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 30 May 2023 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	

Do not write outside the box

Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows a car of mass m travelling at speed v in a horizontal circle of radius r. **Figure 2** is a cross-sectional view of the track showing that it is inclined at an angle θ to the horizontal.

Figure 1

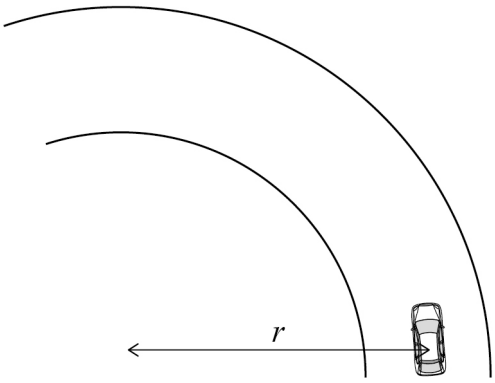
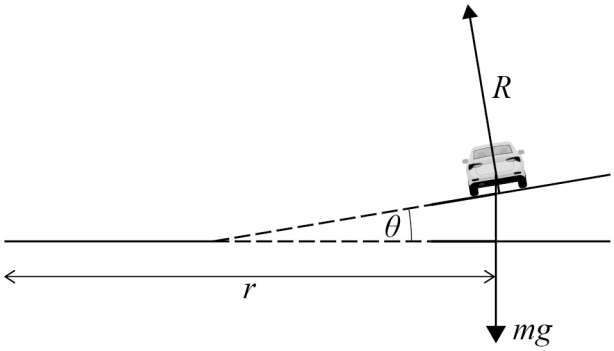


Figure 2



The sum of the normal reactions of the track acting on the wheels of the car is R. Assume that R acts through the centre of mass of the car.

0 1 . 1 The centripetal force is provided entirely by the horizontal components of R.

Show that v is given by:

$$v = \sqrt{rg\tan\theta}$$

[3 marks]

Do not write outside the box

0 1 . 2 Two cars **P** and **Q** travel around another angled track.
Figure 3 shows the plan view of the track. The section from **A** to **B** is semi-circular.
Figure 4 shows the cross-section of the track at the point **A** where the cars enter the semi-circular section.
The steepness of the angled track increases with radius.

Figure 3

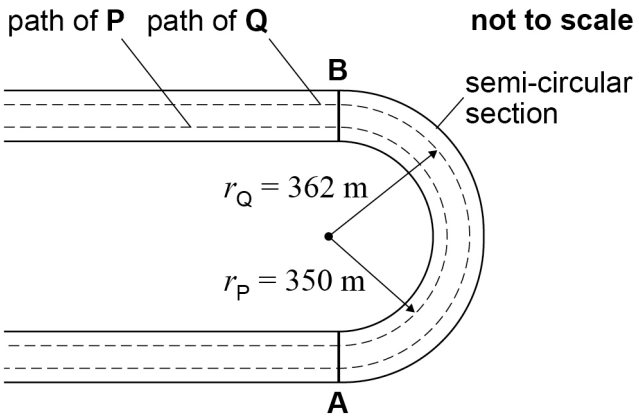
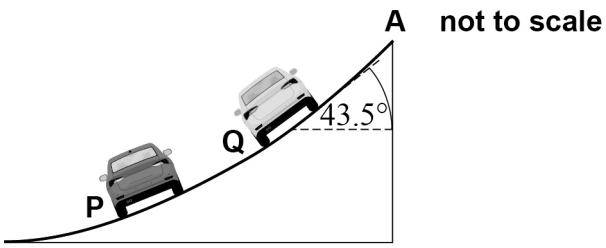


Figure 4



Both cars travel with constant speed and pass **A** at the same time.
P travels at a constant speed of $54.6\ \mathrm{m\ s^{-1}}$. The radius r_P of its path is $350\ \mathrm{m}$.
The radius r_Q of the path of **Q** is $362\ \mathrm{m}$.

Q travels at speed u where $u = \sqrt{r_Q g \tan\theta}$

θ for car **Q** is $43.5°$.

