. The trolley now accelerates down the ramp and arrives at position **A** at 1.42 s.

Sketch, on **Figure 13**, the new variation of induced emf with time as the magnet travels from position **A** to position **B**.

**[4 marks]**

**Figure 13**




10

**END OF SECTION A**

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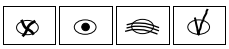
## Section B

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 sheets for this working.

**0 6** Which is a scalar quantity?

**[1 mark]**

**A** change in momentum

**B** absolute electric potential

**C** gravitational field strength

**D** magnetic flux density

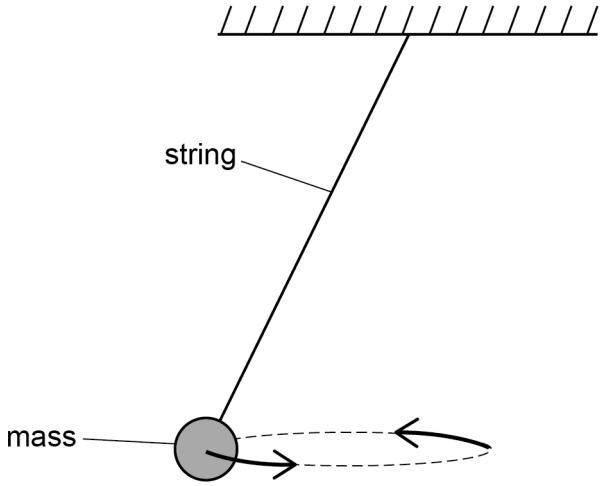
**Turn over for the next question**

*Do not write outside the box*

**0 7** A mass of $0.25\ \text{kg}$ is suspended on a string and rotates in a horizontal circle.

The diameter of the circle is $60\ \text{cm}$.

The mass completes one revolution every $1.4\ \text{s}$.




What is the centripetal force acting on the mass?

**[1 mark]**

**A** 0.5 N ⬭

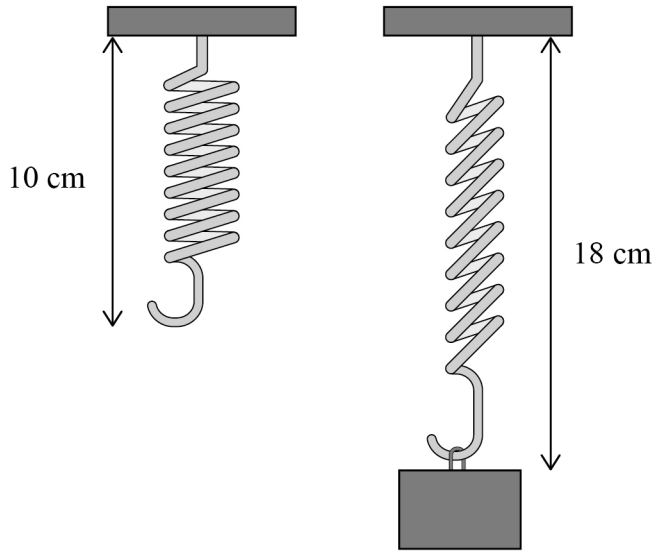
**B** 1.5 N ⬭

**C** 2.1 N ⬭

**D** 3.0 N ⬭

**0 8** The unextended length of a light spring is 10 cm.

The length of the spring is 18 cm when a 400 g mass is suspended from it.




The mass–spring system oscillates with a small amplitude.

What is the period of the oscillation?

**[1 mark]**

**A** 0.57 s ⬭

**B** 0.85 s ⬭

**C** 5.7 s ⬭

**D** 8.5 s ⬭

**Turn over for the next question**

**0 9** An equation describing a system undergoing simple harmonic motion is

$$v = \omega\sqrt{\left(A^2 - x^2\right)}$$

What is $x$?

