OXFORD

INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

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I declare this is my own work.

INTERNATIONAL A-LEVEL

PHYSICS

Unit 3 Fields and their consequences

Monday 18 January 2021 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 One of the moons of Jupiter is named Io.

The mass of Io is 8.93×10^{22} kg.

The gravitational potential due to Io at its surface is -3.27×10^{6} J kg^{-1}.

0 1 . 1 State what is meant by a gravitational potential of -3.27×10^{6} J kg^{-1} at the surface of Io.

[2 marks]

0 1 . 2 Show that the radius of Io is approximately 1.8×10^{6} m.

[1 mark]

Do not write outside the box

A volcanic rock of mass $3.00\ \text{kg}$ is ejected vertically upwards from the surface of Io with an initial velocity of $760\ \text{m s}^{-1}$.
The rock reaches a maximum height h above the surface of Io.

0 1 . 3 Show that the rock's gravitational potential energy at height h is approximately $-9\ \text{MJ}$.

[3 marks]

0 1 . 4 Calculate h.

[2 marks]

$h =$ _____ m

0 1 . 5 Another rock of greater mass is ejected vertically upwards from the surface with the same initial velocity.

State and explain how the height reached by the rock of greater mass compares to h.

[2 marks]

_____

_____

_____

_____

10

Turn over ►

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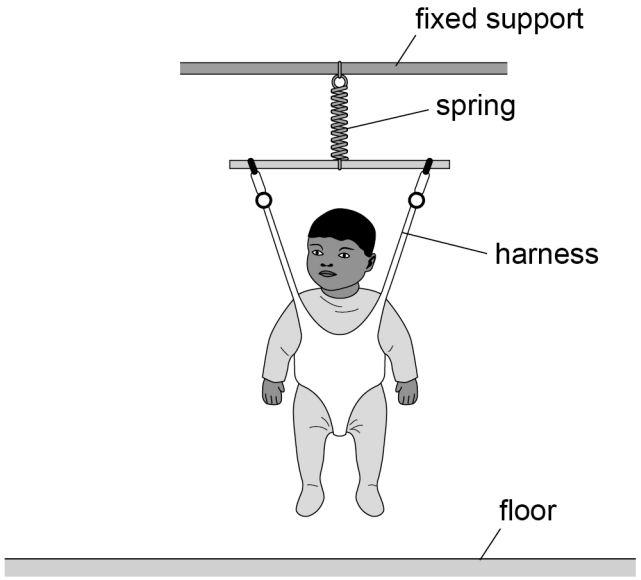
0 2 **Figure 1** shows a mass–spring system that consists of a baby in a harness.
The system is suspended from a fixed support by a vertical spring.

The total mass of the baby and harness is $8.5\ \text{kg}$.
The spring has negligible mass and obeys Hooke's Law.

Figure 1



0 2 . 1 The extension of the spring is $0.16\ \text{m}$ when the system is in equilibrium.

Show that the spring constant of the spring is approximately $520\ \text{N m}^{-1}$.

[1 mark]

Do not write outside the box

The baby is displaced vertically downwards by $4.0\ \text{cm}$ from the equilibrium position and released at time $t = 0$
The system then oscillates vertically with simple harmonic motion.

0 2 . 2 Show that the time period of the oscillation is approximately $0.8\ \text{s}$.

[1 mark]

0 2 . 3 Calculate the initial total energy of the system due to the oscillation.

[3 marks]

