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

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	

Section A

Answer **all** questions in this section.

0 1 A student investigates the emf induced in a coil of wire when it is rotating at constant angular speed in a uniform magnetic field.

An oscilloscope is connected across the output of the coil. **Figure 1** shows the trace on the oscilloscope screen.

Figure 2 shows the time-base setting for the oscilloscope.

Figure 1

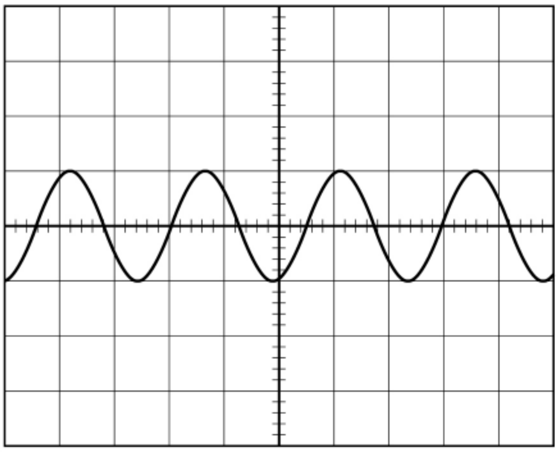
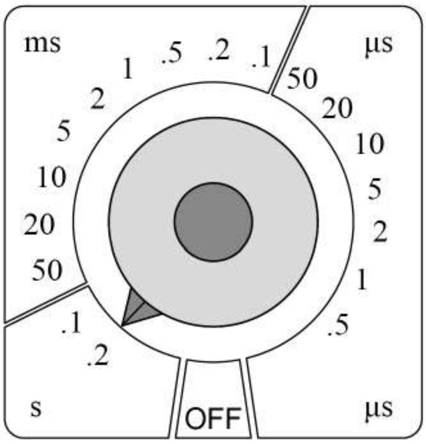


Figure 2



time base

0 1 . 1 Describe what the student should do to determine an accurate value for the peak emf induced in the coil.

[3 marks]

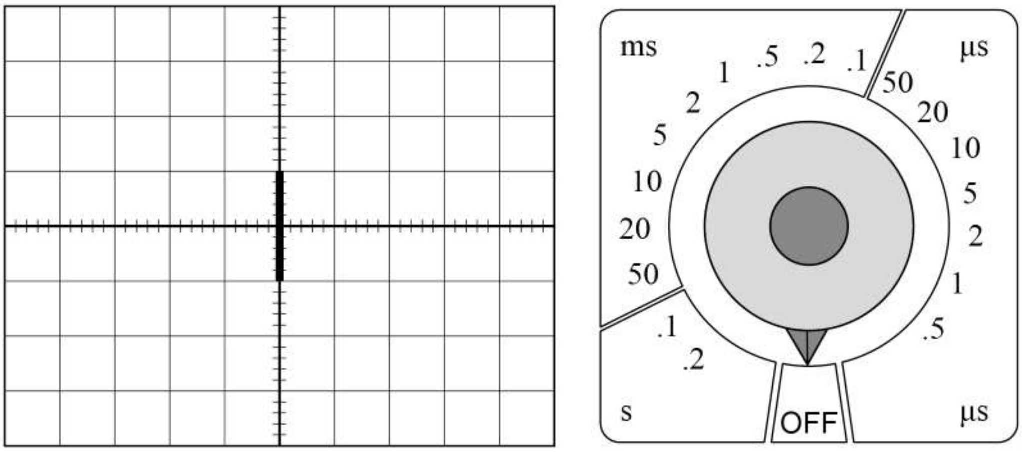
Do not write outside the box

0 1 . 2 Show that the angular speed of the coil is approximately 13 rad s^{-1}.
Use **Figure 1** and **Figure 2**.

[3 marks]

0 1 . 3 **Figure 3** shows the oscilloscope screen with the time-base set to OFF.

Figure 3



The student wishes to make an **accurate** measurement of the time period of the induced emf.

Calculate an appropriate time-base setting.
Explain your answer.

[3 marks]

time-base setting = ____________________

____

____

Question 1 continues on the next page

The peak emf is 7.5×10^{-2} V.

0 1 . 4 The coil has an area of $6.0 \times 10^{-3}\ \text{m}^2$ and 25 turns of wire.

