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

Tuesday 28 May 2024 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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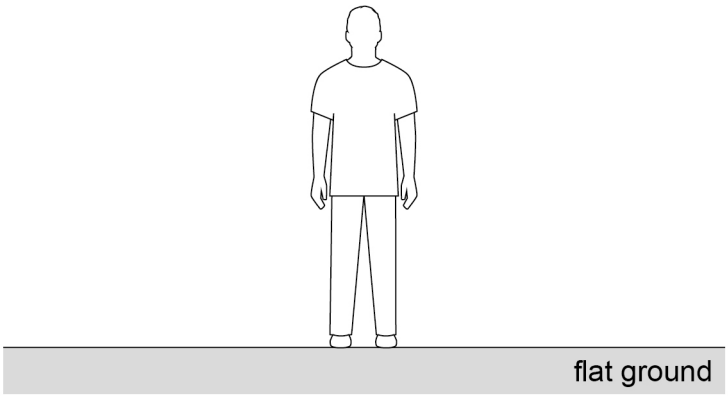
Section A

Answer **all** questions in this section.

0 1 . 1 **Figure 1** shows a stationary person standing on flat ground on the Earth's surface.

Figure 1



Draw and label arrows on **Figure 1** to represent the forces acting on the person.
Draw all your arrows to the same scale.

[2 marks]

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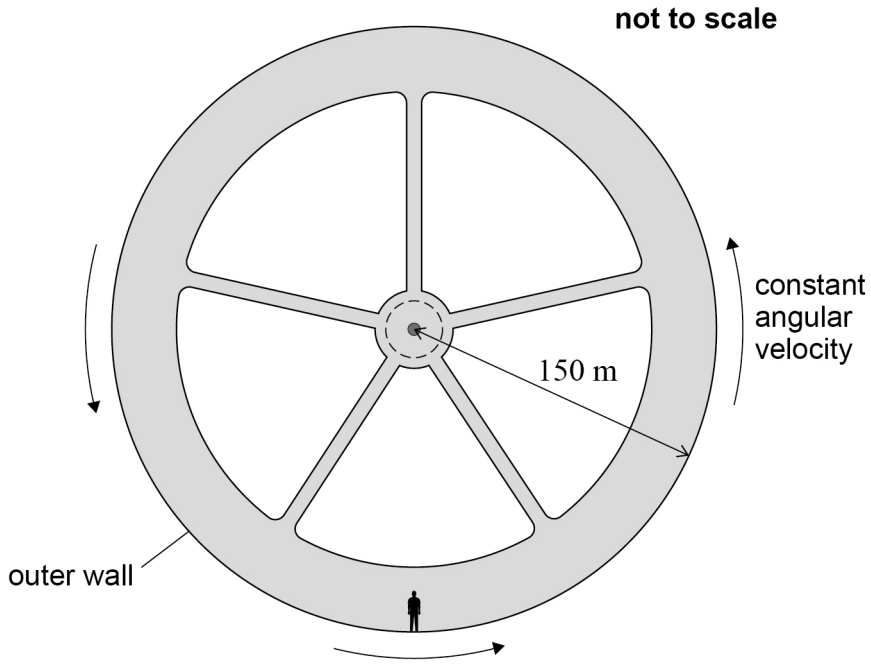
A space station in deep space rotates about its centre with a constant angular velocity. This simulates the effect of the force of gravity on a person who is standing inside the space station on its outer wall.

Figure 2 shows a person standing on the outer wall with his head towards the centre of the station. The outer wall is $150\ \text{m}$ from the centre of the station.

Figure 2



The person experiences a centripetal acceleration of $9.81\ \text{m s}^{-2}$ as the station rotates.

0 1 . 2 Draw an arrow on **Figure 2** to show the direction of the resultant force on the person.

[1 mark]

Question 1 continues on the next page

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0 1 . 3 Explain how the station simulates the effect of the force of gravity on the person shown in **Figure 2**.

[2 marks]

0 1 . 4 The person has a linear momentum of $2500\ \text{kg m s}^{-1}$.

Calculate the mass of the person.

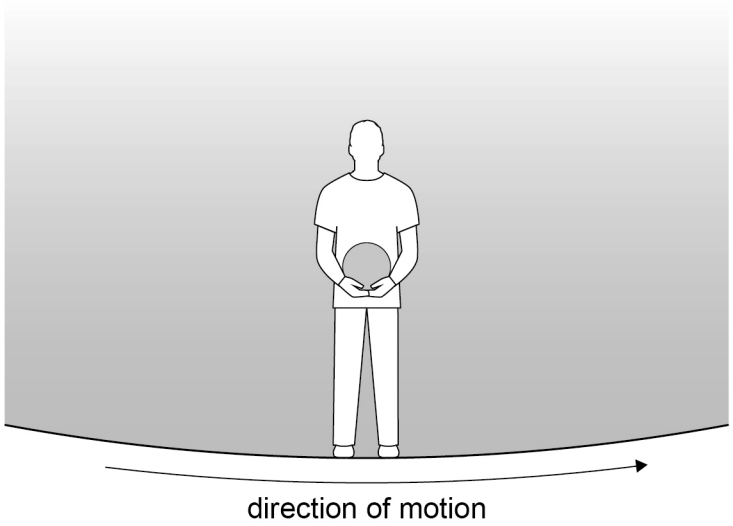
[3 marks]

mass = _____ kg

Do not write outside the box

0 1 . 5 **Figure 3** shows the part of the space station where the person is standing.
The person is holding a ball.
The direction of motion of the station relative to an observer outside the station is shown.

Figure 3



The person releases the ball.

State and explain the motion of the ball, relative to the observer, after it is released.

[3 marks]

11

0 2 **Figure 4** shows a pendulum of length $1.80\ \text{m}$. A rod is a distance h vertically below the point where the pendulum string is clamped.