initial total energy = _____ J

Question 2 continues on the next page

Do not write outside the box

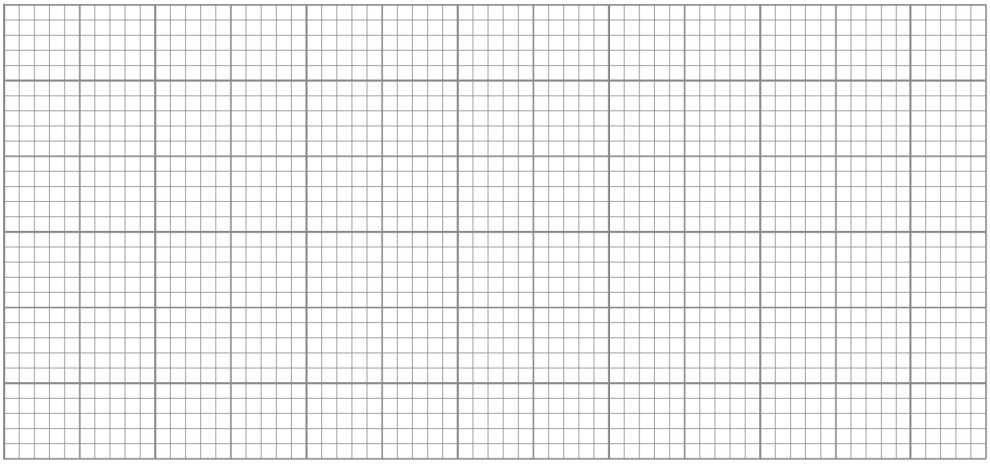
The baby does not add energy to the oscillating system.

0 2 . 4 Sketch a graph on **Figure 2** to show the variation of the kinetic energy of the system with time from $t = 0$ to $t = 1.2$ s.

Label the axes and add appropriate scales.

[4 marks]

Figure 2



0 2 . 5 In practice, the oscillations are damped by air resistance.

Describe how the damping force varies with time.

[2 marks]

11

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0 3 Carbon dating is a process that can be used to find the age of dead wood.
Wood contains a mixture of the carbon isotopes carbon-14 and carbon-12.

In living wood, the ratio $\frac{\text{number of carbon-14 atoms}}{\text{number of carbon-12 atoms}}$ is assumed to be constant.

In dead wood, the ratio $\frac{\text{number of carbon-14 atoms}}{\text{number of carbon-12 atoms}}$ changes with time.

Carbon-12 is not radioactive.
Carbon-14 is radioactive with a decay constant of $3.85 \times 10^{-12}\ \text{s}^{-1}$.

0 3 . 1 State what is meant by decay constant.

[1 mark]

0 3 . 2 45% of the mass of living wood is from carbon-12 atoms.

Show that 30 g of living wood contains approximately 1 mol of carbon-12 atoms.

molar mass of carbon-12 = 12 g

[1 mark]

Question 3 continues on the next page

Do not write outside the box

The number of carbon-14 atoms in 30 g of living wood is 8.2×10^{11}.

0 3 . 3 Calculate the ratio $\frac{\text{number of carbon-14 atoms}}{\text{number of carbon-12 atoms}}$ in 30 g of living wood.

[2 marks]

ratio = _____

0 3 . 4 Show that the activity due to the carbon-14 in 30 g of living wood is approximately 3 Bq.

[1 mark]

Do not write outside the box

Scientists estimate the age of an ancient wooden object by carbon dating.
The mass of the object is 30 g.

0 3 . 5 State and explain how the ratio $\frac{\text{number of carbon-}14\text{ atoms}}{\text{number of carbon-}12\text{ atoms}}$ in the object compares with the ratio in living wood.

[2 marks]

0 3 . 6 The object has an activity of 2.6 Bq due to carbon-14.

Estimate, in years, the age of the object.

[3 marks]

age = _____ years

0 3 . 7 Suggest **two** reasons why the age of the object might be different from your answer to Question **03.6**.

[2 marks]

