OXFORD
INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

Centre number [ ][ ][ ][ ][ ] Candidate number [ ][ ][ ][ ]

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Candidate signature ______________________
I declare this is my own work.

INTERNATIONAL A-LEVEL
PHYSICS
Unit 3 Fields and their consequences

Monday 17 January 2022 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	
7–21	
TOTAL	

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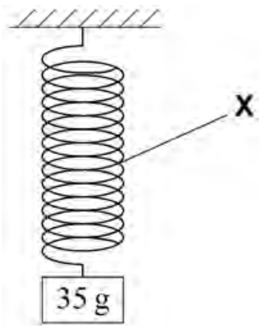
Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows a load of mass $35\ \mathrm{g}$ attached to a vertical spring **X**.
The load is at rest in its equilibrium position.

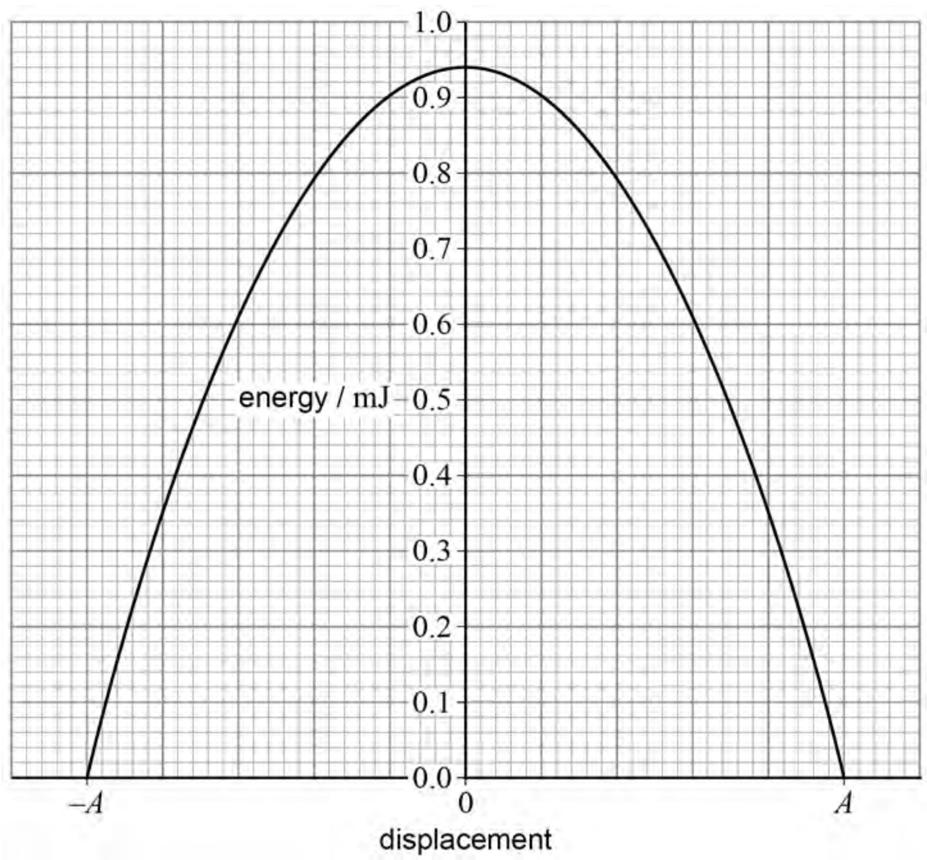
Figure 1



The load is pulled vertically downwards below its equilibrium position and released. The load oscillates with simple harmonic motion (SHM) with a period of $0.68\ \mathrm{s}$ and amplitude A.

Figure 2 shows the variation of kinetic energy of the load with its displacement from the equilibrium position during an oscillation.

Figure 2



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0 1 . 1 Calculate, in mm, A.

[4 marks]

A = ______________________ mm

0 1 . 2 The load is brought to rest and then pulled vertically downwards a distance $\frac{A}{2}$ below its equilibrium position.

It is released and oscillates with SHM.
Spring **X** has negligible mass.

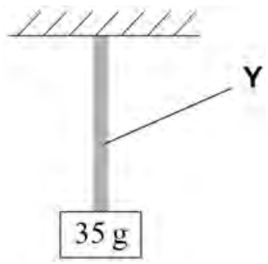
Sketch, on **Figure 2**, the variation of the **total** energy of the mass–spring system with displacement.