**[1 mark]**

**A** $x = \omega A - v$ ⬭

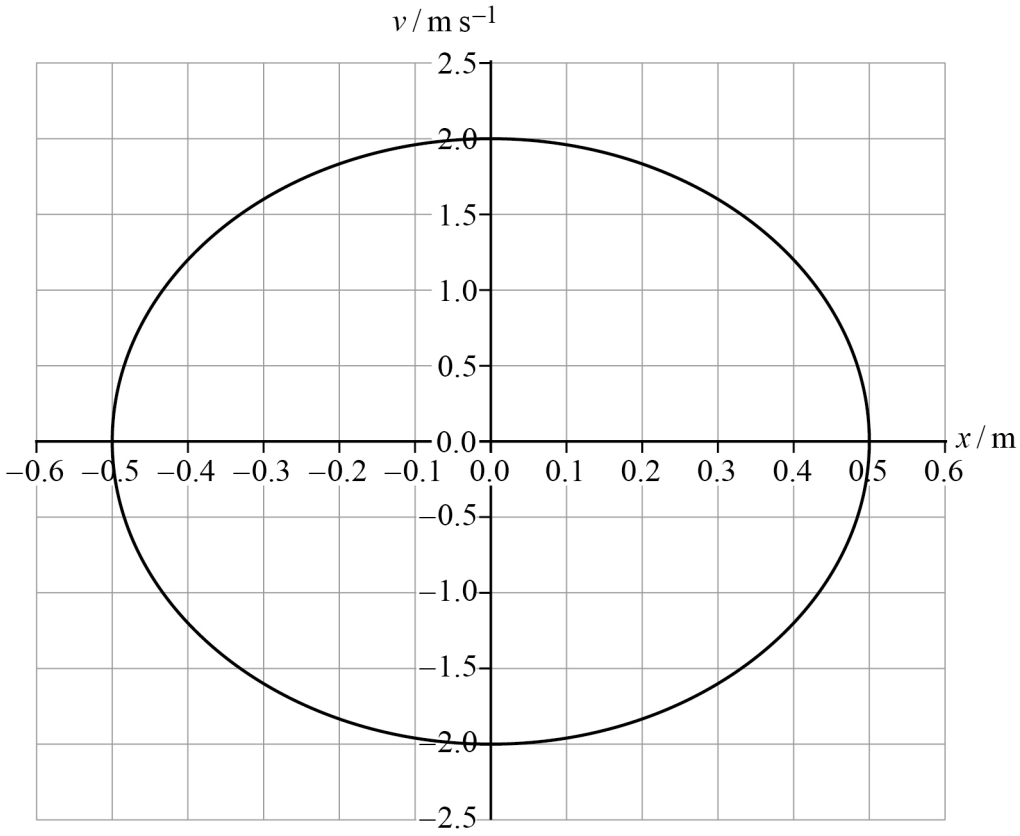
**B** $x = \sqrt{\omega A - v}$ ⬭

**C** $x = A - \frac{v}{\omega}$ ⬭

**D** $x = \sqrt{A^2 - \frac{v^2}{\omega^2}}$ ⬭

Do not write outside the box

**1 0** The graph shows the variation of velocity $v$ with displacement $x$ for a simple harmonic oscillator.




What is the maximum acceleration of the oscillator?

**[1 mark]**

**A** $1.0\ \text{m s}^{-2}$ ⬭

**B** $4.0\ \text{m s}^{-2}$ ⬭

**C** $8.0\ \text{m s}^{-2}$ ⬭

**D** $16\ \text{m s}^{-2}$ ⬭

**Turn over ►**

*Do not write outside the box*

**1 1** Two apples are touching each other.

What is the best estimate for the gravitational force between the two apples?

**[1 mark]**

**A** $10^{-20}$ N ⬭

**B** $10^{-15}$ N ⬭

**C** $10^{-10}$ N ⬭

**D** $10^{-5}$ N ⬭

**1 2** A planet has a density of $1.9 \times 10^3$ kg m$^{-3}$ and a diameter of $5.2 \times 10^3$ km.

What is the gravitational field strength at the surface of the planet?

**[1 mark]**

**A** $1.4 \times 10^{-3}$ N kg$^{-1}$ ⬭

**B** $2.8 \times 10^{-3}$ N kg$^{-1}$ ⬭

**C** $1.4$ N kg$^{-1}$ ⬭

**D** $2.8$ N kg$^{-1}$ ⬭

**1 3** A satellite is moved from a higher orbit to a lower orbit.

What energy changes occur?

**[1 mark]**

| | Kinetic energy | Gravitational potential energy | Total energy | |
|---|---|---|---|---|
| **A** | decreases | decreases | increases | ⬭ |
| **B** | decreases | increases | decreases | ⬭ |
| **C** | increases | decreases | increases | ⬭ |
| **D** | increases | decreases | decreases | ⬭ |

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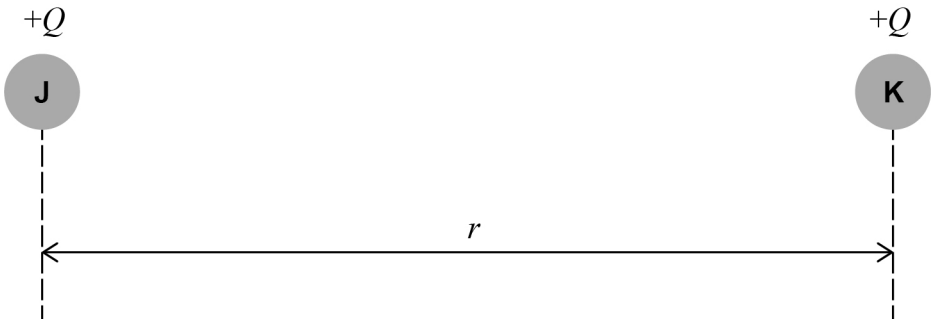
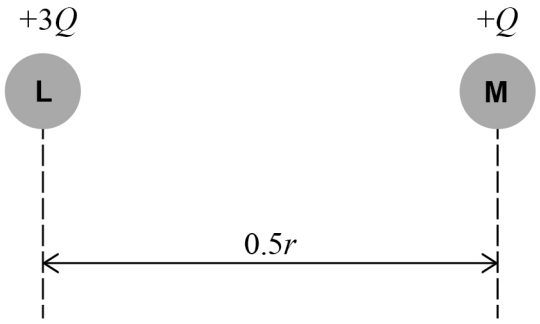
**1 4** **J** and **K** are two point charges separated by a distance $r$.