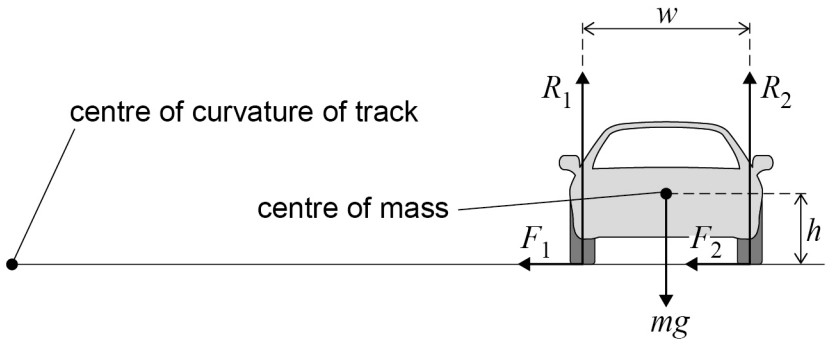
Determine whether **P** or **Q** passes **B** first.

[3 marks]

Do not write outside the box

0 1 . 3 **Figure 5** shows a car travelling around a horizontal circular track. The speed of the car increases as it travels around the track.

Figure 5



The centripetal force is now provided by the frictional forces F_1 and F_2 exerted by the track on the car's wheels.
The separation of the normal reactions R_1 and R_2 is w.
The height of the car's centre of mass is h.

When the speed of the car is V, the left-hand wheels lift from the road surface so that $R_1 = 0$

Show, using the principle of moments, that $V = \sqrt{\dfrac{gwr}{2h}}$

[3 marks]

9

Do not write outside the box

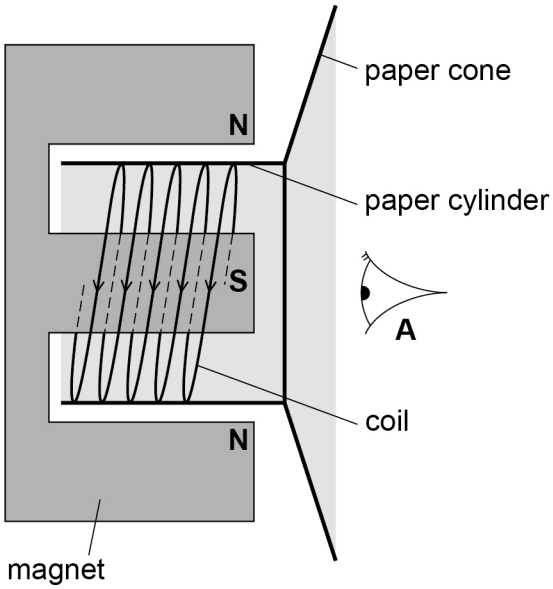
0 2 . 1 State the conditions necessary for a body to perform simple harmonic motion.

[2 marks]

Figure 6 shows a cross-sectional view of a loudspeaker. A coil attached to a paper cylinder and a paper cone is positioned in the cylindrical gap in the magnet.

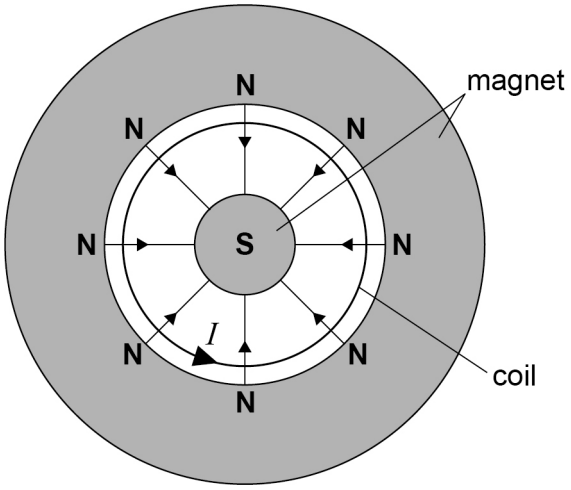
Figure 7 shows a front view of the coil and magnet seen from point **A**. The coil is inside the radial magnetic field created by the magnet. The current in the coil is I.