1 _____

2 _____

12

Do not write outside the box

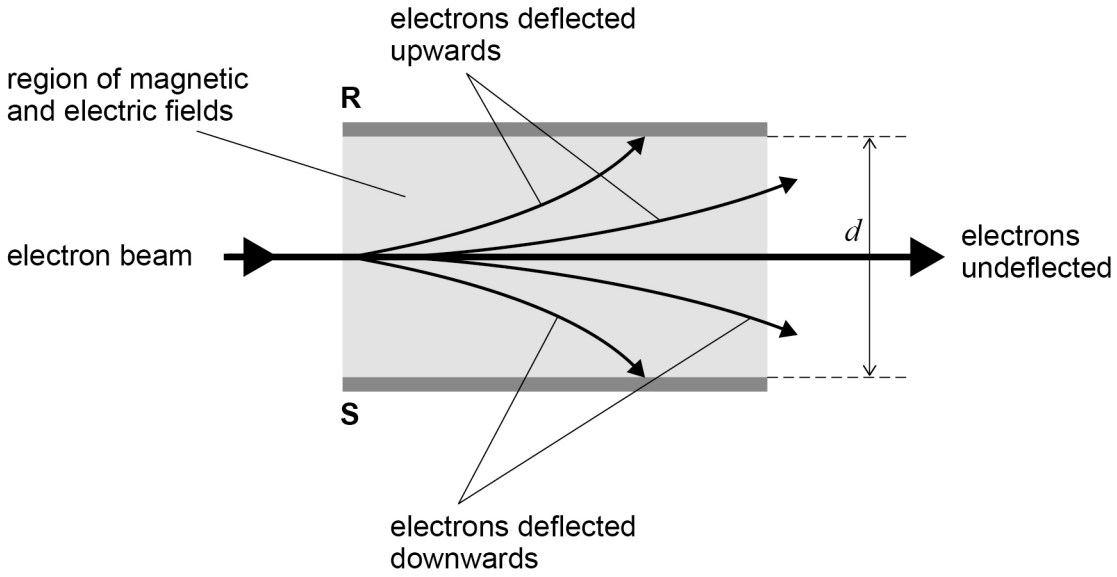
0 4 A beam contains electrons with a range of horizontal velocities. **Figure 3** shows the electron beam entering a device in a vacuum.

The device consists of two horizontal metal plates **R** and **S** separated by a distance d.

A uniform electric field of electric field strength E and a uniform magnetic field of magnetic flux density B are applied between the plates. The fields are perpendicular to each other and to the initial velocity of the electrons.

Only electrons that enter the device at a particular velocity v are undeflected. Electrons with other velocities are deflected such as in **Figure 3**.

Figure 3



0 4 . 1 The electric force on the electrons acts upwards towards plate **R**.

State the direction of E.

[1 mark]

direction of E = _____

0 4 . 2 State the direction of B.

[1 mark]

direction of B = _____

Do not write outside the box

0 4 . 3 The forces acting on the undeflected electrons are balanced.

Show that

$$v = \frac{E}{B}$$

[1 mark]

0 4 . 4 There is a potential difference of 410 V between the metal plates.

$d = 12$ cm
$B = 0.35$ T

Calculate v.

[2 marks]

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

0 4 . 5 State and explain the direction of deflection of electrons that enter the device with a velocity greater than v.

[3 marks]

_____

_____

_____

_____

_____

_____

_____

8

Do not write outside the box

0 5 . 1 Determine the fundamental (base) units for flux linkage.

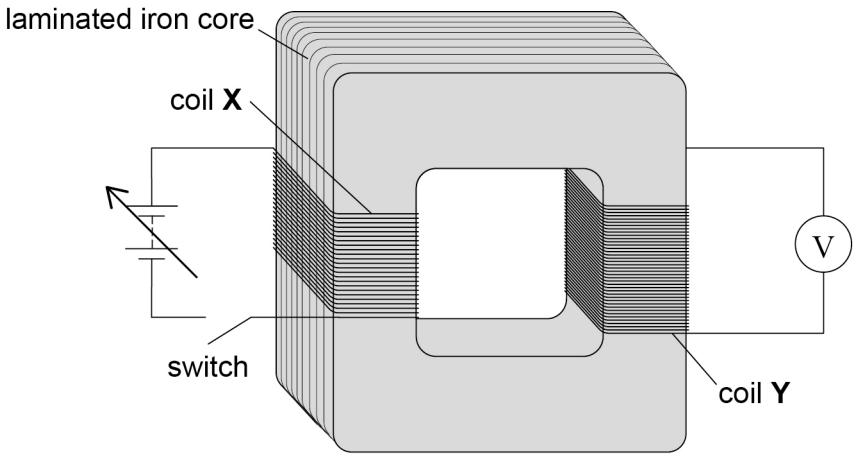
[2 marks]

fundamental (base) units = _____

Figure 4 shows the arrangement that a student uses to investigate electromagnetic induction.