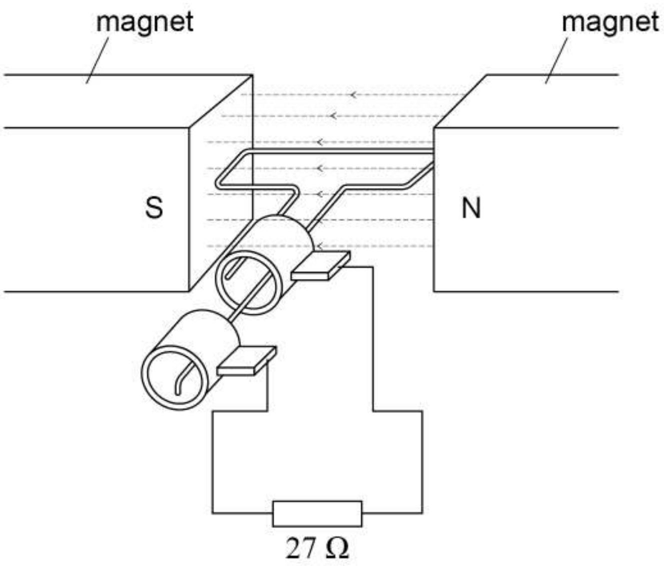
Calculate the magnetic flux density of the magnetic field.

[2 marks]

magnetic flux density = ______________________ T

0 1 . 5 **Figure 4** shows the coil connected to a 27 Ω resistor.
The resistance of the rest of the circuit is negligible.

Figure 4



Calculate the mean power dissipated in the resistor.

[3 marks]

mean power = ______________________ W

14

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0 2 . 1 Show that the total energy E of a satellite orbiting the Moon is given by

$$E = -\frac{GMm}{2r}$$

where m is the mass of the satellite, M is the mass of the Moon and r is the orbital radius of the satellite.

[3 marks]

0 2 . 2 Explain the significance of the negative sign in the equation in Question **02.1**.

[2 marks]

Question 2 continues on the next page

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The satellite has a mass of 1.0×10^3 kg and orbits the Moon in a circular orbit.
The mass of the Moon is 7.3×10^{22} kg.

0 2 . 3 Determine the orbital speed of the satellite when the orbital radius is 1.95×10^3 km.

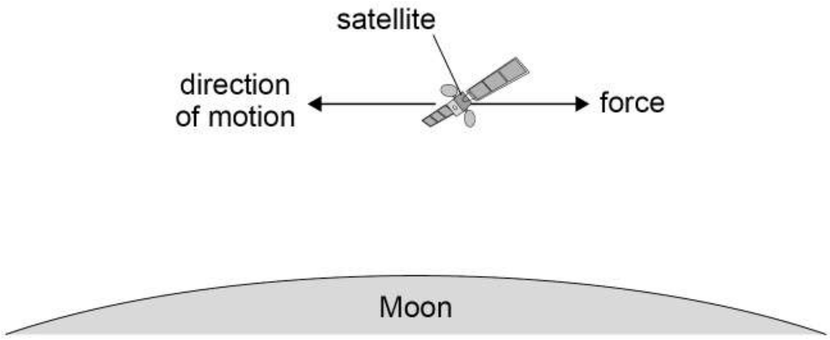
[3 marks]

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

Do not write outside the box

The satellite's thrusters exert a force in the direction opposite to its direction of motion, as shown in **Figure 5**. This causes the radius of the orbit to decrease.

Figure 5



0 2 . 4 Explain, with reference to energy, why the use of the thrusters reduces the radius of the orbit.

[2 marks]

____

____

____

____

____

0 2 . 5 Calculate the work done by the thrusters in reducing the radius of the satellite's orbit. Assume that the final orbit of the satellite is circular.

initial radius of the orbit = 1.95×10^3 km
final radius of the orbit = 1.85×10^3 km

[2 marks]

work done = ____________________ J

12

Turn over ►

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0 3 . 1 Define activity in the context of radioactive decay.