Figure 4

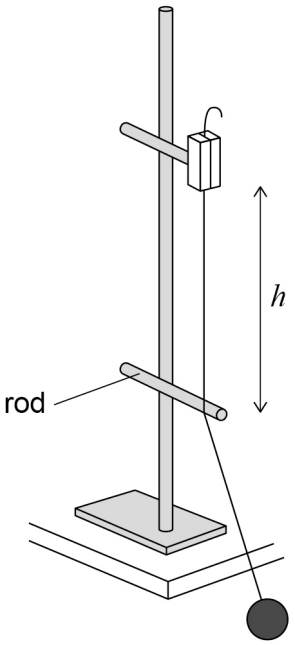
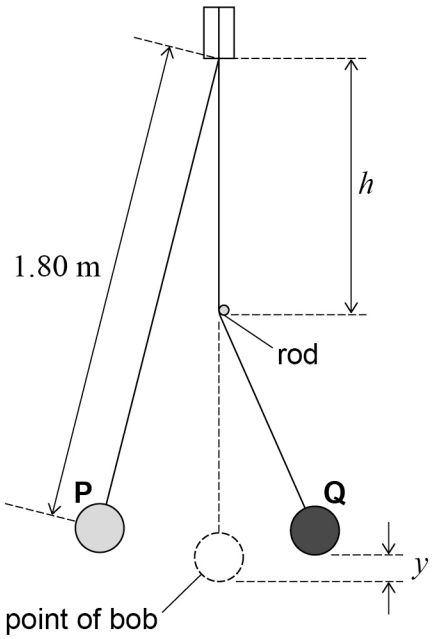


Figure 5 shows a view of the pendulum from the front.

Figure 5



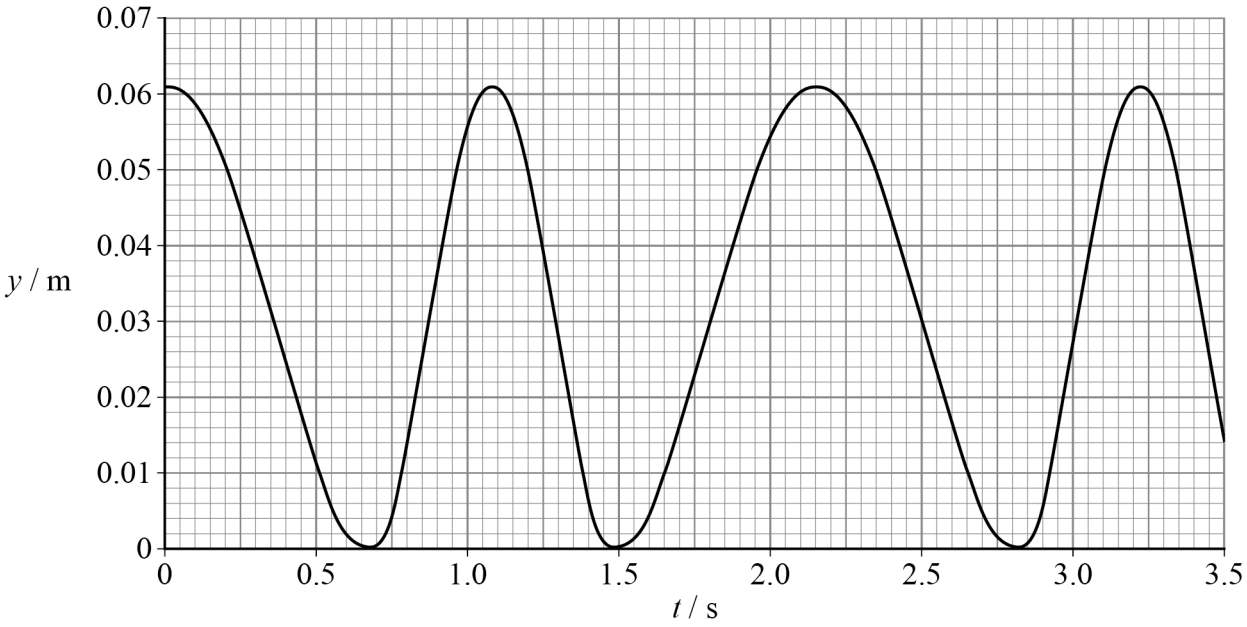
not to scale

P and **Q** are the positions of the bob when it is at its maximum displacement on the left-hand side and the right-hand side respectively.
The vertical distance of the bottom of the bob above its lowest point is y.
In **Figure 5**, y is shown at a maximum value.

The pendulum is released from **P** at time $t = 0$
The string makes contact with the rod when the bob is at the lowest point of its oscillation. At this point, only the lower part of the pendulum continues to oscillate. The bob comes to rest at **Q** for an instant. The bob continues to move between **Q** and **P**.

Figure 6 shows the variation of y with time t.

Figure 6



For the time shown in **Figure 6** the effect of air resistance is negligible.

0 2 . 1 Explain how **Figure 6** shows that no energy is transferred from the system.

[2 marks]

Question 2 continues on the next page

Do not write outside the box

0 2 . 2 Determine the speed of the bob when $y = 0$

[3 marks]

speed = _____ m s^{-1}

0 2 . 3 Determine h.
Use data from **Figure 5** and **Figure 6**.