[2 marks]

Question 1 continues on the next page

Spring **X** is replaced with an elastic string **Y** that obeys Hooke's law.
Figure 3 shows the load attached to the end of **Y**.
Y has negligible mass.
Y has an extension of $42\ \text{mm}$ when the load is at rest in its equilibrium position.

Figure 3



0 1 . 3 The load is pulled $20\ \text{mm}$ vertically downwards below its equilibrium position.
It is then released and oscillates with SHM.

Show that the period of the oscillations is approximately $0.4\ \text{s}$.

[2 marks]

The load on **Y** is now pulled $50\ \text{mm}$ vertically downwards below its equilibrium position and released.
The movement of the load fulfils the conditions for SHM until the load reaches a position **P**. When the load is at **P**, the elastic string **Y** is at its unstretched length.

0 1 . 4 Calculate the velocity of the load at **P**.

[3 marks]

velocity = ______________________ m s^{-1}

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0 1 . 5 The load continues to move upwards after reaching **P**.

Explain why this movement above **P** does **not** fulfil the conditions for SHM.

[2 marks]

0 1 . 6 State whether spring **X** or elastic string **Y** has the greater stiffness.
Explain your answer.

[2 marks]

15

Turn over for the next question

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0 2 Drinking water is taken from an underground lake.

The water contains small quantities of radioactive isotopes such as tritium $\left({}^{3}_{1}\mathrm{H}\right)$.

The decay of tritium has a half-life of 12.3 years.

0 2 . 1 Water is unsafe to drink when its activity due to tritium decay is greater than 7.6×10^{7} Bq per cubic metre of water.

$2.50 \times 10^{-4}\ \mathrm{m}^{3}$ of water from the lake contains 1.1×10^{10} tritium atoms.

Deduce whether the amount of tritium in water from this lake makes it unsafe to drink.

[3 marks]

0 2 . 2 No more tritium can enter the underground lake.
The activity due to tritium decay can be measured to estimate the time for which the water has been in the lake. This time is called the residence time.

Suggest why this method is only used when the residence time is less than approximately 150 years.

[2 marks]

0 2 . 3 Kr-81 is a radioactive isotope of krypton that is found in water.
The amount of Kr-81 dissolved in the water can also be used to find the residence time.

An amount of water from another underground lake contains 2.2×10^6 atoms of Kr-81

When the water was originally trapped, the same amount of water contained 3.7×10^6 atoms of Kr-81
No more krypton entered the lake after the water was trapped.

Calculate, in years, the residence time for this lake.

decay constant of Kr-81 = 3.03×10^{-6} year^{-1}

[2 marks]

residence time = ____________________ years

7

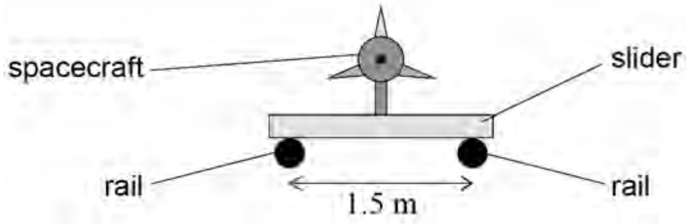
Turn over for the next question

0 3 A rail launcher is a system designed to launch a spacecraft using magnetic forces.

The launcher consists of two parallel metal rails connected to a power supply.
A metal slider carries the spacecraft on the rails.

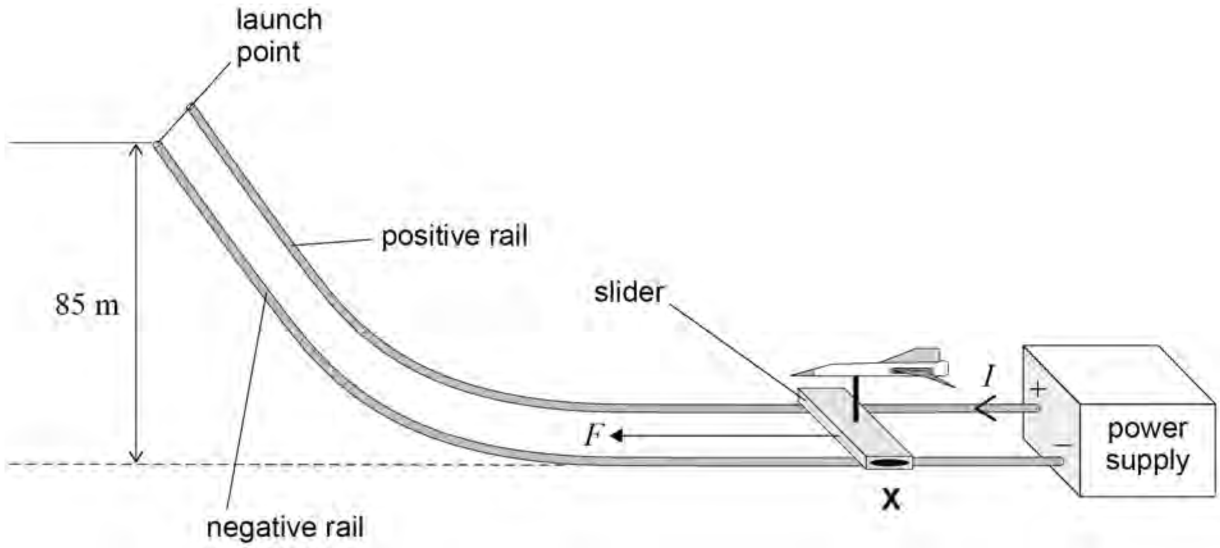
Figure 4 shows the spacecraft and slider on the rails. The distance between the points where the slider makes contact with each rail is $1.5\ \mathrm{m}$.