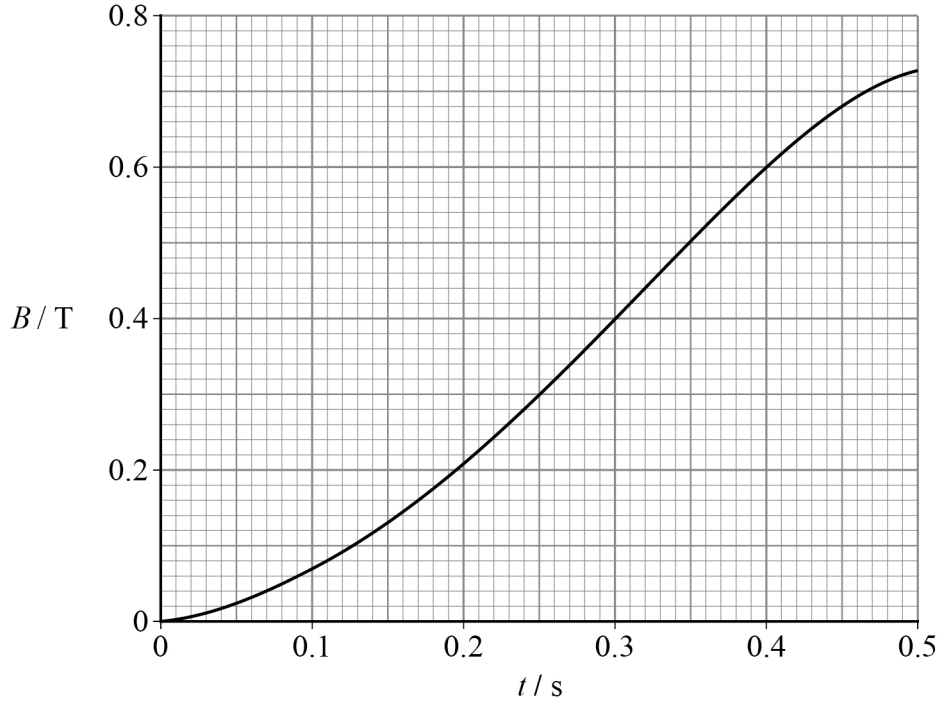
The voltmeter connected across coil **Y** can measure both positive and negative potential differences.

Figure 4



The student closes the switch and gradually adjusts the variable resistor so that the magnetic flux density B in the core varies with time t as shown in **Figure 5**.

Figure 5



0 5 . 2 The voltmeter measures ε, the induced emf across coil **Y**.

Show that

$$\varepsilon = ANm$$

where

A is the cross-sectional area of the core
N is the number of turns on coil **Y**
m is the gradient of the line shown in **Figure 5**.

[2 marks]

Question 5 continues on the next page

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0 5 . 3 Estimate the maximum value of ε during the 0.5 s shown in **Figure 5**.

$A = 5.5 \times 10^{-4}\ \text{m}^2$
$N = 200$

[3 marks]

maximum value of ε = _____ V

0 5 . 4 The student opens the switch and the current in coil **X** decreases to zero in a very short time.

Describe what happens to the reading on the voltmeter during this time.
Go on to explain why this happens.

[3 marks]

Do not write outside the box

0 5 . 5 The arrangement shown in **Figure 4** can be used as a transformer when coil **X** is connected to an alternating current supply.

Explain the reason for using a laminated core.

[2 marks]

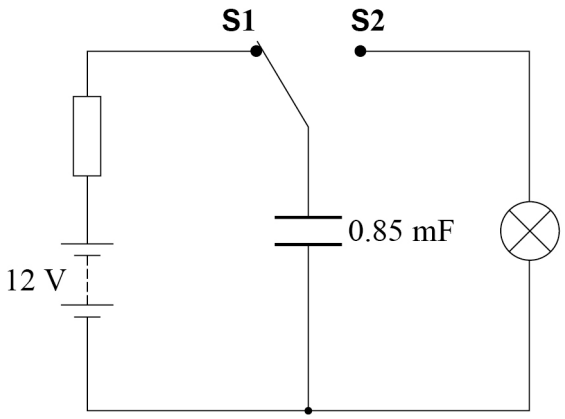
12

Turn over for the next question

Do not write outside the box

0 6 **Figure 6** shows a circuit used to transfer energy to the lamp in a camera flash.