[4 marks]

h = _____ m

9

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Turn over for the next question

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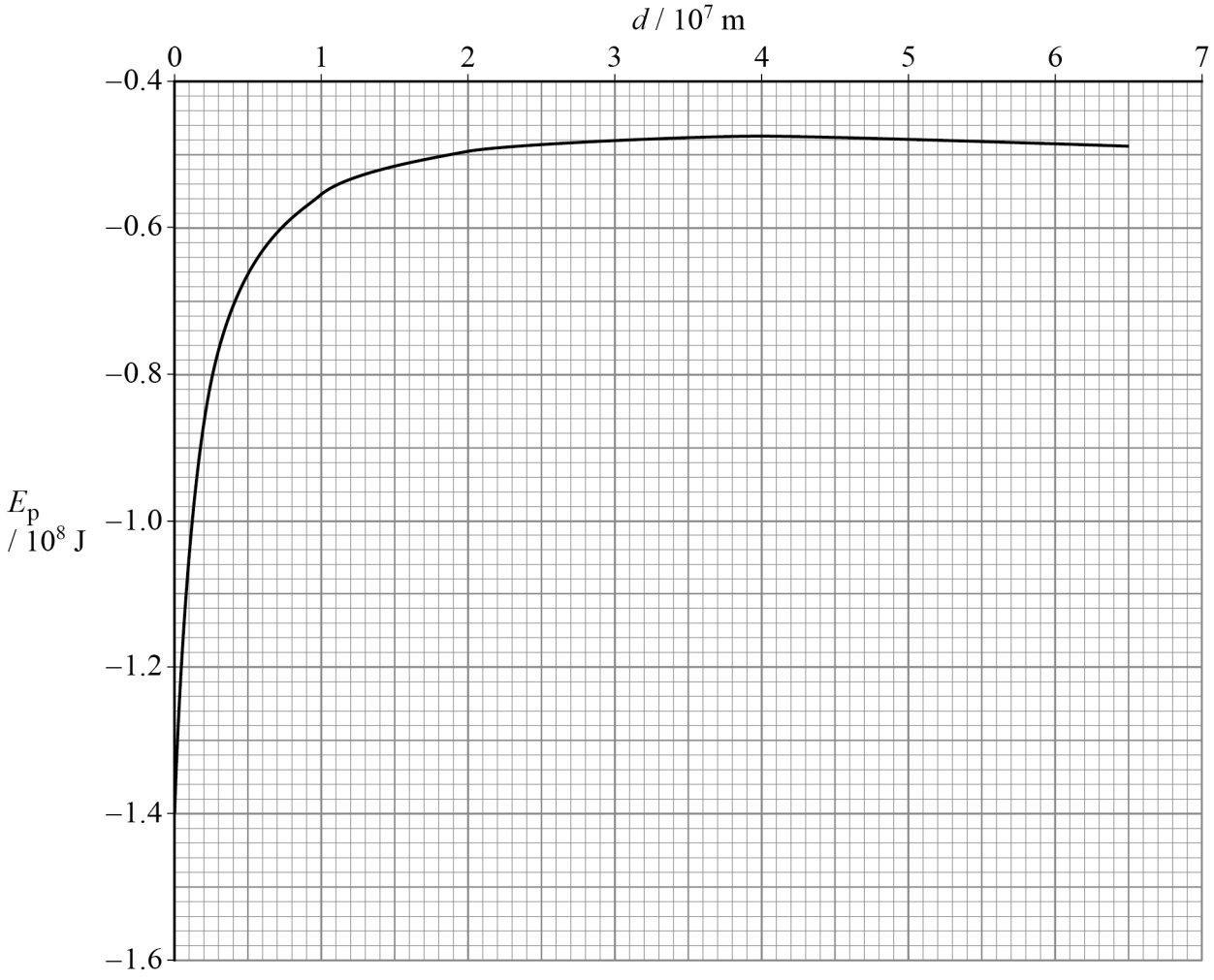
ANSWER IN THE SPACES PROVIDED

0 3 An asteroid hits the surface of the Moon and causes pieces of Moon rock to travel in many different directions. One rock travels along a line joining the centres of the Moon and the Earth.

Figure 7 shows the variation of gravitational potential energy E_p of the rock with the height d above the Moon's surface in the direction of the Earth.

Figure 7



0 3 . 1 Explain why the values of E_p in **Figure 7** are negative.

[2 marks]

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0 3 . 2 The value of E_p is a maximum where d is approximately 4×10^7 m, as shown in **Figure 7**.

Explain, without calculation, why there is a maximum value of E_p as the rock travels from the Moon to the Earth.

[2 marks]

The mass of the rock is 37 kg.

0 3 . 3 Calculate, using **Figure 7**, the gravitational field strength where $d = 1.0 \times 10^7$ m.

[3 marks]

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

Question 3 continues on the next page

Do not write outside the box

0 3 . 4 The value of E_p at the surface of the Moon is -1.4×10^8 J.

The rock leaves the surface of the Moon with a speed v.

Determine, using data from **Figure 7**, the minimum value of v needed for the rock to reach the Earth.

[3 marks]

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

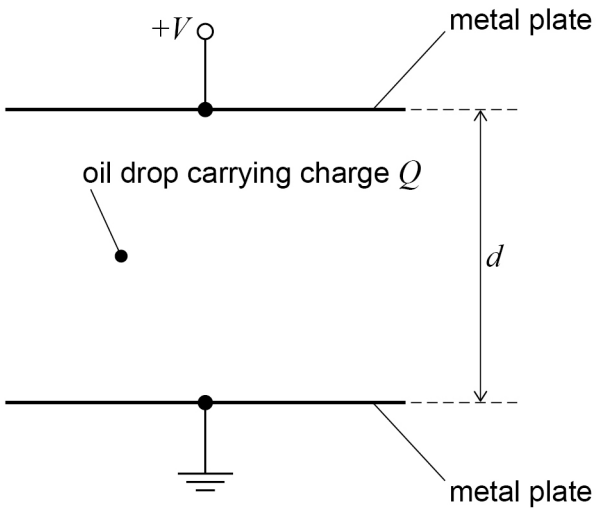
10

Do not write outside the box

0 4 A spherical oil drop has a mass m, a radius r and carries a charge Q.

Figure 8 shows the oil drop between two horizontal metal plates.
There is a potential difference V between the plates.
The separation of the plates is d.