[1 mark]

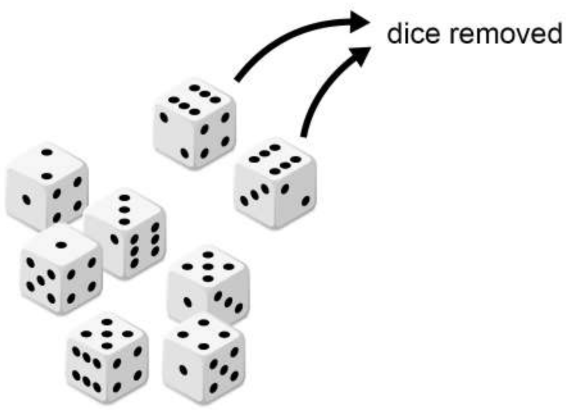
A dice-rolling experiment models radioactive decay. Standard six-sided dice are used. One dice represents one radioactive nucleus.

At time $t = 0$, there are N_0 dice.

- The dice are rolled.
- The dice showing six dots on the top surface are removed, as shown in **Figure 6**.
- The number N of the remaining dice is counted.

The process of rolling, removing and counting the dice is repeated at intervals of 1 minute.

Figure 6



In this experiment the variation of N with time t can be modelled mathematically as

$$N = N_0 e^{-\lambda t}$$

0 3 . 2 Explain why λ is approximately 0.2 minute^{-1}.

[1 mark]

Do not write outside the box

0 3 . 3 Estimate the time t at which $N = \frac{N_0}{2}$

[2 marks]

$t =$ ________________________ minute

0 3 . 4 This experiment is done with $N_0 = 500$

Estimate, using the mathematical model for the variation of N with t, the time t at which $N = 20$

[3 marks]

$t =$ ________________________ minute

0 3 . 5 Explain why the actual time taken might be significantly different to your estimate in Question **03.4**.

[1 mark]

____

____

____

8

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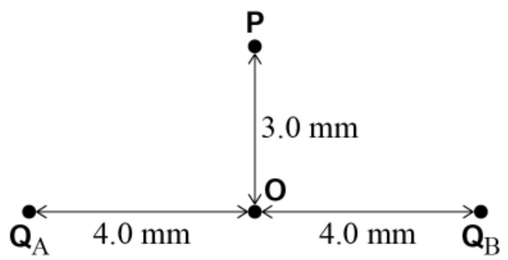
0 4 **Figure 7** shows two identical negative point charges, **Q**$_A$ and **Q**$_B$, in fixed positions 8.0 mm apart.
O is a point midway between the charges.
P is a point 3.0 mm away from **O** and equidistant from **Q**$_A$ and **Q**$_B$.

Figure 7



0 4 . 1 The resultant electric field strength at **P** is 1400 N C^{-1} towards **O**.

Calculate the charge of **Q**$_A$.

[3 marks]