Figure 4



The slider is placed at **X** as shown in **Figure 5**.

Figure 5



When the power supply is switched on there is a constant current I in the rails and slider.

The current in the rails produces a magnetic field that passes through the slider.
This magnetic field can be assumed to be vertical in the region of the slider.
A force F acts on the slider.

Do not write outside the box

0 3 . 1 State and explain the direction of the magnetic field in the slider.
Refer to the direction of F in your answer.

[1 mark]

In one test of the system, the slider and spacecraft are initially at rest at **X** in **Figure 5**.
The power supply is switched on and the magnetic field that passes through the slider has an average flux density of $2.5\ \mathrm{T}$.
The magnitude of F is $1.8 \times 10^{7}\ \mathrm{N}$.

0 3 . 2 Calculate I.

[1 mark]

$I =$ ____________________ A

0 3 . 3 The total mass of the spacecraft and slider is $125\ \mathrm{kg}$.

The spacecraft and slider travel $250\ \mathrm{m}$ before reaching the launch point.
The launch point is $85\ \mathrm{m}$ higher than **X**.

Assume that the magnitude of F is constant and always acts in the same direction as the velocity of the slider.
Friction and drag forces are negligible.

Determine the speed of the spacecraft and slider when they reach the launch point.

[4 marks]

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

Question 3 continues on the next page

Turn over ►

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Scientists want to increase the launch speed of the spacecraft from the value obtained in the test. The launch point remains $85\ \mathrm{m}$ higher than the starting position.

The gain in potential energy is negligible compared to the gain in kinetic energy. The current remains constant as the slider moves along the rails.

0 3 . 4 One scientist suggests increasing the launch speed by increasing the horizontal section of the rails so that the total length travelled by the slider is doubled.

Discuss the effect that this change would have on the launch speed.

[2 marks]

0 3 . 5 The average flux density of the magnetic field in the region of the slider is directly proportional to the current in the rails.

A different scientist suggests increasing the launch speed by doubling the current in the rails and slider.

Discuss the effect that doubling the current would have on the launch speed.

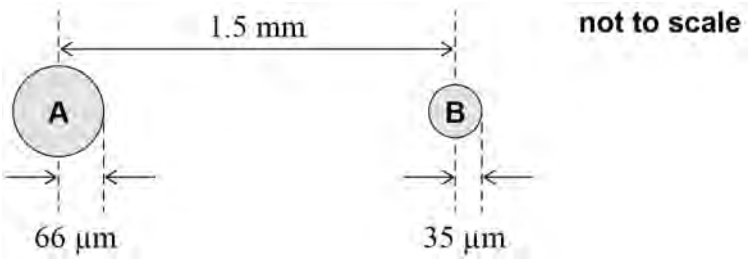
[2 marks]

10

0 4 **Figure 6** shows two charged water droplets **A** and **B** in a thundercloud.

The radius of **A** is $66\ \mu m$ and the radius of **B** is $35\ \mu m$.
Each droplet has a charge of -1.2×10^{-12} C.
Assume that the charge on **A** and the charge on **B** are concentrated at their centres.
The distance between the centres of **A** and **B** is 1.5 mm.

Figure 6



0 4 . 1 Calculate the electrostatic force between **A** and **B**.

[2 marks]

force = ____________________ N

0 4 . 2 Movement of the air in the cloud causes **A** and **B** to move together until they touch.

Calculate the work done against the electrostatic force in moving **A** and **B** from the position shown in **Figure 6** to the position where they touch.