Figure 6



cross-sectional view

Figure 7



front view

0 2 . 2 Deduce the direction of the magnetic force on the coil at the instant shown in **Figure 7**.

Explain your answer.

[2 marks]

Turn over ►

Do not write outside the box

When a sinusoidal ac current is in the coil, the coil, cylinder and cone perform simple harmonic motion.

The coil has 40 turns and a diameter of 24 mm.
The mass of the coil, paper cylinder and cone is 7.8 g.

The peak current in the coil is 1.73 A. This produces a maximum acceleration of the coil of 542 m s^{-2}.

0 2 . 3 Calculate the magnetic flux density at the position of the coil.

[3 marks]

magnetic flux density = _____ T

The coil oscillates with a frequency of 260 Hz.

0 2 . 4 Calculate the amplitude of oscillation of the coil.

[2 marks]

amplitude = _____ m

0 2 . 5 Calculate the maximum velocity of the coil.

[1 mark]

maximum velocity = _____ m s^{-1}

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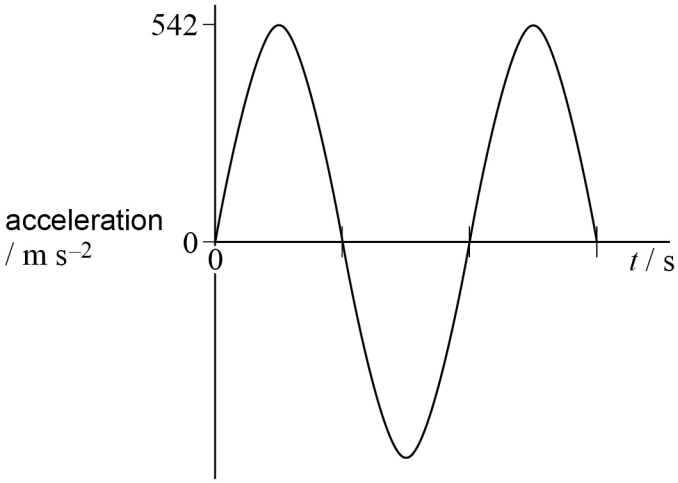
0 2 . 6 **Figure 8** shows the variation of the acceleration of the coil with time t for 1.5 cycles of the motion.

Figure 8

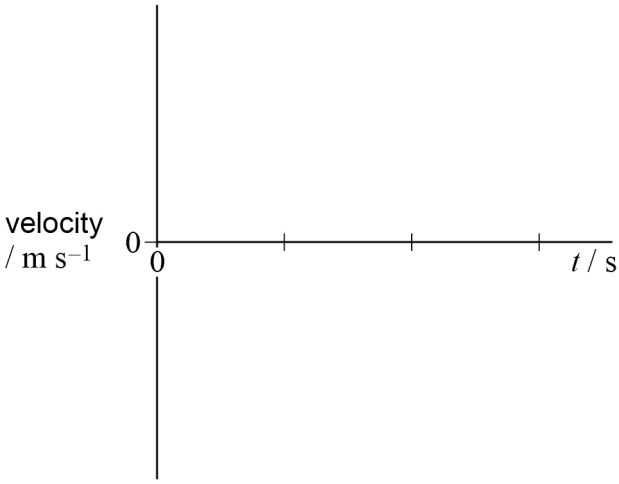


Sketch, on **Figure 9**, the variation of the velocity of the coil with t for 1.5 cycles of the motion.

Show the values of the period of oscillation and the maximum velocity on your sketch.

[2 marks]

Figure 9



12

Do not write outside the box

0 3 . 1 Show that a geosynchronous satellite orbits the Earth at a distance of approximately $36\ 000\ \mathrm{km}$ above the surface of the Earth.

[4 marks]

0 3 . 2 Show that the orbital speed of the satellite is approximately $3100\ \mathrm{m\ s^{-1}}$.

[2 marks]

Do not write outside the box

0 3 . 3 The satellite has a mass of 380 kg.

Calculate the total energy of the satellite when it is in a geosynchronous orbit.

[3 marks]

energy = _____ J

0 3 . 4 Geostationary satellites are geosynchronous satellites that remain above the same point of the Earth's surface.