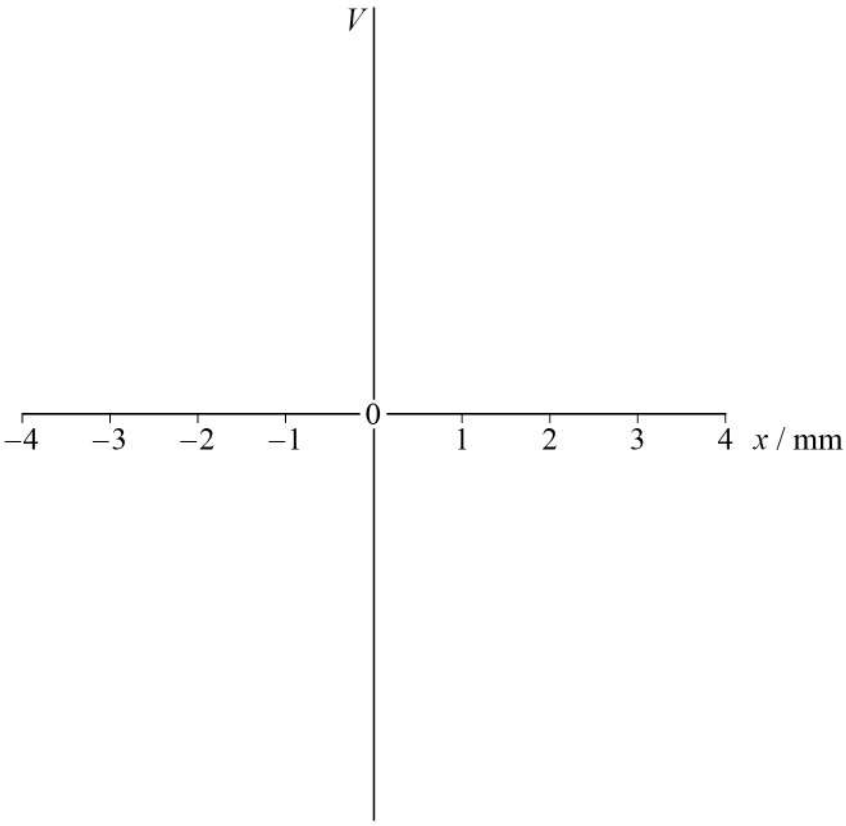
charge = ____________________ C

Do not write outside the box

0 4 . 2 Sketch, on **Figure 8**, the variation of electric potential V with displacement x from **O** between $\mathbf{Q}_A$ and $\mathbf{Q}_B$.
Calculations and numerical values for V are not required.

[2 marks]

Figure 8



Question 4 continues on the next page

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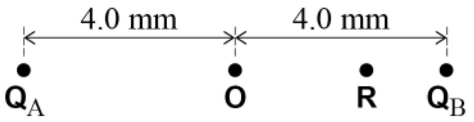
Figure 9 shows a point **R** between **O** and $\mathbf{Q}_B$.

Figure 9



$\mathbf{Q}_A$ and $\mathbf{Q}_B$ are in fixed positions.

A small mass **m** with negative charge q is released from rest at **R**.
Only electrostatic forces act on **m**.
After release, **m** oscillates about **O** along the line between $\mathbf{Q}_A$ and $\mathbf{Q}_B$.

0 4 . 3 State and explain how the direction of the resultant force on **m** varies during oscillation.

[2 marks]

0 4 . 4 Describe the energy changes of **m** from its release until it reaches **O** for the first time.

[2 marks]

0 4 . 5 Deduce whether or not **m** performs simple harmonic motion.

[1 mark]

10

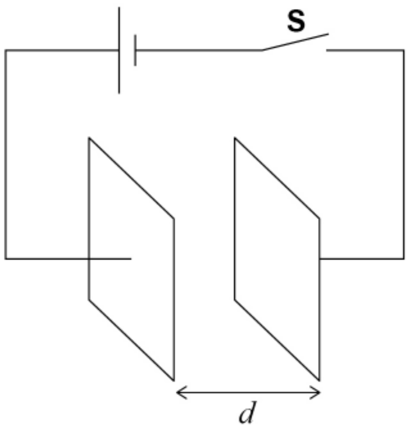
Do not write outside the box

0 5 . 1 State what is meant by a capacitance of $37\ \mathrm{mF}$.

[1 mark]

A capacitor is made up of two parallel metal plates, which are separated in air by a distance d.
A cell of negligible internal resistance is connected across the capacitor as shown in **Figure 10**. Switch **S** is closed and the capacitor becomes fully charged.

Figure 10



0 5 . 2 While **S** is still closed, the plate separation is reduced to $\frac{d}{2}$.

State and explain what happens to the magnitude of the charge stored by the capacitor.

[3 marks]

Question 5 continues on the next page

Do not write outside the box

0 5 . 3 Explain how charge is conserved when the plate separation is reduced.

[1 mark]

0 5 . 4 **S** is now opened.
The plate separation is increased to d.

State and explain how the energy stored in the capacitor changes during this process.

[3 marks]

0 5 . 5 Explain how energy is conserved when the plate separation is increased as described in Question **05.4**.

[1 mark]

9

Do not write outside the box

0 6 . 1 Describe what is necessary for a charged particle to experience a force due to its movement in a magnetic field.

[1 mark]

0 6 . 2 Show that the radius r of the circular path of a charged particle in a uniform magnetic field in a vacuum is given by

$$r = \frac{p}{Bq}$$

where p is the momentum of the particle, B is the magnetic flux density and q is the charge of the particle.

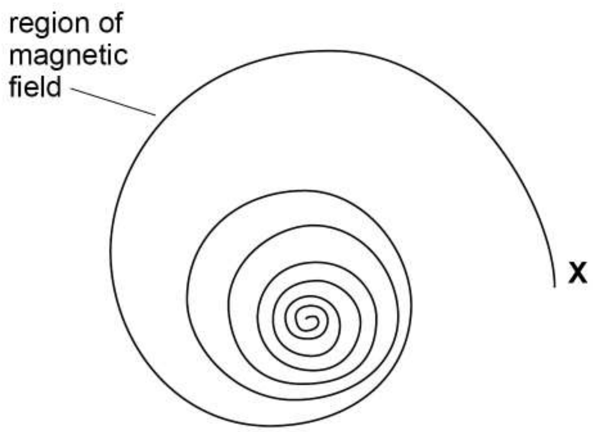
[2 marks]

Question 6 continues on the next page

A cloud chamber is a particle detector that produces visible tracks. The tracks form as charged particles ionise air molecules along their paths. Charged particles produce spiral tracks when the cloud chamber is placed in a uniform magnetic field.