[3 marks]

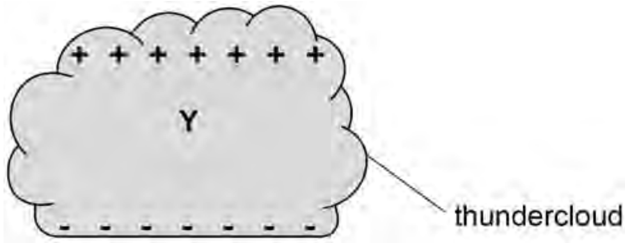
work done = ____________________ J

Question 4 continues on the next page

Turn over ►

Figure 7 shows a simplified diagram of a thundercloud. The bottom of the thundercloud is negatively charged and the top is positively charged.
Y is a point inside the thundercloud.

Figure 7



E_Y is the electric field strength at **Y**.

0 4 . 3 State the direction of E_Y.

[1 mark]

---

0 4 . 4 A charged water droplet is stationary at **Y**.
The weight of the droplet and the force on it due to E_Y are equal in magnitude.
The mass of the droplet is 1.38×10^{-9} kg.
The charge on the droplet is -2.1×10^{-12} C.

Calculate E_Y.

[3 marks]

$E_Y =$ ______________________ $\mathrm{V\ m^{-1}}$

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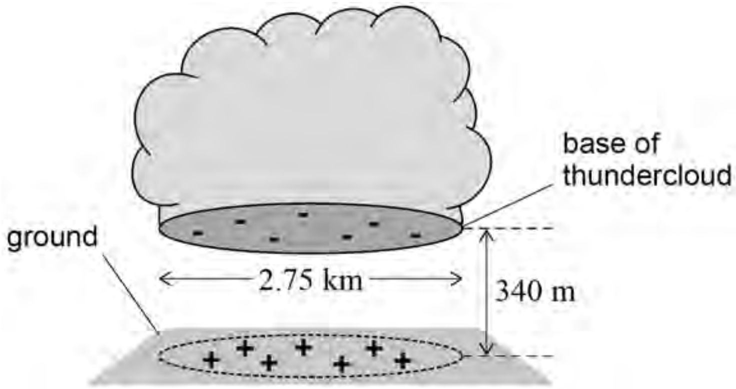
The base of the thundercloud and the ground beneath it can be modelled as two plates of a parallel-plate capacitor with air between them as shown in **Figure 8**.

Figure 8



The base of the cloud is circular, with a diameter of 2.75 km.
The base of the cloud is 340 m above the ground.

0 4 . 5 Show that the capacitance of the capacitor is about 1.5×10^{-7} F.

[2 marks]

0 4 . 6 The capacitor discharges when lightning strikes the ground.
The charge stored in the capacitor before it discharges is 87 C.

Calculate the energy available for the lightning strikes.

[2 marks]

energy = ____________________ J

13

Turn over ►

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0 5 Lunar Prospector was a space probe that orbited the Moon.
Table 1 shows data about the Moon and Lunar Prospector.

Table 1

Moon	**mass / kg**	7.348×10^{22}
	radius / m	1.737×10^{6}
Lunar Prospector	**mass / kg**	1.263×10^{2}

Lunar Prospector had an initial orbital radius of 1.84×10^{6} m.

0 5 . 1 Calculate the acceleration of Lunar Prospector in this orbit.

[2 marks]

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

0 5 . 2 Calculate the orbital period of Lunar Prospector in this orbit.

[2 marks]

orbital period = ____________________ s

Do not write outside the box

Lunar Prospector was moved to a different orbit where its gravitational potential energy (GPE) was -3.47×10^8 J.

0 5 . 3 Calculate the height above the Moon's surface of this different orbit.

[3 marks]

height = ______________________ m

0 5 . 4 The speed of Lunar Prospector in this orbit was 1.66 km s^{-1}.

Lunar Prospector left orbit and crashed onto the surface of the Moon.

Calculate the kinetic energy of Lunar Prospector when it hit the surface of the Moon. Assume that the contribution to the kinetic energy from Lunar Prospector's engines was negligible.

[3 marks]

kinetic energy = ______________________ J

Question 5 continues on the next page

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0 5 . 5 There are variations in the density of the material of the surface of the Moon. Measurements of Lunar Prospector in orbit were used to detect these variations.

At one point in its orbit, Lunar Prospector passed over a region where the density of the surface was greater than average.

Suggest how this affected the centripetal acceleration of Lunar Prospector.