Geostationary satellites are usually launched towards the east from a point on the Equator.

Suggest why this is done.

[3 marks]

_____

_____

_____

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_____

12

Do not write outside the box

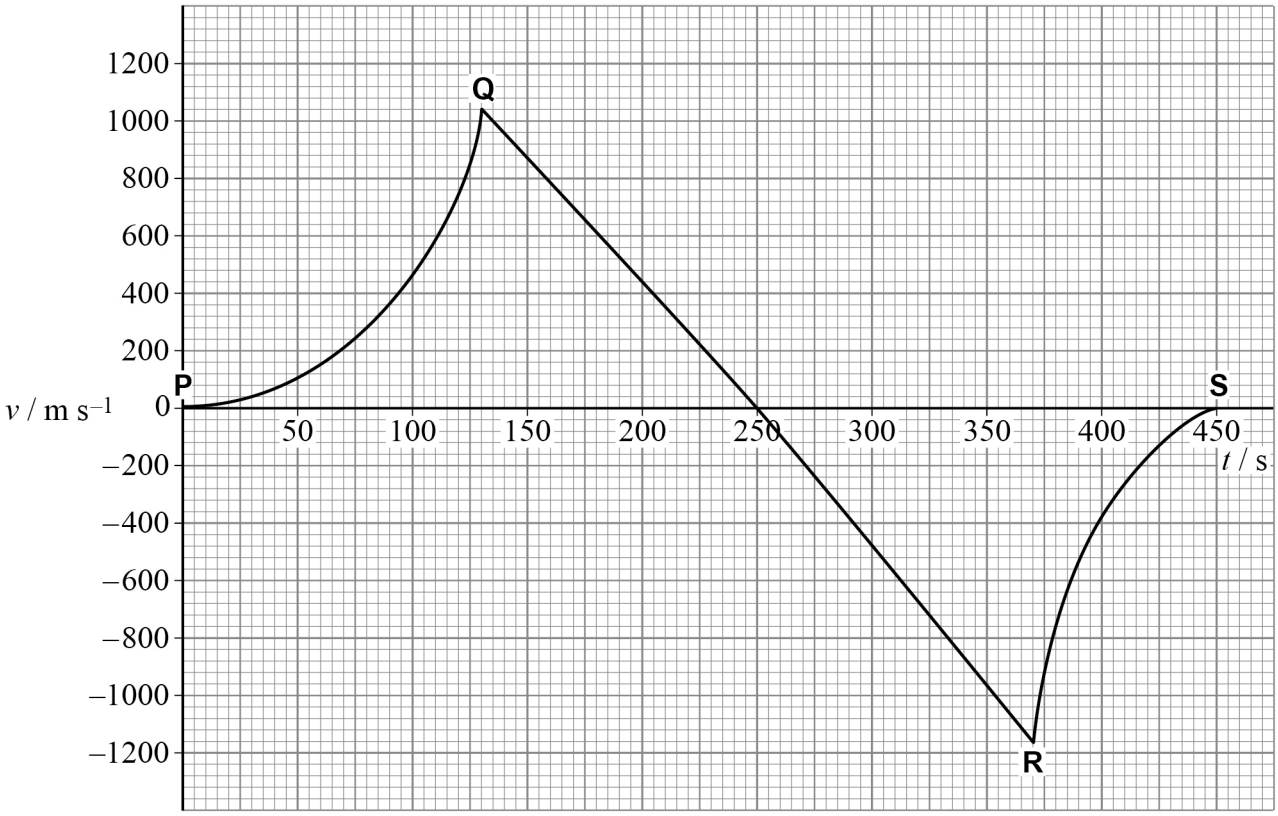
0 4 A spacecraft carrying astronauts is launched vertically from the Earth's surface.

The spacecraft's engines stop 130 s after the launch. The spacecraft continues to rise until it reaches its maximum altitude of 106 km. It then falls freely back to Earth.

Parachutes open 370 s after the launch to slow the descent of the spacecraft. The spacecraft returns to the Earth's surface 450 s after the launch.

Figure 10 shows the variation of velocity v with time t for the flight.