Figure 11 is a full-size image showing the track of a particle created at point **X** in a cloud chamber. The particle travels in a horizontal plane.

Figure 11



The magnetic field direction is into the plane of the page.

0 6 . 3 Explain why the radius of the path decreases as the particle created at **X** travels through the cloud chamber.

[3 marks]

Do not write outside the box

0 6 . 4 The particle created at **X** has a charge of 1.6×10^{-19} C.

The magnetic flux density in the cloud chamber is 0.20 T and acts vertically into the plane of the page.

Determine, by taking measurements from **Figure 11**, an estimate for the initial momentum of the particle.

Figure 11 is a full-size image.

[3 marks]

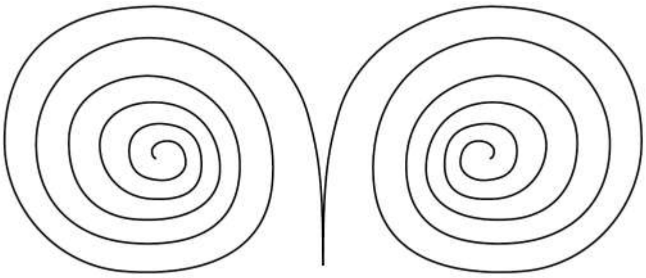
momentum = ______________________ $kg\ m\ s^{-1}$

Question 6 continues on the next page

Do not write outside the box

0 6 . 5 A gamma photon produces two particles in a pair-production event in the cloud chamber. **Figure 12** shows the tracks due to the pair-production event.

Figure 12



Explain what **Figure 12** indicates about the three particles involved in the pair-production event.

[3 marks]

12

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.

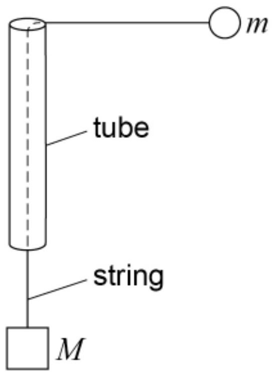
CORRECT METHOD ⬬ WRONG METHODS

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 pages for this working.

0 7 In an experiment to investigate centripetal force, mass M and mass m are attached to the ends of a string.
Mass m is moved in a horizontal circle of constant radius.



Mass M is varied as the independent variable.

Which could be a directly measurable dependent variable?

[1 mark]