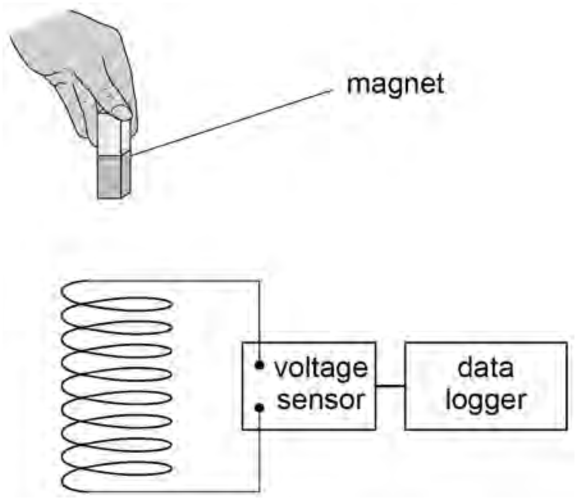
[2 marks]

12

0 6 A student does an experiment to investigate electromagnetic induction.

She drops a magnet vertically through a coil of wire.
The coil is connected to a voltage sensor and data logger, as shown in **Figure 9**.

Figure 9



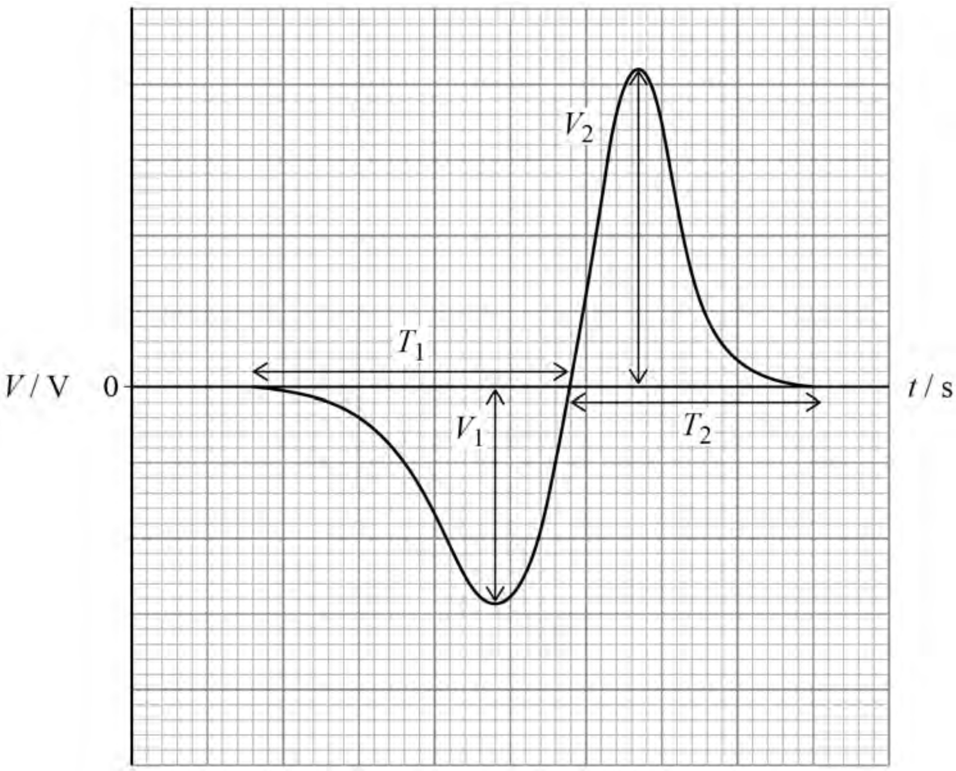
0 6 . 1 Explain why an emf is induced as the magnet falls towards the coil.

[2 marks]

Question 6 continues on the next page

Figure 10 shows the variation of the induced voltage V with time t after the magnet is released.

Figure 10



The durations T_1 and T_2 and maximum values V_1 and V_2 of two peaks are labelled.

0 6 . 2 Explain why V_1 and V_2 have opposite signs.

[2 marks]

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0 6 . 3 Explain why the magnitude of V_1 is less than the magnitude of V_2.

[2 marks]

0 6 . 4 Explain why T_1 is greater than T_2.

[2 marks]

8

END OF SECTION A

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ANSWER IN THE SPACES PROVIDED

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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 pages for this working.

0 7 What is the tesla (T) in fundamental (base) units?