Figure 10



0 4 . 1 Calculate the mean magnitude of the acceleration due to gravity for the part of the flight between **Q** and **R**. Air resistance is negligible for this part of the flight.

[2 marks]

mean acceleration due to gravity = _____ m s^{-2}

Do not write outside the box

An astronaut pilots the spacecraft.

0 4 . 2 Describe how the weight of the astronaut varies during the flight.

[1 mark]

During one part of the flight, the astronaut has no sensation of weight.

0 4 . 3 Explain why the astronaut feels weightless during part of the flight.

[1 mark]

0 4 . 4 Describe how the astronaut's sensation of weight varies during the other parts of the flight.

[2 marks]

6

Turn over for the next question

Do not write outside the box

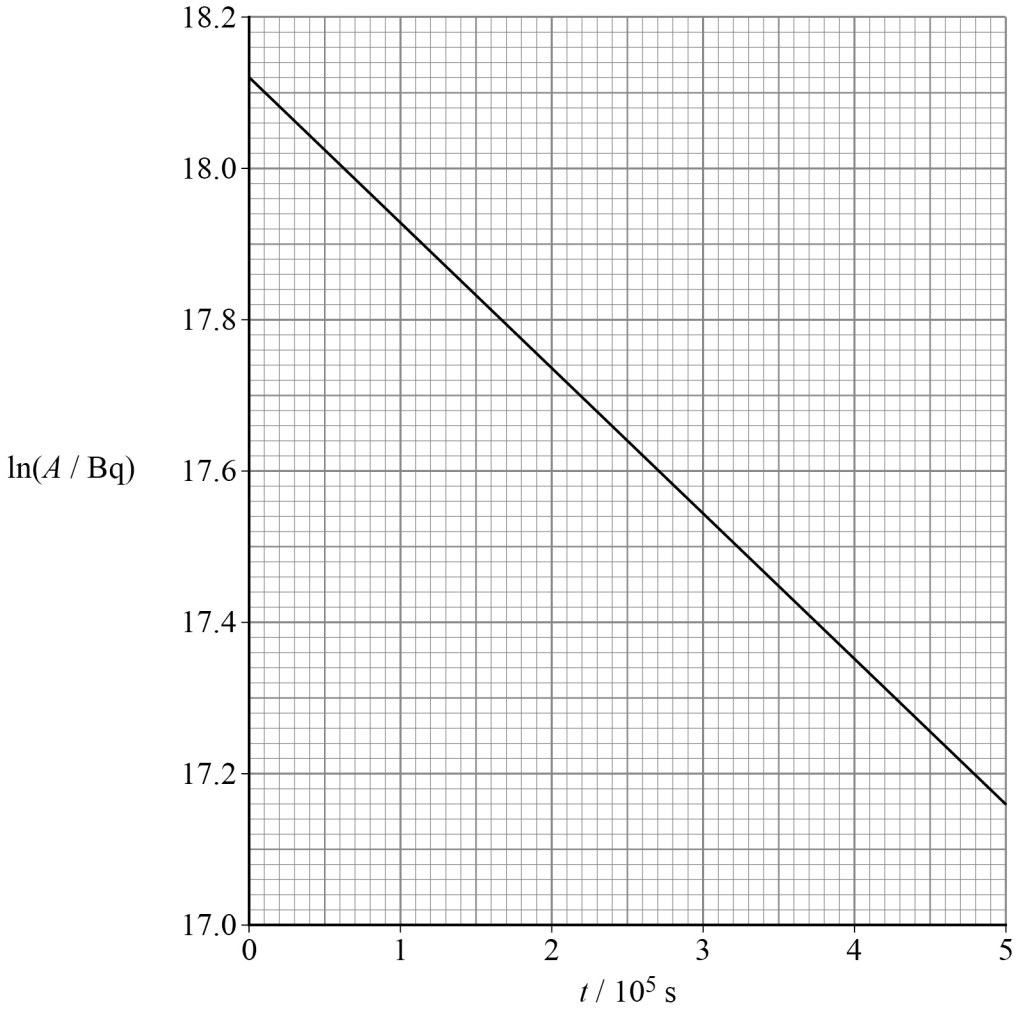
0 5 Iodine-124 $\left({}^{124}_{53}\mathrm{I}\right)$ is used in the detection of cancers in the thyroid gland.