Figure 6



A battery of emf $12\ \text{V}$ and negligible internal resistance charges the capacitor when the switch is in position **S1**.

The capacitor discharges through the lamp when the switch is in position **S2**.
Assume that the capacitor is discharged completely after each use.

0 6 . 1 The capacitor has a capacitance of $0.85\ \text{mF}$.

Show that the energy stored in the capacitor when it is fully charged is approximately $0.06\ \text{J}$.

[1 mark]

0 6 . 2 The lamp emits a flash of visible light when the voltage across it is greater than a minimum voltage V_{min}.

The duration of the flash is $55\ \text{ms}$.
Assume that the resistance of the lamp is constant and has a value of $31\ \Omega$.

Calculate V_{min}.

[2 marks]

$V_{\text{min}} =$ _____ V

Do not write outside the box

The charging circuit includes a resistor and a $12\ \mathrm{V}$ battery. The battery transfers a total energy of $50\ \mathrm{mW\ h}$ during its lifetime.

0 6 . 3 Explain why only half of this energy can be transferred to the capacitor.

[2 marks]

0 6 . 4 Calculate the maximum number of times the battery can charge the capacitor during the battery's lifetime.

[2 marks]

maximum number of times = _____

Question 6 continues on the next page

Do not write outside the box

The capacitor is replaced with one of much greater capacitance.

0 6 . 5 Explain how the replacement capacitor affects the duration and the brightness of each flash.

[3 marks]

0 6 . 6 Explain how the replacement capacitor affects the number of flashes the battery can deliver.

Assume that the capacitor discharges completely each time the flash is used.

[2 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 sheets for this working.

0 7 Which row identifies a vector and a scalar?

[1 mark]

	Vector	Scalar	
A	centripetal force	gravitational field strength	⬭
B	gravitational potential	electric potential energy	⬭
C	centripetal acceleration	capacitance	⬭
D	time constant	magnetic flux linkage	⬭

0 8 An object moves at a constant speed in a horizontal circle.

Which statement is true?

[1 mark]

A The object is in equilibrium. ⬭

B The velocity of the object is constant. ⬭

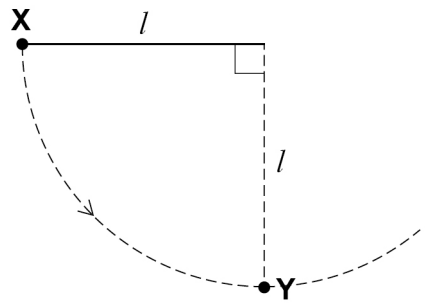
C The total energy of the object is constant. ⬭

D There is a resultant force on the object in the direction of its motion. ⬭

Turn over ►

Do not write outside the box

0 9 An object of mass m on the end of a string of length l is released from rest at **X**. It moves in a circular path and passes through **Y** when the string is vertical.



What is the tension in the string when the object passes through **Y**?

[1 mark]

A mg ⬭

B $3mg$ ⬭

C mgl ⬭

D $\sqrt{2gl}$ ⬭

1 0 An object is performing simple harmonic motion. There are phase differences between the acceleration, displacement and velocity of the object.

Which row is correct?

[1 mark]

	Phase difference between the acceleration and the displacement / rad	**Phase difference between the acceleration and the velocity / rad**	
A	0	π	⬭
B	π	$\frac{\pi}{2}$	⬭
C	0	$\frac{\pi}{2}$	⬭
D	π	π	⬭

Do not write outside the box

1 1 The separation between the Earth and the Sun varies.

The minimum separation is 1.7% smaller than the average separation.

The maximum separation is 1.7% greater than the average separation.

What is $\frac{\text{force of attraction between Earth and Sun at the minimum separation}}{\text{force of attraction between Earth and Sun at the maximum separation}}$?