Figure 8



The oil drop is stationary because the forces acting on the oil drop are in equilibrium.
Ignore any forces on the oil drop due to the air.

0 4 . 1 Show that $Q = -\frac{mgd}{V}$

[2 marks]

Question 4 continues on the next page

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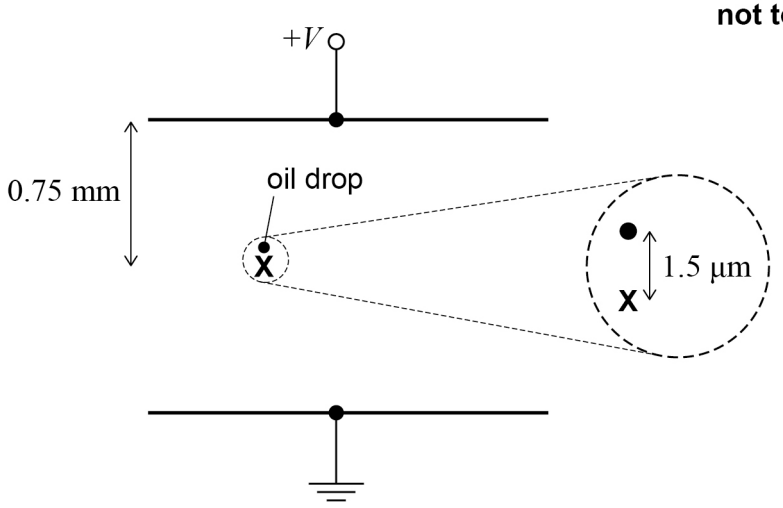
0 4 . 2 **Figure 9** shows point **X** that is 0.75 mm below the positive plate.
The centre of the oil drop is 1.5 μm vertically above **X**.

Figure 9

not to scale



Determine the magnitude and direction of the resultant electric field strength at **X**.

$V = 16$ V
$d = 1.5$ mm
$Q = -4.8 \times 10^{-19}$ C

[5 marks]

magnitude of resultant electric field strength = _____ N C^{-1}

direction = _____

Do not write outside the box

0 4 . 3 A change occurs to the situation shown in **Figure 8** so that the oil drop accelerates downwards.

Suggest **two** changes that can each cause this acceleration.

[2 marks]

1 _____

_____

_____

2 _____

_____

_____

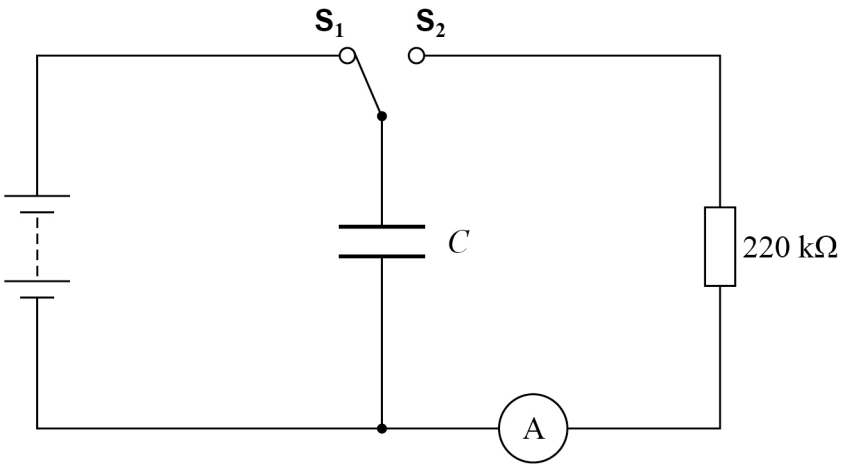
9

Turn over for the next question

Do not write outside the box

0 5 A student uses the circuit in **Figure 10** to determine the capacitance C of a capacitor. The resistance of the resistor is $220\ \text{k}\Omega$.

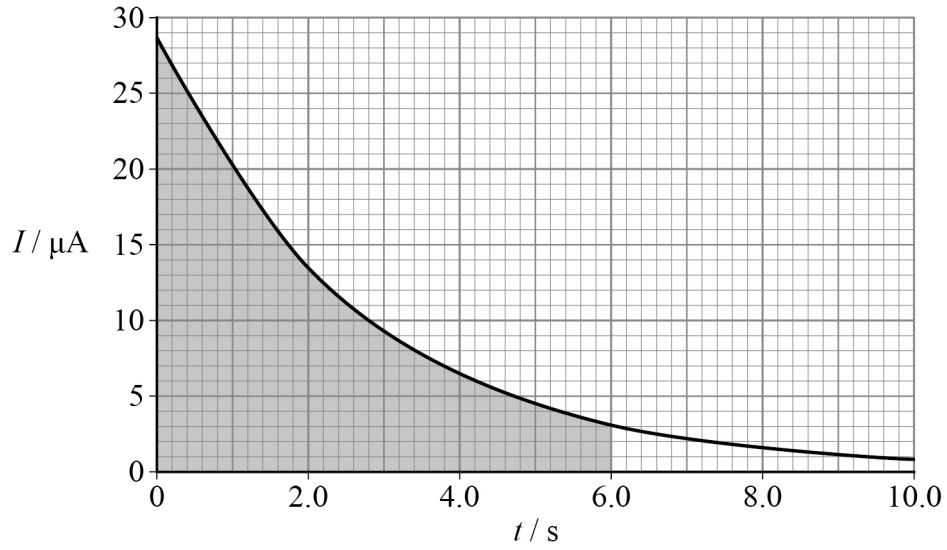
Figure 10



The switch is initially at $\mathbf{S_1}$ and the capacitor is fully charged.
At time $t = 0$, the switch is moved to $\mathbf{S_2}$ and the capacitor discharges through the resistor.

Figure 11 shows the variation of the current I in the resistor with t.

Figure 11



Do not write outside the box

0 5 . 1 Explain how the shaded area in **Figure 11** relates to the amount of charge that remains on the capacitor when $t = 6.0$ s.