**L** and **M** are two different point charges separated by a distance $0.5r$.




The force between **J** and **K** is $F$.

What is the force between **L** and **M**?

**[1 mark]**

**A** $\frac{3F}{2}$ ⬭

**B** $6F$ ⬭

**C** $12F$ ⬭

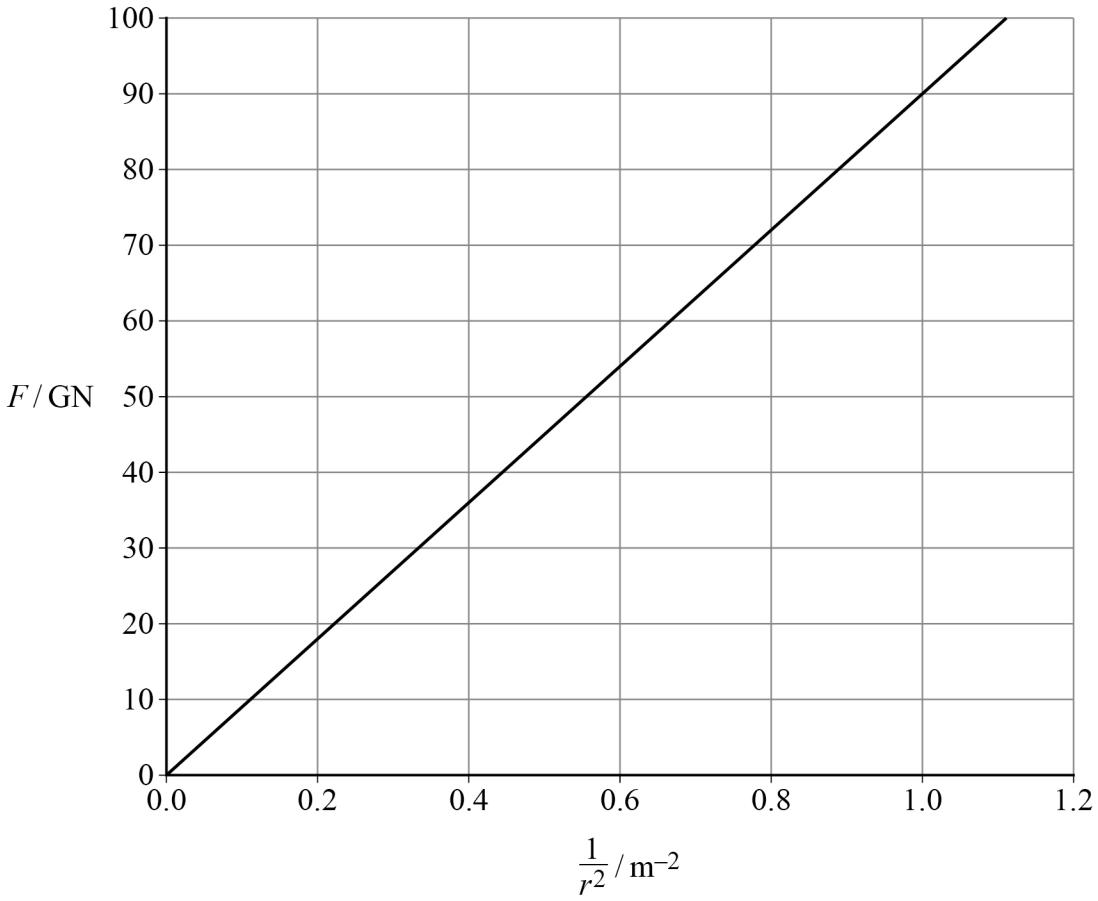
**D** $36F$ ⬭

**Turn over ►**

Do not write outside the box

**1 5** Two point charges experience a force $F$ between them when separated by a distance $r$.

The graph shows how $F$ varies with $\frac{1}{r^2}$.




One charge has a magnitude of 2.5 C.

What is the magnitude of the other charge?

**[1 mark]**

**A** 4 mC ⬭

**B** 10 mC ⬭

**C** 4 C ⬭

**D** 10 C ⬭

Do not write outside the box

**1 6** A deuterium atom consists of one electron and a nucleus.

The nucleus has one proton and one neutron.