[1 mark]

A 0.934 ⬭

B 0.967 ⬭

C 1.035 ⬭

D 1.070 ⬭

1 2 Two satellites **X** and **Y** have the same mass and orbit the same planet.
X has total energy of magnitude E and orbital radius r.
Y has orbital radius $2r$.

What is the magnitude of the total energy of **Y**?

[1 mark]

A $\frac{E}{4}$ ⬭

B $\frac{E}{2}$ ⬭

C E ⬭

D $2E$ ⬭

Turn over ►

Do not write outside the box

1 3 Two charged objects are placed at different positions in the same uniform electric field.

Which quantity must be the same for the two charged objects?

[1 mark]

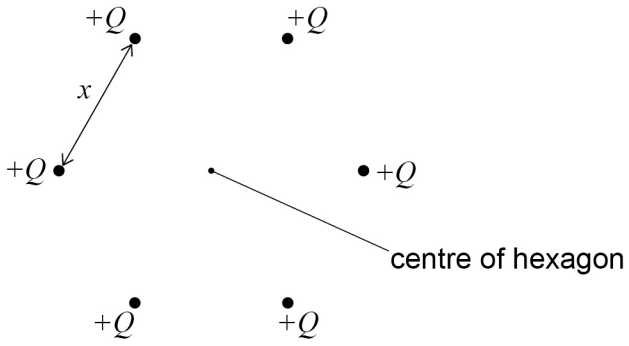
A electric field strength ⬭

B electric force ⬭

C electric potential ⬭

D electric potential energy ⬭

1 4 Identical positively charged particles are fixed at the points of a regular hexagon of side length x. The magnitude of each charge is Q.



What are the magnitudes of the resultant electric field strength and the resultant electric potential at the centre of the hexagon?

[1 mark]

	Resultant electric field strength	Resultant electric potential	
A	zero	zero	⬭
B	zero	$\frac{6Q}{4\pi\varepsilon_0 x}$	⬭
C	$\frac{6Q}{4\pi\varepsilon_0 x^2}$	zero	⬭
D	$\frac{6Q}{4\pi\varepsilon_0 x^2}$	$\frac{6Q}{4\pi\varepsilon_0 x}$	⬭

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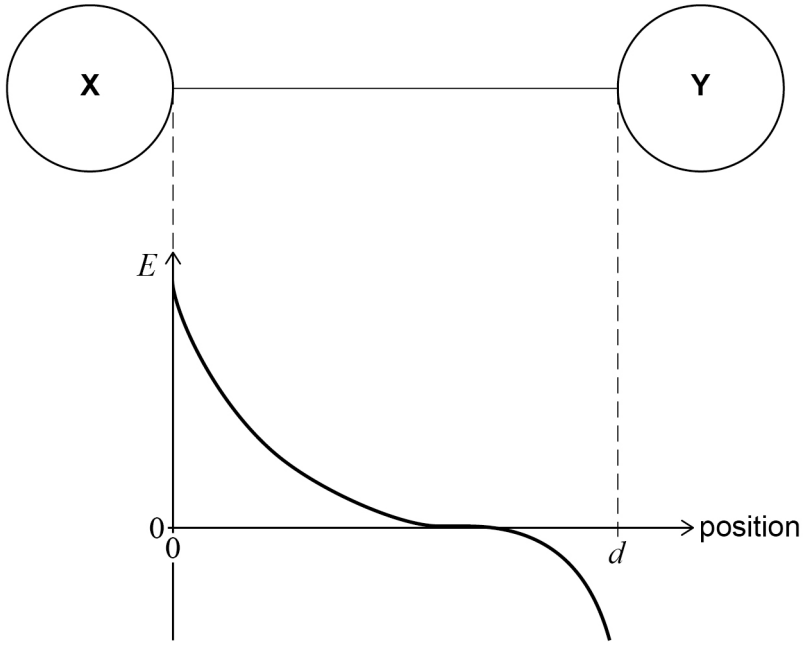
1 5 Two charged bodies **X** and **Y** have the same size, and their surfaces are separated by a distance d.
The charge on **X** is Q_X and the charge on **Y** is Q_Y.