[1 mark]

A $\mathrm{kg\ C^{-1}\ s^{-1}}$

B $\mathrm{V\ s\ m^{-2}}$

C $\mathrm{A\ kg\ s^{-2}}$

D $\mathrm{kg\ A^{-1}\ s^{-2}}$

0 8 A sinusoidal voltage with a peak value of 81 V is applied across a resistor.
The mean power dissipated in the resistor is 48 W.

What **direct** current causes a power of 48 W to be dissipated in the resistor?

[1 mark]

A 0.42 A

B 0.59 A

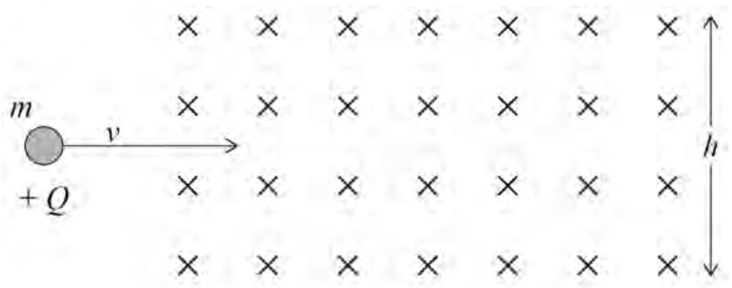
C 0.84 A

D 1.19 A

Do not write outside the box

Use the information below to answer Question **09** and Question **10**.

A charged particle has mass m and charge $+Q$.
The particle is travelling with a horizontal velocity v when it enters a uniform magnetic field of flux density B.
The magnetic field is horizontal and at right angles to v.
The region of the field has a height h.
Ignore the effect of gravity in these questions.



magnetic field is into page

0 9 What is the magnitude of the acceleration of the particle?

[1 mark]

A $\frac{BQv}{m}$ ⬭

B $\frac{BQv}{h}$ ⬭

C $\frac{BQv}{mh}$ ⬭

D $\frac{Qv}{mh}$ ⬭

1 0 What is the initial path of the particle in the field?

[1 mark]

A circular, curving upwards ⬭

B parabolic, curving upwards ⬭

C circular, curving downwards ⬭

D parabolic, curving downwards ⬭

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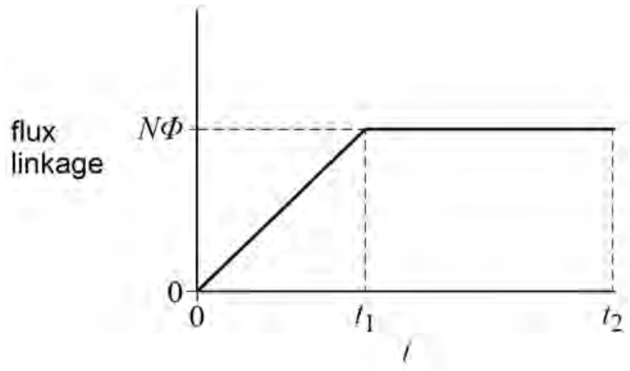
1 1 The graph shows how the flux linkage in a coil varies with time t.



What is the average emf induced in the coil between $t = 0$ and $t = t_2$?

[1 mark]

A $\frac{N\Phi}{t_1}$ ○

B $\frac{N\Phi}{t_2}$ ○

C $N\Phi\left(t_2 - \frac{t_1}{2}\right)$ ○

D $\frac{N\Phi}{2t_1}$ ○

1 2 A capacitor of capacitance C initially stores charge Q_0.
It is discharged through a resistor of resistance R.

What percentage of Q_0 has been transferred from the capacitor in a time equivalent to $2RC$ after the discharge begins?

[1 mark]

A 14% ○

B 39% ○

C 61% ○

D 86% ○

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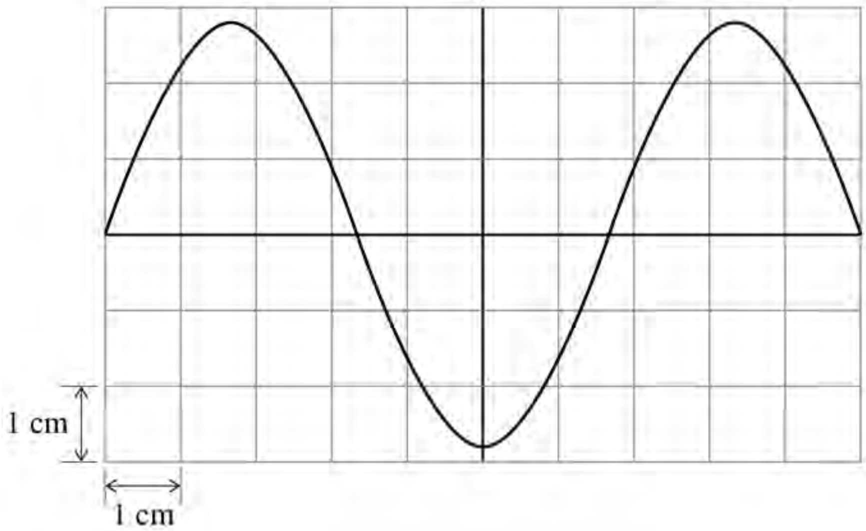
1 3 An oscilloscope trace displays an ac waveform that has a peak voltage of 5.6 V and a frequency of 1.5 kHz.