[2 marks]

0 5 . 2 Determine the emf of the battery.

[2 marks]

emf = _____ V

0 5 . 3 Determine C.

[2 marks]

C = _____ F

Question 5 continues on the next page

Do not write outside the box

0 5 . 4 The student adapts the circuit in **Figure 10** using the same components.

This new circuit is used to measure the current in the $220\ \text{k}\Omega$ resistor when:
- the capacitor is discharging through the resistor
- the capacitor is charging through the resistor.

Draw the circuit diagram for this circuit.

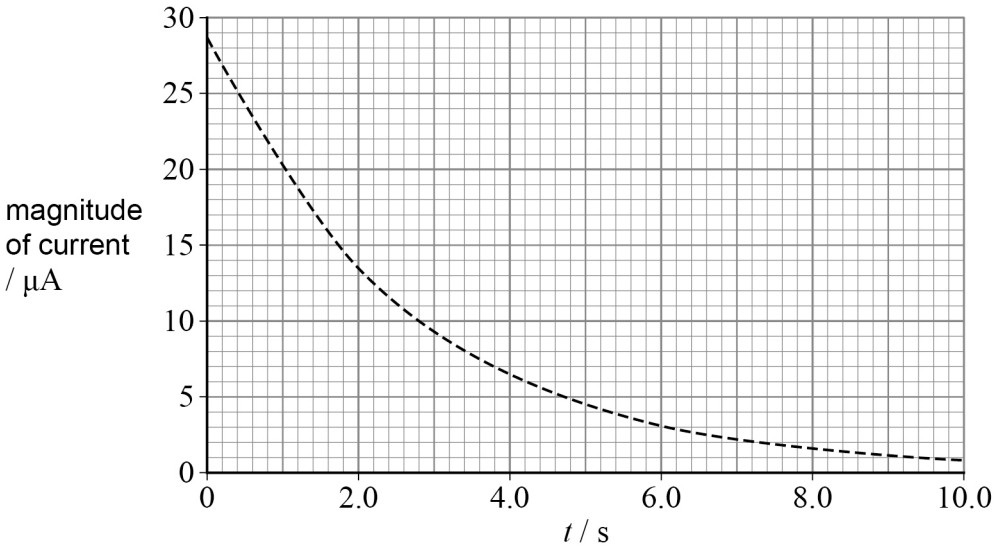
[2 marks]

0 5 . 5 The capacitor is put in series with the battery and the $220\ \text{k}\Omega$ resistor.
At time $t = 0$ the capacitor is uncharged.

Sketch, on **Figure 12**, the variation of the magnitude of the current with time as the capacitor charges.
The dashed line is the curve from **Figure 11**.

[2 marks]

Figure 12



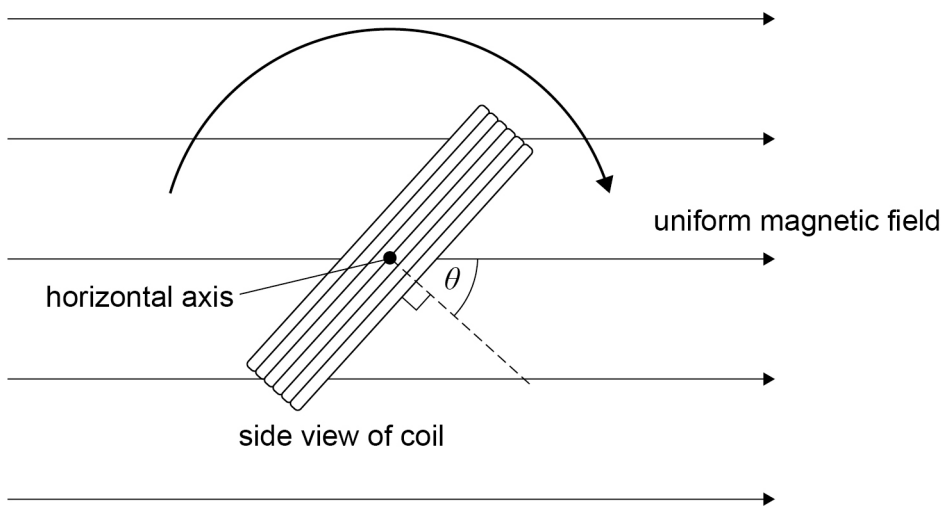
10

Do not write outside the box

0 6 A coil of wire in a uniform magnetic field rotates about its horizontal axis at a constant frequency f. **Figure 13** shows the side view of the coil at one instant.

Figure 13

not to scale



The coil has an area A of 7.5×10^{-4} m^2 and N turns.
The field has a magnetic flux density of 4.2×10^{-2} T.
$\theta = 51°$

0 6 . 1 For the position shown in **Figure 13**, the flux linkage is 2.4×10^{-3} Wb for the coil.

Calculate N.

[1 mark]

$N =$ _____

0 6 . 2 Explain why an emf is induced in the coil.
Refer to Faraday's law.