$F_E$ is the electrostatic force on the electron due to the deuterium nucleus.

$F_G$ is the gravitational force on the electron due to the deuterium nucleus.

What is the ratio $\frac{F_E}{F_G}$?

**[1 mark]**

**A** $8.4 \times 10^{18}$ ⬭

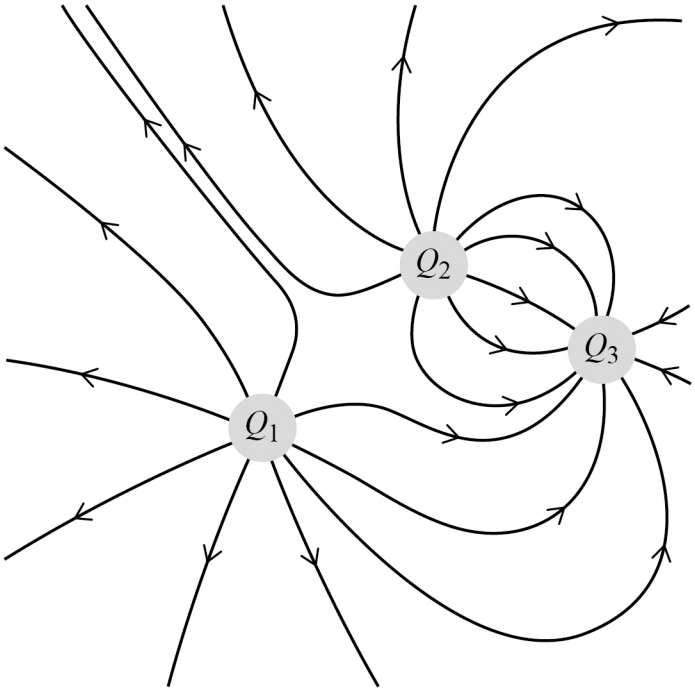
**B** $1.2 \times 10^{36}$ ⬭

**C** $1.1 \times 10^{39}$ ⬭

**D** $2.3 \times 10^{39}$ ⬭

**Turn over for the next question**

**1 7** The diagram shows electric field lines around three charges $Q_1$, $Q_2$ and $Q_3$.




Which row gives the signs of the charges $Q_1$, $Q_2$ and $Q_3$?

**[1 mark]**

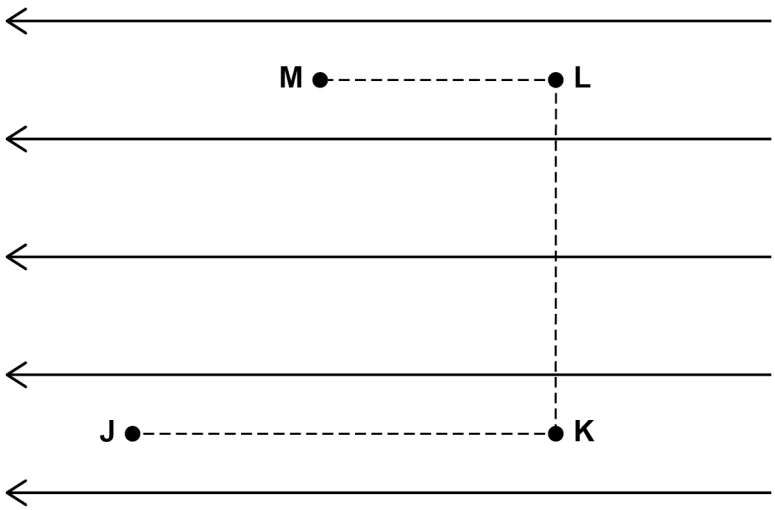
| | $Q_1$ | $Q_2$ | $Q_3$ | |
|---|---|---|---|---|
| **A** | negative | negative | positive | ⬭ |
| **B** | negative | positive | negative | ⬭ |
| **C** | positive | negative | positive | ⬭ |
| **D** | positive | positive | negative | ⬭ |

Do not write outside the box

**1 8** The diagram shows a uniform electric field strength $E$ of $20\ \text{V m}^{-1}$.

A charge of $+8.0\ \text{mC}$ is moved along the path **JKLM**.

The distance **J** to **K** is $2.0\ \text{m}$.
The distance **K** to **L** is $1.0\ \text{m}$.
The distance **L** to **M** is $1.0\ \text{m}$.




**not to scale**

What is the net work done moving the charge from **J** to **M**?