A speed of m ⬭

B centripetal acceleration of m ⬭

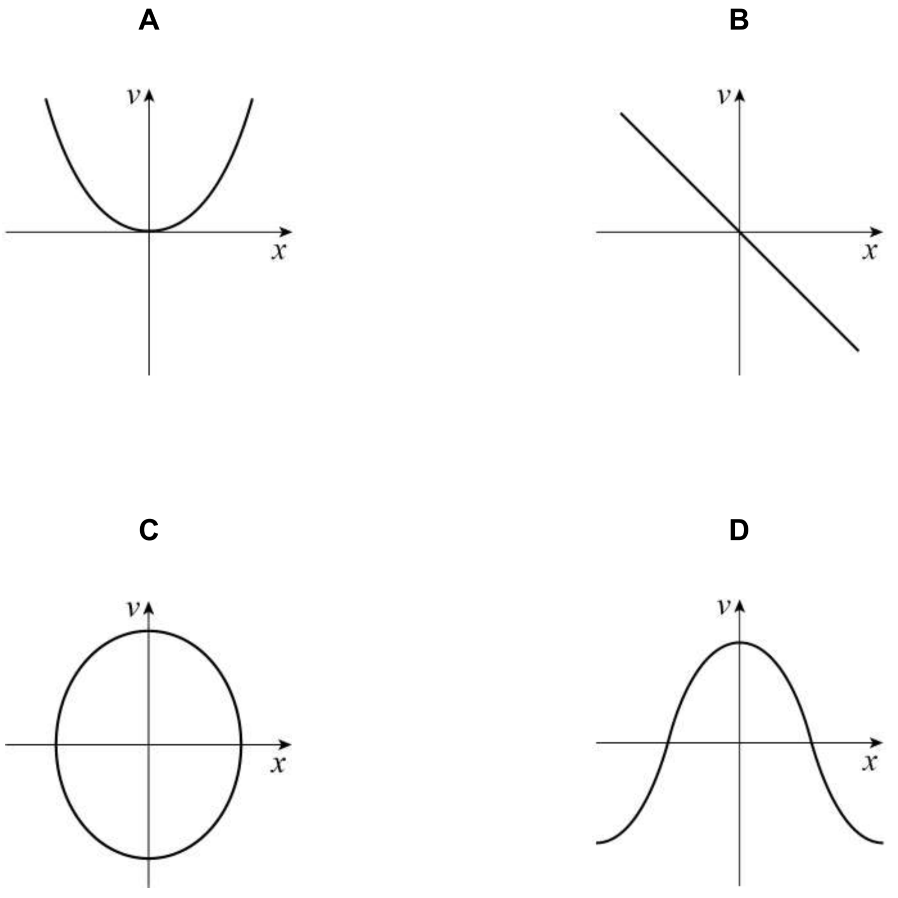
C mass of m ⬭

D time period of rotation of m ⬭

0 8 A body is moving with simple harmonic motion.

What is the variation of its velocity v with its displacement x?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

Do not write outside the box

0 9 A mass oscillates with amplitude A and frequency f on a spring of spring constant k. The total energy of the mass–spring system is E.

A second mass–spring system has an identical mass and a different spring.
The second system oscillates with amplitude $2A$ and frequency $2f$.

Which shows the spring constant of the second spring and the total energy of the second system?

[1 mark]

	Spring constant	Total energy	
A	$\sqrt{2}k$	$4E$	⬭
B	$2k$	$16E$	⬭
C	$4k$	$4E$	⬭
D	$4k$	$16E$	⬭

1 0 A pendulum bob is pulled to one side so that its string makes an angle θ to the vertical. The bob is released and the pendulum oscillates freely.

What is the maximum acceleration of the bob?

[1 mark]

A g ⬭

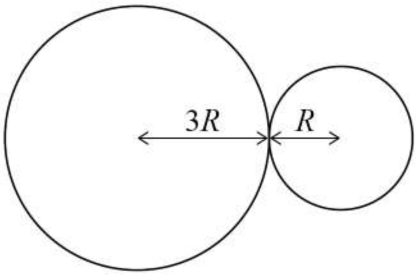
B $g\cos\theta$ ⬭

C $g\sin\theta$ ⬭

D $g\tan\theta$ ⬭

Do not write outside the box

1 1 Two uniform solid spheres of radius R and $3R$ touch. They have the same density ρ.



What is the gravitational force between them?

[1 mark]

A $\frac{5}{6}\pi G R \rho^2$

B $\pi^2 G R^2 \rho^2$

C $3\pi^2 G R^4 \rho^2$

D $\frac{4}{9}\pi^2 G R^5 \rho^2$

1 2 The average density of the Earth is 1.4 times greater than the average density of planet **X**. The radius of the Earth is 1.9 times greater than the radius of **X**.

What is the gravitational field strength on the surface of **X**?

[1 mark]

A $3.7\ \text{N kg}^{-1}$

B $7.2\ \text{N kg}^{-1}$

C $13\ \text{N kg}^{-1}$

D $26\ \text{N kg}^{-1}$

Do not write outside the box

1 3 The average mass of a nucleon in a nucleus of the atom ${}^{A}_{Z}\mathrm{X}$ is M_n.

The mass of an electron is m_e.

What is $\dfrac{\text{gravitational force}}{\text{electrostatic force}}$ for the forces between the nucleus and an electron in the atom?