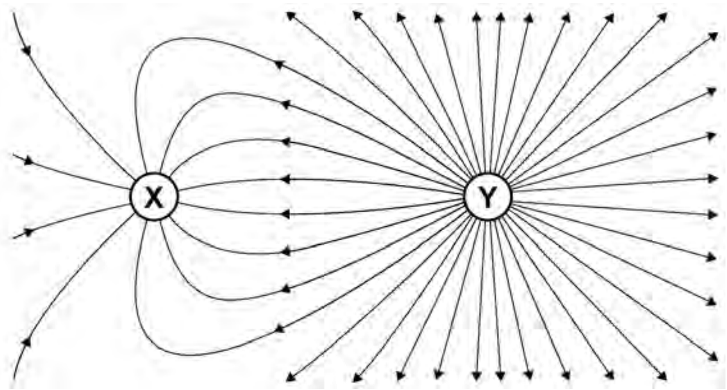


What are the settings for the time-base and y-gain on the oscilloscope?

[1 mark]

	Time-base / ms cm^{-1}	y-gain / V cm^{-1}	
A	0.1	2	○
B	10	2	○
C	0.1	0.5	○
D	10	0.5	○

1 4 The diagram shows a field around two objects **X** and **Y**.



Which is correct for this field?

[1 mark]

	Type of field	Relationship between X and Y	
A	electric field	magnitude of charge on **X** > magnitude of charge on **Y**	⬭
B	electric field	magnitude of charge on **Y** > magnitude of charge on **X**	⬭
C	gravitational field	mass of **X** > mass of **Y**	⬭
D	gravitational field	mass of **Y** > mass of **X**	⬭

Turn over for the next question

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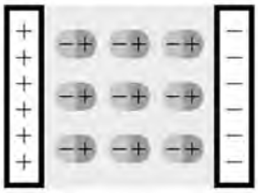
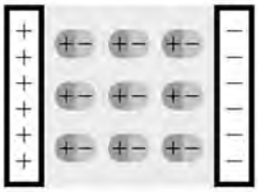
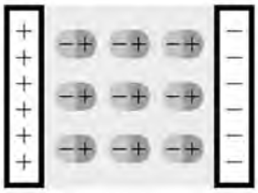
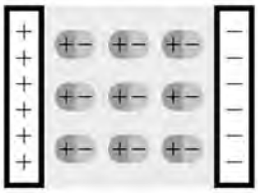
1 5 A dielectric material contains polar molecules that rotate in an electric field.
The dielectric material is inserted between the plates of a charged parallel-plate capacitor.
The capacitance of the capacitor changes.

Which row shows the alignment of the polar molecules and the effect on the capacitance?

[1 mark]

	Alignment of polar molecules	**Effect on capacitance**	
A		decreases	⬭
B		decreases	⬭
C		increases	⬭
D		increases	⬭

1 6 Eddy currents are produced in the core of a transformer when there is an alternating current in the secondary coil.

Which statement about eddy currents is correct throughout a complete cycle of the alternating current?

[1 mark]