**[1 mark]**

**A** 160 mJ ⬭

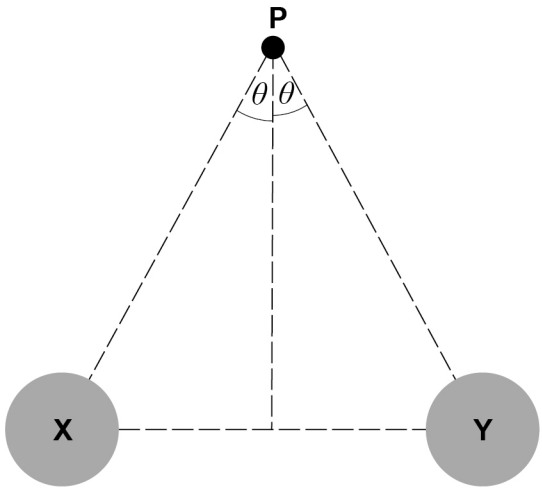
**B** 230 mJ ⬭

**C** 480 mJ ⬭

**D** 640 mJ ⬭

Do not write outside the box

**1 9** **P** is a point equidistant from two charged particles **X** and **Y**.
The charge on **X** is $+Q$ and the charge on **Y** is $-2Q$.




The electric field strength at **P** due to **X** is $E_X$.
The electric field strength at **P** due to **Y** is $E_Y$.

Which diagram on page 33 shows how $E_X$ and $E_Y$ produce the resultant electric field strength $E_R$ at **P**?

**[1 mark]**

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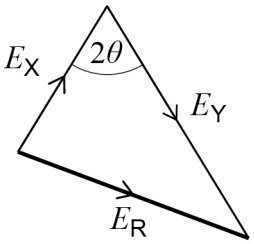
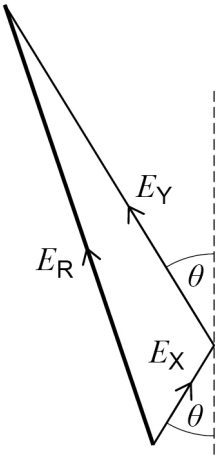
**A**




**B**

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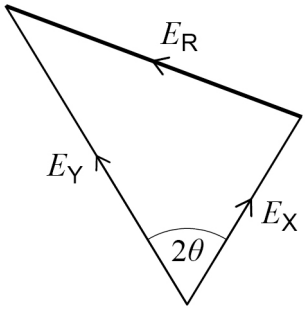
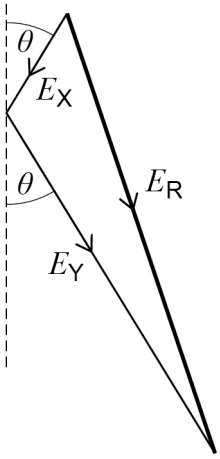



**D**




**A** ⬭

**B** ⬭

**C** ⬭

**D** ⬭

**Turn over ►**

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**2 0** The electron in a hydrogen atom orbits the proton at a constant distance of $5.3 \times 10^{-11}$ m.

What is the work done $W$ to ionise this hydrogen atom?
Ignore any kinetic energy of the electron.

**[1 mark]**

**A** $\dfrac{2 \times 1.60 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times 5.3 \times 10^{-11}}$ ⬭

**B** $\dfrac{2 \times 1.60 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times \left(5.3 \times 10^{-11}\right)^2}$ ⬭

**C** $\dfrac{\left(1.60 \times 10^{-19}\right)^2}{4\pi \times 8.85 \times 10^{-12} \times 5.3 \times 10^{-11}}$ ⬭

**D** $\dfrac{\left(1.60 \times 10^{-19}\right)^2}{4\pi \times 8.85 \times 10^{-12} \times \left(5.3 \times 10^{-11}\right)^2}$ ⬭

**2 1** What is the unit of capacitance in fundamental (base) SI units?

**[1 mark]**

**A** $A^2\ kg^{-1}\ m^{-2}$ ⬭

**B** $A^2\ s^4\ kg^{-1}\ m^{-2}$ ⬭

**C** $A^2\ s^5\ kg^{-1}\ m^{-2}$ ⬭

**D** $C^2\ s^2\ kg^{-1}\ m^{-2}$ ⬭

*Do not write outside the box*

**2 2** A parallel plate capacitor is charged and isolated.

A dielectric material is inserted between the two plates of the capacitor.

What happens to the potential difference across the capacitor and the energy stored by the capacitor when the dielectric is inserted?

**[1 mark]**

| | Potential difference | Energy | |
|---|---|---|---|
| **A** | decreases | decreases | ⬭ |
| **B** | decreases | increases | ⬭ |
| **C** | increases | decreases | ⬭ |
| **D** | increases | increases | ⬭ |

**2 3** A capacitor has capacitance $180\ \text{mF}$.

The capacitor is charged by a constant current for $36\ \text{s}$.

During this time, the potential difference across the capacitor increases from $3.0\ \text{V}$ to $9.0\ \text{V}$.

What is the magnitude of the constant current?