The graph shows the variation of the resultant electric field strength E with position along the line joining **X** and **Y**.



What are the relationships between the signs of Q_X and Q_Y and between the magnitudes of Q_X and Q_Y?

[1 mark]

	Signs	Magnitudes	
A	Q_X and Q_Y have opposite signs	The magnitude of Q_Y is greater than the magnitude of Q_X	⬭
B	Q_X and Q_Y have opposite signs	The magnitude of Q_X is greater than the magnitude of Q_Y	⬭
C	Q_X and Q_Y have the same sign	The magnitude of Q_Y is greater than the magnitude of Q_X	⬭
D	Q_X and Q_Y have the same sign	The magnitude of Q_X is greater than the magnitude of Q_Y	⬭

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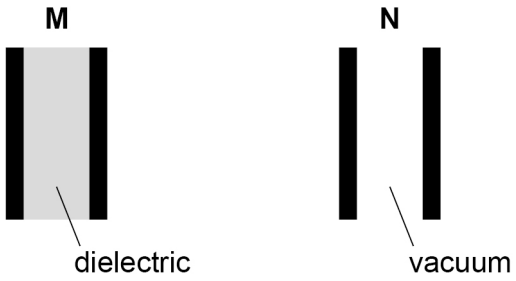
Questions **16** and **17** are about two parallel-plate capacitors **M** and **N**.

M and **N** have identical dimensions.



In **M**, the plates are separated by a dielectric with a relative permittivity of 9

In **N**, the plates are separated by a vacuum.

1 6 **M** and **N** are both charged so that they store the same energy.

What is $\frac{\text{charge stored by } \mathbf{M}}{\text{charge stored by } \mathbf{N}}$?

[1 mark]

A $\frac{1}{9}$ ⬭

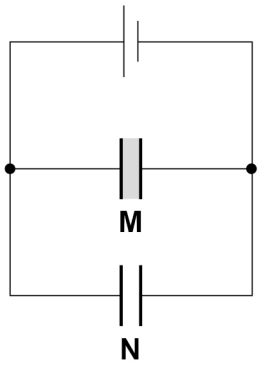
B $\frac{1}{3}$ ⬭

C 3 ⬭

D 9 ⬭

Do not write outside the box

1 7 **M** and **N** are discharged and then connected in parallel to a cell.



What is $\frac{\text{charge stored by } \mathbf{M}}{\text{charge stored by } \mathbf{N}}$ now?

[1 mark]

A $\frac{1}{9}$ ⬭

B $\frac{1}{3}$ ⬭

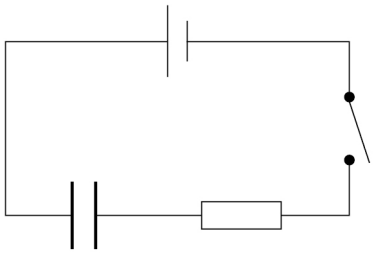
C 3 ⬭

D 9 ⬭

Turn over for the next question

Do not write outside the box

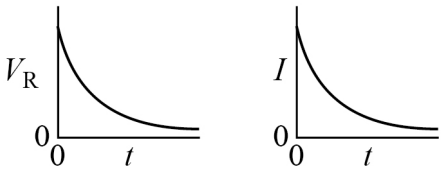
1 8 A capacitor is initially uncharged. The switch is closed at time $t = 0$



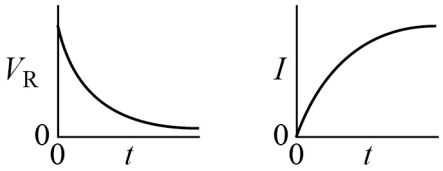
Which pair of graphs shows the variation with time t of the voltage V_R across the resistor and the current I in the circuit after the switch is closed?