[2 marks]

_____

_____

_____

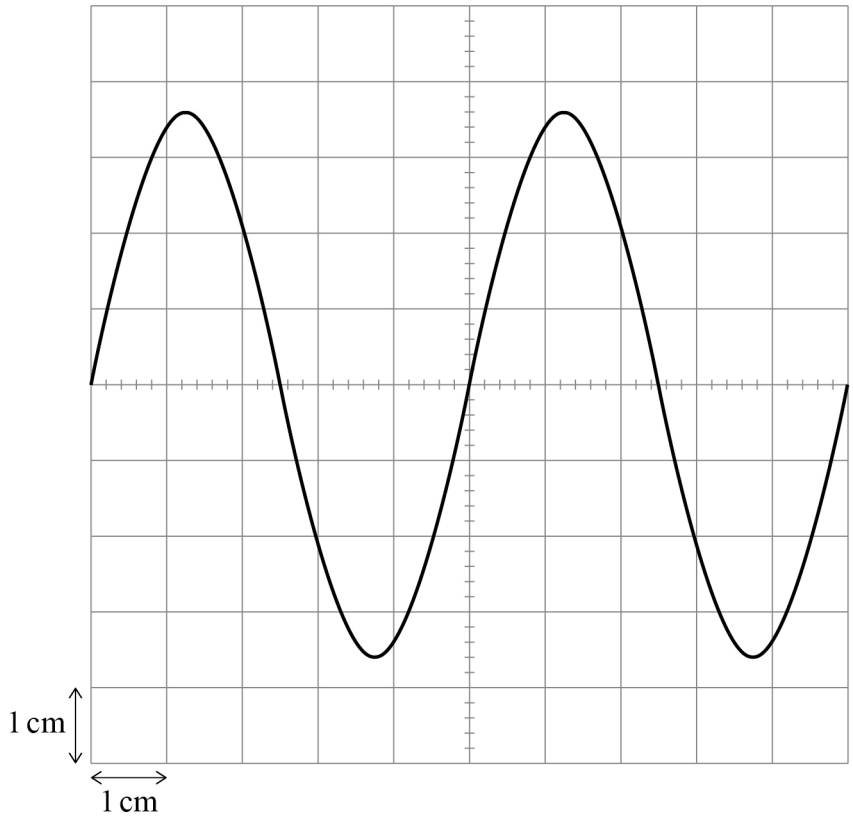
_____

Question 6 continues on the next page

Turn over ►

Figure 14 shows a trace on an oscilloscope displaying the emf induced in the rotating coil.

Figure 14



0 6 . 3 Annotate **Figure 14** with an **X** to show a point on the trace that corresponds to the position of the coil shown in **Figure 13**.
Support your answer with a suitable calculation.

[2 marks]

Do not write outside the box

The induced emf has a root mean square value of 1.27 V.

0 6 . 4 The frequency f of rotation of the coil is 50.0 Hz.

Determine the settings for the time-base and the y-gain on the oscilloscope.

[4 marks]

time-base = _____ ms cm^{-1}

y-gain = _____ V cm^{-1}

Question 6 continues on the next page

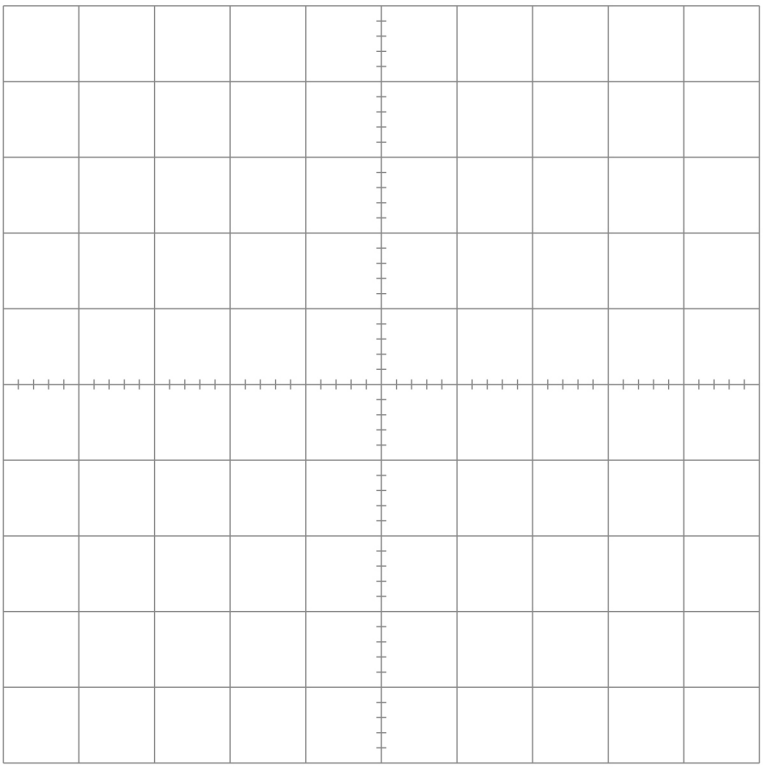
Do not write outside the box

0 6 . 5 The coil now rotates with a frequency of 25 Hz. The settings on the oscilloscope are the same settings as those used to make the trace in **Figure 14**.

Sketch the new trace on **Figure 15**.

[2 marks]

Figure 15



11

Do not write outside the box

0 7 A smoke detector contains americium-241 (Am-241).
Am-241 decays to neptunium-237 (Np-237) by alpha emission.
The initial activity of the Am-241 is 39 kBq.

The smoke detector will function until the number of alpha particles emitted per second is too small to be detected. The manufacturer predicts that this will occur after 140 years, at which time the activity of Am-241 will be 32 kBq.

0 7 . 1 Calculate the change in mass of Am-241 during the 140-year life of the detector.

molar mass of Am-241 = 0.241 kg
half-life of Am-241 = 432 years

[4 marks]

change in mass = _____ kg

0 7 . 2 Np-237 is also an alpha emitter.

The combined activity of the Am-241 and the Np-237 is not sufficient to keep the smoke detector functioning beyond the 140 years.

Suggest why.

[1 mark]

_____

_____

_____

_____

5

END OF SECTION A

Turn over ►

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 mass−spring system is oscillating with simple harmonic motion (SHM).

The kinetic energy E_k and the displacement x of the mass vary between zero and maximum values.

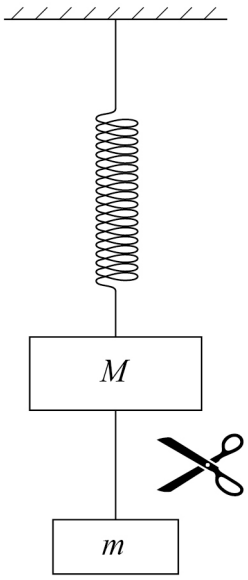
Which row describes E_k and x at the instant when the momentum of the mass is at a maximum?