**[1 mark]**

**A** $5\ \text{mA}$ ⬭

**B** $30\ \text{mA}$ ⬭

**C** $45\ \text{mA}$ ⬭

**D** $60\ \text{mA}$ ⬭

*Do not write outside the box*

**2 4** A capacitor of capacitance $100\ \mu\text{F}$ stores charge $Q_0$.

The capacitor is discharged through a $120\ \text{k}\Omega$ fixed resistor.

What is the time taken for the charge on the capacitor to become $0.25Q_0$?

**[1 mark]**

**A** $4.2\ \text{s}$ ⬭

**B** $8.3\ \text{s}$ ⬭

**C** $17\ \text{s}$ ⬭

**D** $24\ \text{s}$ ⬭

**2 5** A $220\ \mu\text{F}$ capacitor is charged to a potential difference of $6.0\ \text{V}$. The capacitor is then discharged through an $18\ \text{k}\Omega$ resistor.

What is the potential difference across the resistor after $2.0\ \text{s}$?

**[1 mark]**

**A** $0.6\ \text{V}$ ⬭

**B** $2.4\ \text{V}$ ⬭

**C** $3.6\ \text{V}$ ⬭

**D** $4.4\ \text{V}$ ⬭

**2 6** A sample of gallium−67 has an initial activity of $37\ \text{MBq}$.

The half-life of gallium−67 is $78$ hours.

What is the initial number of gallium−67 atoms in the sample?

**[1 mark]**

**A** $4.2 \times 10^{9}$ ⬭

**B** $2.2 \times 10^{11}$ ⬭

**C** $2.5 \times 10^{11}$ ⬭

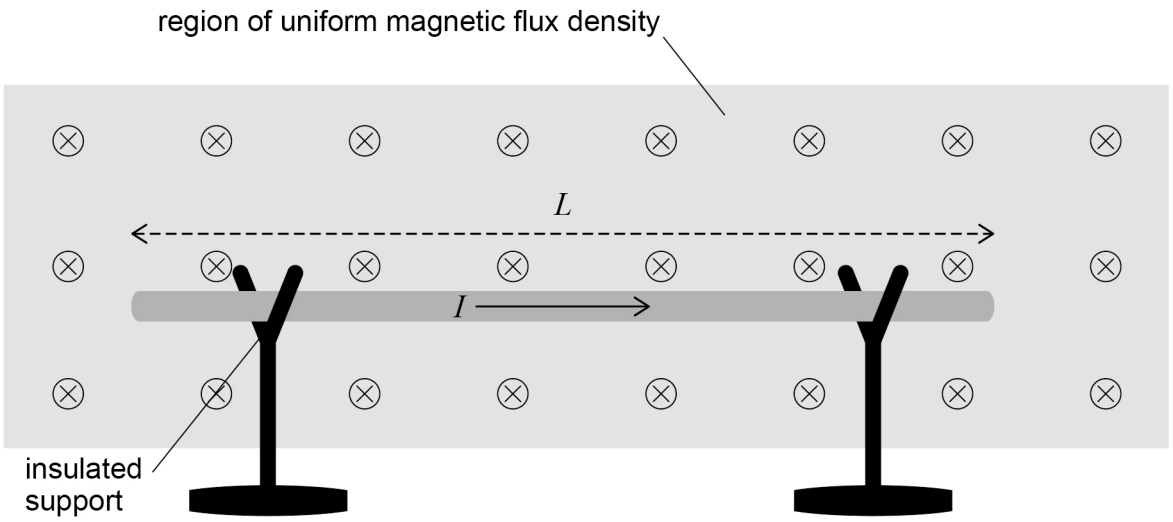
**D** $1.5 \times 10^{13}$ ⬭

Do not write outside the box

**2 7** A uniform wire of length $L$ rests on two insulated supports within a uniform magnetic field.

The magnetic flux density $B$ acts horizontally and perpendicularly to the wire.

The cross-sectional area of the wire is $A$ and the density of the wire is $\rho$.




The electrical connections to the wire are not shown.

The wire just lifts off the supports when there is a current $I$ in the wire.

What is the magnitude of $I$?

**[1 mark]**

**A** $\frac{\rho g}{BA}$ ⬭

**B** $\frac{\rho gA}{B}$ ⬭

**C** $\frac{\rho gA}{BL}$ ⬭

**D** $\frac{\rho gAL}{B}$ ⬭

*Do not write outside the box*

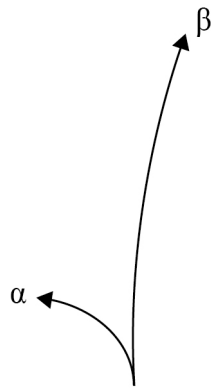
**2 8** An alpha particle and a beta particle separately enter a uniform magnetic field at $90°$ to the field lines.

Both particles enter the field with the same velocity.