A They are eliminated using a laminated core. ⬭

B They reduce the flux density of the magnetic field in the core. ⬭

C They increase if the peak current in the secondary coil increases. ⬭

D They circulate around the core in the direction of the magnetic field. ⬭

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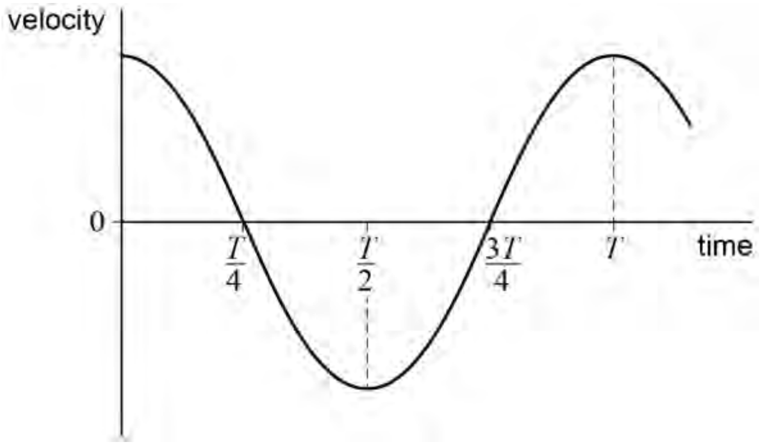
1 7 The graph shows the variation with time of the velocity of a particle performing simple harmonic motion.



Which statement about the particle is correct?

[1 mark]

A At time $\frac{T}{4}$ the restoring force on the particle is zero.

B At time $\frac{T}{2}$ the potential energy E_p of the particle is a minimum.

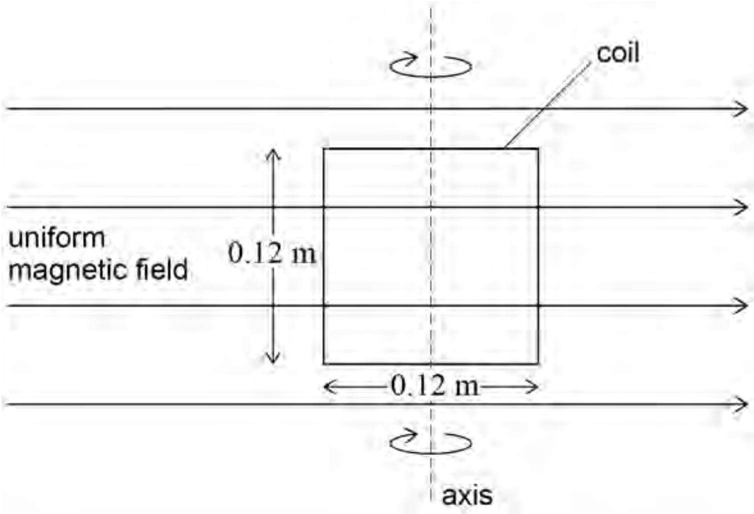
C At time $\frac{3T}{4}$ the displacement of the particle is zero.

D At time T the acceleration of the particle is a maximum.

Turn over for the next question

Do not write outside the box

1 8 A single square coil of side $0.12\ \text{m}$ is in a uniform magnetic field that has a magnetic flux density of $24\ \text{mT}$.
The coil is rotating at a constant angular speed about an axis at right angles to the field.
The emf induced in the coil has a peak value of $0.63\ \text{V}$.



How many times does the coil rotate in one second?

[1 mark]

A 192

B 290

C 552

D 1820

1 9 A satellite orbiting the Earth has an orbital radius r and orbital speed v.

Which is correct?

[1 mark]

A $r \propto v^2$

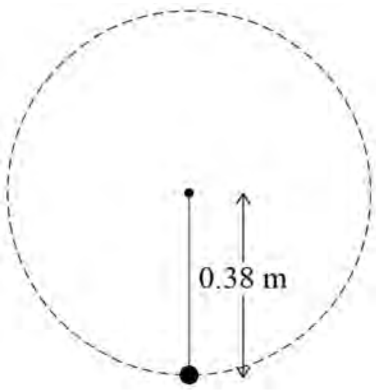
B $r^2 \propto v$

C $r \propto \dfrac{1}{v}$

D $r \propto \dfrac{1}{v^2}$

Do not write outside the box

2 0 An object of mass $1.5\ \mathrm{kg}$ is attached to the end of a string. The string has a cross-sectional area of $0.79\ \mathrm{mm}^2$.
The object is rotated in a vertical circle at a constant angular speed of $7.5\ \mathrm{rad\ s^{-1}}$.
The radius of the circle is $0.38\ \mathrm{m}$.



What is the stress in the string when the object is at the bottom of the circle?

[1 mark]

A 22 kPa ○

B 22 MPa ○

C 59 kPa ○

D 59 MPa ○

2 1 A planet has a mass half that of the Earth and a density half that of the Earth.

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

[1 mark]

A $2.5\ \mathrm{N\ kg^{-1}}$ ○

B $3.5\ \mathrm{N\ kg^{-1}}$ ○

C $4.9\ \mathrm{N\ kg^{-1}}$ ○

D $9.8\ \mathrm{N\ kg^{-1}}$ ○

15

END OF QUESTIONS

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