[1 mark]

A $\dfrac{4\pi\varepsilon_0 GZm_e M_n}{Ae^2}$ ⬭

B $\dfrac{4\pi\varepsilon_0 GAm_e M_n}{Ze^2}$ ⬭

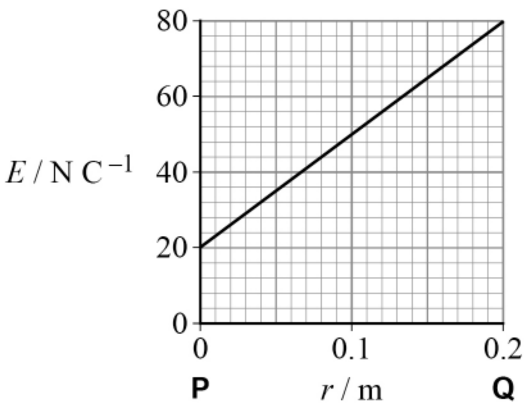
C $\dfrac{Am_e M_n}{4\pi\varepsilon_0 GZe^2}$ ⬭

D $\dfrac{GAm_e M_n}{4\pi\varepsilon_0 Ze^2}$ ⬭

1 4 Points **P** and **Q** are 0.2 m apart in an electric field. The graph shows the variation of electric field strength E with position r between **P** and **Q**.

What is the potential difference between **P** and **Q**?

[1 mark]



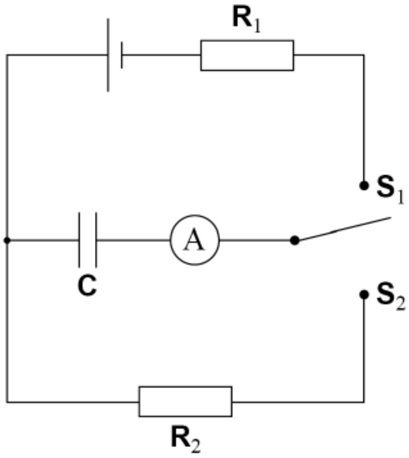
A 6 V ⬭

B 10 V ⬭

C 60 V ⬭

D 300 V ⬭

1 5 In the circuit, the resistance of resistor $\mathbf{R}_2$ is greater than the resistance of resistor $\mathbf{R}_1$. The capacitor **C** is initially uncharged.

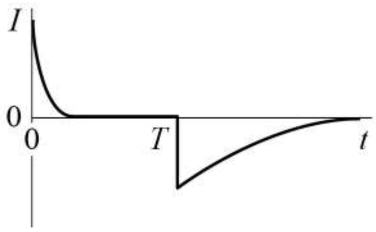


At time $t = 0$ the switch is set to position $\mathbf{S}_1$.
At time $t = T$ the switch is moved to position $\mathbf{S}_2$.

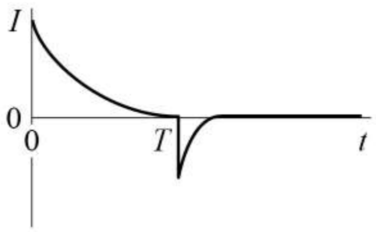
Which graph shows the variation of current I in the ammeter with t?

[1 mark]

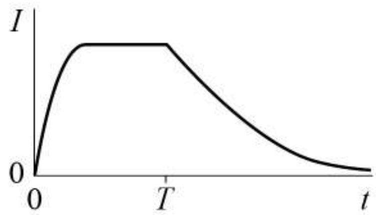
A



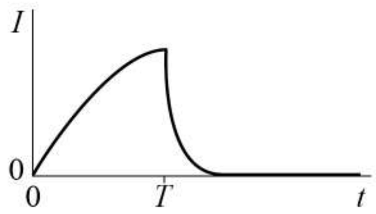
B



C



D



A ○

B ○

C ○

D ○

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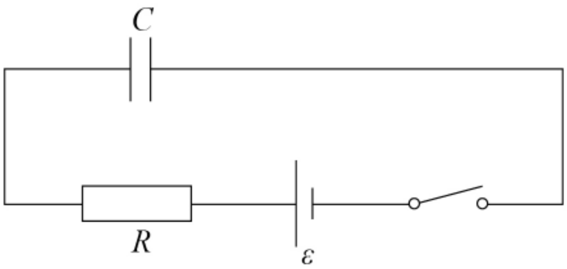
1 6 A capacitor of capacitance C is connected to a switch, a cell of emf ε and a resistor of resistance R.
The cell has negligible internal resistance.
The capacitor is initially uncharged.



The switch is then closed.

What is the time taken for the voltage across the capacitor to reach $\frac{\varepsilon}{3}$?