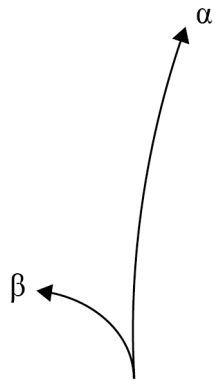
Which diagram best shows the paths of the particles in the magnetic field?

**[1 mark]**

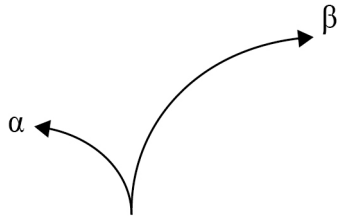
**A**



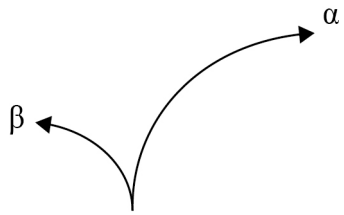

**B**




**C**




**D**




**A** ⬭

**B** ⬭

**C** ⬭

**D** ⬭

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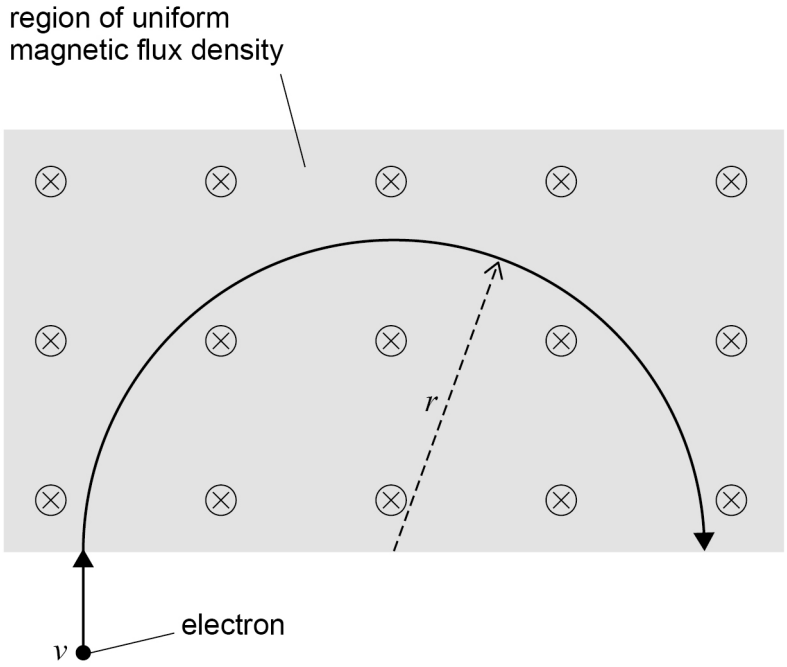
**2 9** An electron enters a region of uniform magnetic flux density $B$ at $90°$ to the field lines.

The electron travels at a constant speed $v$ and a constant radius $r$.

The time between the electron entering the field and leaving the field is $T$.




The electron mass is $m$ and the electron charge is $e$.

What is the value of $B$?

**[1 mark]**

**A** $\frac{\pi m}{Te}$ ⬭

**B** $\frac{Te}{\pi m}$ ⬭

**C** $\frac{\pi r^2 m}{Te}$ ⬭

**D** $\frac{Te}{\pi r^2 m}$ ⬭

*Do not write outside the box*

**3 0** Which statement is true for a charged particle in a cyclotron?

**[1 mark]**

**A** Its speed is constant as it travels through a dee. ⬭

**B** Its speed is constant in the gap between the dees. ⬭

**C** It accelerates in the dees only. ⬭

**D** It accelerates in the gap between the dees only. ⬭

**3 1** Lenz's law is an example of the conservation of

**[1 mark]**

**A** charge. ⬭

**B** energy. ⬭

**C** flux linkage. ⬭

**D** momentum. ⬭

**3 2** A coil has $40$ turns and an area of $0.20\ \text{m}^2$.

The coil rotates at a constant frequency $f$ in a uniform magnetic flux density of $1.5\ \text{mT}$.

The maximum emf induced in the coil is $0.24\ \text{V}$.

What is $f$?

**[1 mark]**

**A** $3.2 \times 10^{-3}\ \text{Hz}$ ⬭

**B** $2.0 \times 10^{-2}\ \text{Hz}$ ⬭

**C** $3.2\ \text{Hz}$ ⬭

**D** $20\ \text{Hz}$ ⬭

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**3 3** An ac power source has a peak power of $P_0$ and a root mean power of $P_{\text{rms}}$.

What is $\frac{P_0}{P_{\text{rms}}}$ ?