[1 mark]

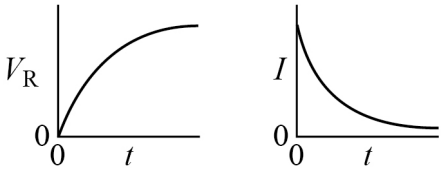
A



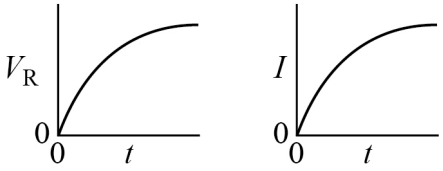
B



C



D



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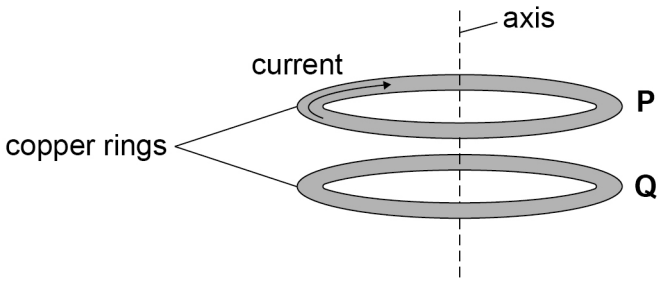
1 9 Two identical horizontal copper rings **P** and **Q** are fixed on a common axis.
P is vertically above **Q**. Initially, there is a clockwise current in **P** and no current in **Q**.



The clockwise current in **P** is reduced at a constant rate.

This reduction results in

[1 mark]

A a clockwise current in **Q**. ⬭

B an anticlockwise current in **Q**. ⬭

C an alternating current in **Q**. ⬭

D no current in **Q**. ⬭

Turn over for the next question

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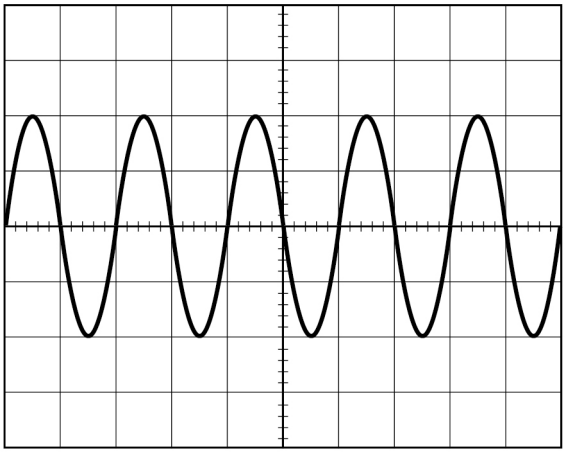
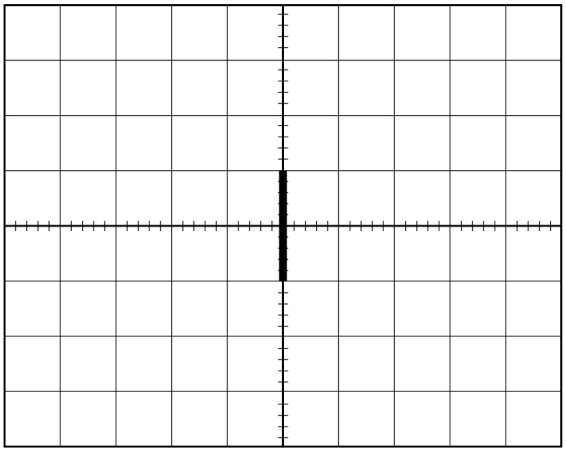
2 0 The diagram shows the trace of a voltage on an oscilloscope screen.



Which two actions are required to cause the voltage to appear as the trace below?



[1 mark]

	Action 1	Action 2	
A	turning off the time-base	doubling the Y-gain (volts / division)	⬭
B	turning off the time-base	halving the Y-gain (volts / division)	⬭
C	doubling the time-base	doubling the Y-gain (volts / division)	⬭
D	doubling the time-base	halving the Y-gain (volts / division)	⬭

Do not write outside the box

2 1 A mains power supply has a sinusoidal voltage with a root mean square value of 230 V.

What is the peak-to-peak voltage?

[1 mark]

A 163 V ⬭

B 325 V ⬭

C 460 V ⬭

D 651 V ⬭

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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