[1 mark]

A $RC\ln 3$ ○

B $RC\ln\frac{3}{2}$ ○

C $RC(\ln 2 - \ln 3)$ ○

D $\frac{1}{3}RC\ln 2$ ○

1 7 Which is a unit for magnetic flux?

[1 mark]

A $\mathrm{N\ m\ A^{-1}}$ ○

B $\mathrm{N\ m^{2}\ A^{-1}}$ ○

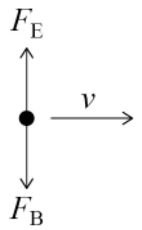
C $\mathrm{N\ m^{-1}\ A}$ ○

D $\mathrm{N\ m^{-2}\ A}$ ○

Turn over ►

Do not write outside the box

Questions **18** and **19** refer to the following situation.
An electron moves to the right at a constant velocity v in a region where a magnetic field of flux density B and an electric field of strength E are applied.
Force F_E due to the electric field and force F_B due to the magnetic field act on the electron.



1 8 F_E is up the page and F_B is down the page as shown.

What are the directions of E and B?

[1 mark]

	Direction of E	Direction of B	
A	up the page	down the page	⬭
B	up the page	out of the page	⬭
C	down the page	into the page	⬭
D	down the page	out of the page	⬭

1 9 The resultant force on the electron is zero.

Which equation relates E, B and v?

[1 mark]

A $Bv = E$ ⬭

B $B = vE$ ⬭

C $v = BE$ ⬭

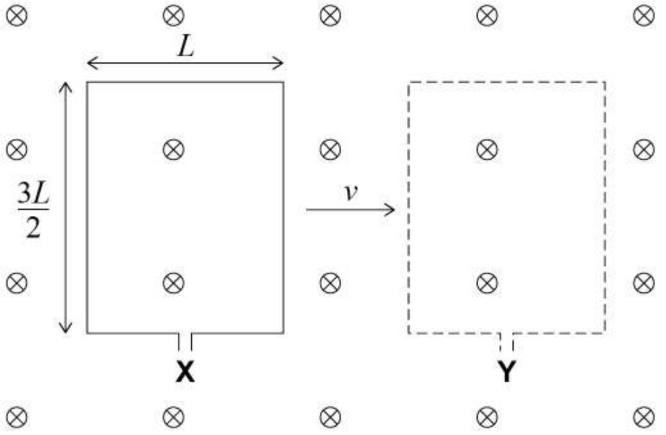
D $BEv = 1$ ⬭

Do not write outside the box

2 0 A rectangular coil has dimensions L and $\frac{3L}{2}$.

The coil moves in a magnetic field at a velocity v perpendicular to the field.

The magnetic field has a uniform magnetic flux density B perpendicular to the plane of the coil.



What is the emf induced in the coil as it moves from position **X** to position **Y**?

[1 mark]

A BLv ☐

B $\frac{3}{2}BLv$ ☐

C $3BLv$ ☐

D 0 ☐

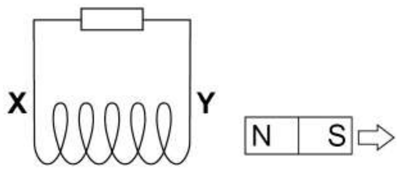
Turn over for the next question

2 1 A bar magnet is moved near a coil **XY** in the direction shown by the arrows.
Two of the actions shown in the diagrams will induce an N-pole at Y.

Which actions will induce an N-pole at **Y**?

[1 mark]

1



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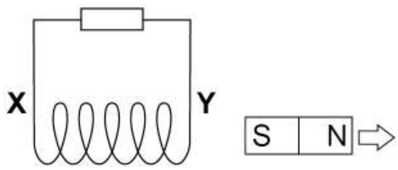

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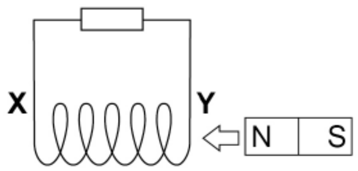

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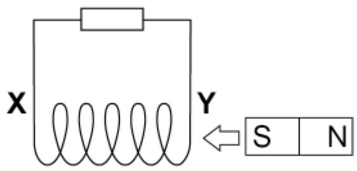

A **1** and **3** ⬭

B **1** and **4** ⬭

C **2** and **3** ⬭

D **2** and **4** ⬭

15

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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

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