**[1 mark]**

**A** $\frac{1}{2}$ ⬭

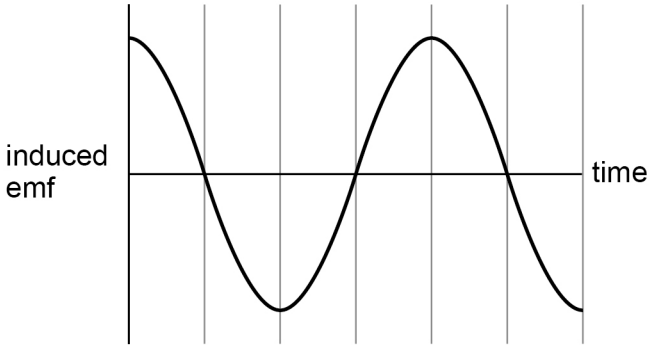
**B** $\frac{1}{\sqrt{2}}$ ⬭

**C** $\sqrt{2}$ ⬭

**D** $2$ ⬭

**Turn over for the next question**

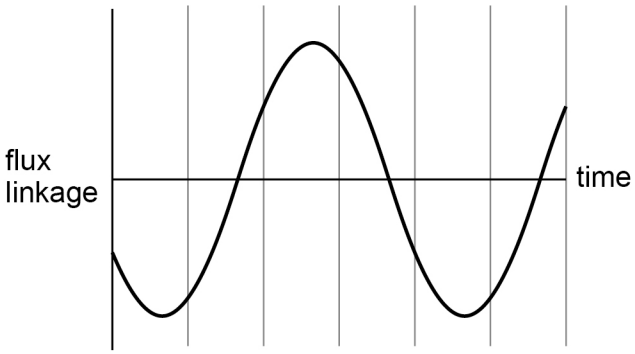
**3 4** The graph shows the variation of induced emf with time for a coil rotating in a magnetic field.



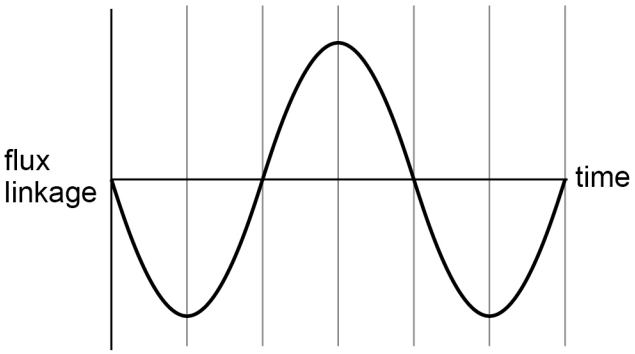

Which graph shows the variation of flux linkage in the coil with time?

**[1 mark]**

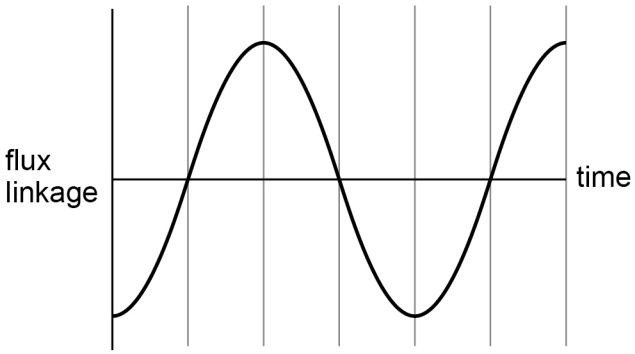
**A**



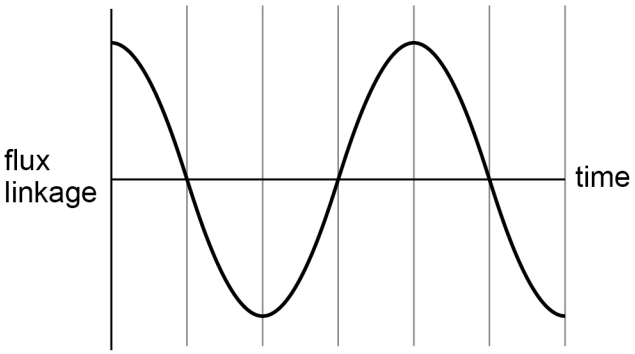

**B**




**C**




**D**




**A** ⬭

**B** ⬭

**C** ⬭

**D** ⬭

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**3 5** An ideal transformer has 300 turns in the primary coil and 600 turns in the secondary coil.

The primary coil is connected to an ac source that has a peak potential difference of 10 V and a frequency of 20 Hz.

What is the peak potential difference and the frequency of the output from the secondary coil?

**[1 mark]**

| | **Peak potential difference / V** | **Frequency / Hz** | |
|---|---|---|---|
| **A** | 5 | 20 | ⬭ |
| **B** | 5 | 40 | ⬭ |
| **C** | 20 | 20 | ⬭ |
| **D** | 20 | 40 | ⬭ |

**30**

**END OF QUESTIONS**

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