[1 mark]

	E_k	x	
A	maximum	zero	⬭
B	maximum	maximum	⬭
C	zero	zero	⬭
D	zero	maximum	⬭

Do not write outside the box

0 9 A small object of mass m is suspended from a larger object of mass M using a thread of negligible mass. The system is in equilibrium and the total extension of the spring is Δl.



The thread is cut and the object of mass M moves with simple harmonic motion (SHM).

What is the time period of the SHM?

[1 mark]

A $2\pi\sqrt{\dfrac{M\Delta l}{(M-m)g}}$ ⬭

B $2\pi\sqrt{\dfrac{M\Delta l}{mg}}$ ⬭

C $2\pi\sqrt{\dfrac{M\Delta l}{(M+m)g}}$ ⬭

D $2\pi\sqrt{\dfrac{(M+m)\Delta l}{Mg}}$ ⬭

Turn over for the next question

Do not write outside the box

1 0 The distance between the Sun and the planet Mercury varies between 7.0×10^7 km and 4.6×10^7 km.
A force of gravity F acts on the Sun due to Mercury when the distance between their centres is 7.0×10^7 km.

What is the force of gravity acting on Mercury due to the Sun when the distance between their centres is 4.6×10^7 km?

[1 mark]

A $0.43F$ ⬭

B $0.66F$ ⬭

C $1.52F$ ⬭

D $2.32F$ ⬭

1 1 A satellite of mass m is in a circular orbit around a planet of mass M.

The orbital radius R of the satellite and the period T of its orbit are related by the equation

$$T^2 = kR^3$$

What is k?

[1 mark]

A $\frac{2\pi}{GMm}$ ⬭

B $\frac{4\pi^2}{GMm}$ ⬭

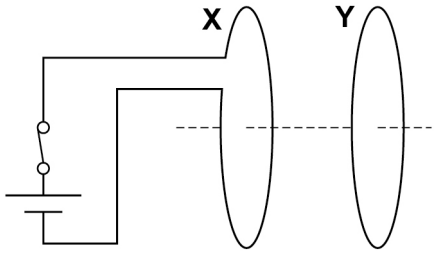
C $\frac{2\pi}{GM}$ ⬭

D $\frac{4\pi^2}{GM}$ ⬭

Do not write outside the box

1 2 A stationary circular loop of copper wire **X** is connected in series with a cell and a switch.

An identical stationary circular loop of copper wire **Y** is parallel to **X**. The centres of **X** and **Y** are on the same axis.



The switch is initially closed (on).

The switch is then opened (off).

Which row describes the force of **X** on **Y** immediately before and immediately after the switch is opened?

[1 mark]

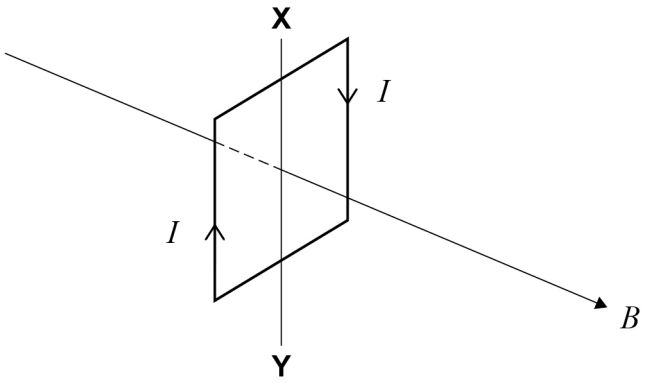
	Immediately before	**Immediately after**	
A	there is a force	there is a force	⬭
B	there is no force	there is a force	⬭
C	there is a force	there is no force	⬭
D	there is no force	there is no force	⬭

Turn over for the next question

1 3 The diagram shows a vertical square coil in a uniform horizontal magnetic field of flux density B.

The coil can rotate about a vertical axis **XY**. The whole coil is inside the magnetic field.

The current in the coil is I.



Which statement is true?

[1 mark]

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

B The forces on each side of the coil act away from the centre of the coil. ⬭

C The forces on the vertical sides of the coil create a turning effect. ⬭

D The forces on the horizontal sides of the coil are in opposite directions. ⬭

Do not write outside the box

1 4 A parallel-plate capacitor is made from two sheets of metal.

A dielectric of relative permittivity ε_r and thickness d fills the space between the sheets.

Which combination of ε_r and d gives the smallest capacitance?

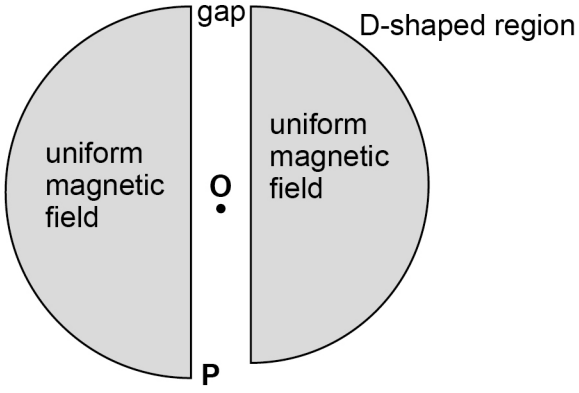
[1 mark]

	ε_r	d / mm	
A	1.5	0.5	⬭
B	2.0	0.7	⬭
C	2.5	0.9	⬭
D	3.2	1.1	⬭

Turn over for the next question

Do not write outside the box

1 5 A proton released at **O** accelerates in a cyclotron and emerges at **P**.



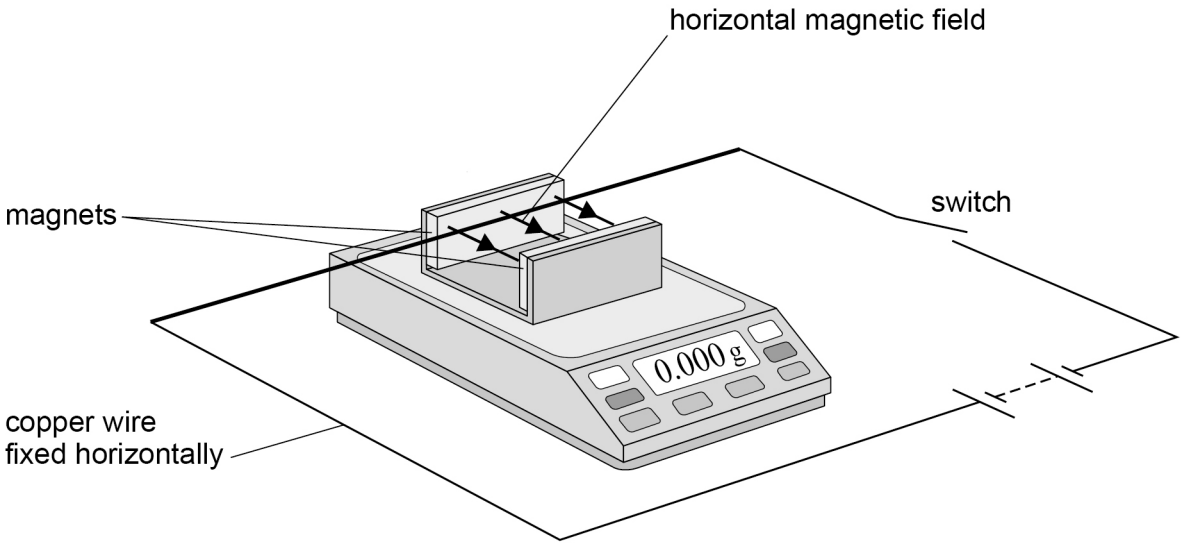
Which row describes the path of the proton within a D-shaped region and in the gap?

[1 mark]

	Path in a D-shaped region	Path in the gap	
A	spiral	spiral	⬭
B	spiral	straight	⬭
C	circular	straight	⬭
D	circular	circular	⬭

Do not write outside the box

1 6 The diagram shows an arrangement used to investigate the force on a current-carrying conductor in a magnetic field. The copper wire is fixed horizontally in a magnetic field.



The field's magnetic flux density acts horizontally towards the front of the balance.

With the switch open the reading on the balance is set to zero.

What happens to the reading when the switch is closed?

[1 mark]

A It decreases before going back to zero. ⬭

B It increases before going back to zero. ⬭

C It decreases to a constant negative value. ⬭

D It increases to a constant positive value. ⬭

Turn over for the next question

Do not write outside the box

1 7 A capacitor is made from two parallel plates separated by an air gap.
It is connected to a power supply and the capacitor stores a charge Q.
The electric field strength between the capacitor's plates is E.

The capacitor is disconnected from the power supply. A dielectric is then inserted between the plates so that it completely fills the air gap.

Which row shows the charge on the capacitor and the electric field strength between the plates after the dielectric is inserted?

[1 mark]

	Charge	Electric field strength	
A	Q	$> E$	⬭
B	Q	$< E$	⬭
C	$< Q$	$> E$	⬭
D	$< Q$	$< E$	⬭

1 8 $\mathbf{Q_1}$ and $\mathbf{Q_2}$ are point charges of $+3.0\ \mu\text{C}$ and $-3.0\ \mu\text{C}$ respectively.
$\mathbf{Q_1}$ and $\mathbf{Q_2}$ are placed at different positions on an equipotential surface that has an electric potential of $25\ \text{kV}$.
The positions of $\mathbf{Q_1}$ and $\mathbf{Q_2}$ are exchanged.

What is the net work done in moving $\mathbf{Q_1}$ and $\mathbf{Q_2}$ to their new positions?

[1 mark]

A $-0.075\ \text{J}$ ⬭

B 0 ⬭

C $0.075\ \text{J}$ ⬭

D $0.15\ \text{J}$ ⬭

Do not write outside the box

1 9 A satellite is in a geostationary orbit.

What is the height of the satellite above the surface of the Earth?

[1 mark]

A 5.1×10^6 m ⬭

B 3.6×10^7 m ⬭

C 4.2×10^7 m ⬭

D 2.2×10^9 m ⬭

2 0 Eddy currents are produced by the changing magnetic field in the laminated iron core of a transformer.

Which statement about eddy currents is correct?

[1 mark]

A They are in the same plane as the laminations of the core. ⬭

B They change direction when the magnetic field changes direction. ⬭

C Their size depends on the resistivity of the material of the core. ⬭

D They do not require an induced emf in the core to be produced. ⬭

Turn over for the next question

Do not write outside the box

2 1 An object is moving with simple harmonic motion (SHM) with a period T.
The total energy of the system is E.

The object is at its maximum displacement at time $t = 0$

Which row gives the kinetic energy E_k of the object when $t = \frac{T}{4}$ and when $t = \frac{T}{2}$?

[1 mark]

	E_k when $t = \frac{T}{4}$	E_k when $t = \frac{T}{2}$	
A	E	0	⬭
B	0	E	⬭
C	0	$\frac{E}{4}$	⬭
D	E	$\frac{3E}{4}$	⬭

2 2 Coulomb's law can be written as

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$$

This equation is used to determine the force of one charged sphere on another charged sphere. Both charged spheres are in air.

What must be true?

[1 mark]

A r is the separation of the centres of the spheres. ⬭

B The two charges carry the same type of charge. ⬭

C There are no other charges nearby. ⬭

D The relative permittivity of the air is added to ε_0. ⬭

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END OF QUESTIONS

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