A dose of iodine-124 is given to a patient at time $t = 0$
The iodine-124 is absorbed by the thyroid gland and emissions from decaying iodine-124 are detected outside the patient's body.

The activity A of the dose of iodine-124 decreases with time.

Figure 11 shows the variation of $\ln(A / \mathrm{Bq})$ with time t.

Figure 11



Do not write outside the box

0 5 . 1 Determine the activity of the dose at $t = 0$

[2 marks]

activity = _____ Bq

0 5 . 2 Determine the half-life of iodine-124.

[3 marks]

half-life = _____ s

Question 5 continues on the next page

Do not write outside the box

0 5 . 3 A different patient is given a dose of iodine-131.

Calculate the mass of iodine-131 in the dose when its activity is 24 MBq.

decay constant of iodine-131 = $1.0 \times 10^{-6}\ \mathrm{s}^{-1}$
molar mass of iodine-131 = 0.131 kg

[3 marks]

mass = _____ kg

0 5 . 4 $^{131}_{53}\mathrm{I}$ decays into $^{131}_{54}\mathrm{Xe}^{*}$:

$$^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe}^{*} + \beta^{-} + \bar{\nu}_{e}$$

$^{131}_{54}\mathrm{Xe}^{*}$ then decays by γ emission:

$$^{131}_{54}\mathrm{Xe}^{*} \rightarrow {}^{131}_{54}\mathrm{Xe} + \gamma$$

Only one type of particle from this decay series is detected outside the body.

Explain why.

[2 marks]

_____

_____

_____

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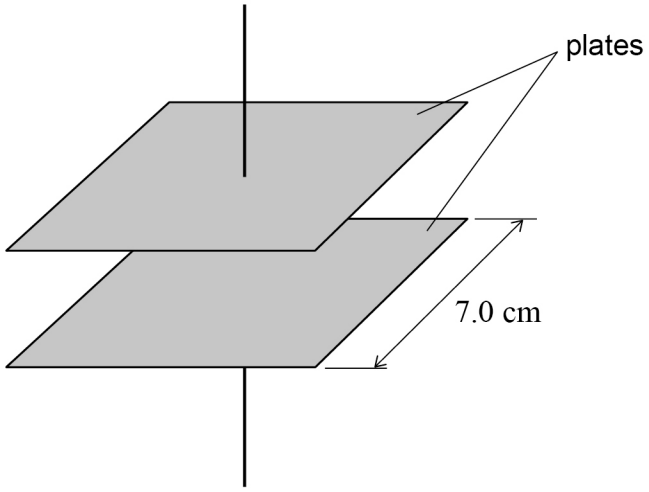
_____

10

Do not write outside the box

0 6 . 1 **Figure 12** shows a capacitor with two overlapping parallel square plates with sides of length 7.0 cm.

Figure 12



There is an air gap between the plates. The air acts as an insulator when the electric field strength in the gap does not exceed 3.0×10^4 V m^{-1}.

Estimate the maximum charge that can be stored on the capacitor.

[3 marks]

maximum charge = _____ C

Question 6 continues on the next page

Do not write outside the box

0 6 . 2 A parallel-plate capacitor is charged.
When a dielectric material is inserted between the plates, the capacitance of the capacitor increases.

Explain this increase in capacitance.

[2 marks]

Do not write outside the box

Supercapacitors have very high capacitances. Engineers think that supercapacitors may replace batteries in some applications.

Supercapacitor **X** has a capacitance of $144\ \mathrm{F}$ and has a potential difference of $2.5\ \mathrm{V}$ across it when fully charged.

A battery **Z** has an emf of $3.6\ \mathrm{V}$ and provides a current of $0.40\ \mathrm{A}$ for 2.5 hours.

0 6 . 3 Deduce whether **X** or **Z** stores more energy.

[2 marks]

0 6 . 4 A different supercapacitor **Y** can store the same amount of energy as the battery **Z**.

Suggest why it is better to use **Z** rather than **Y** to supply constant power to a component.

[1 mark]

8

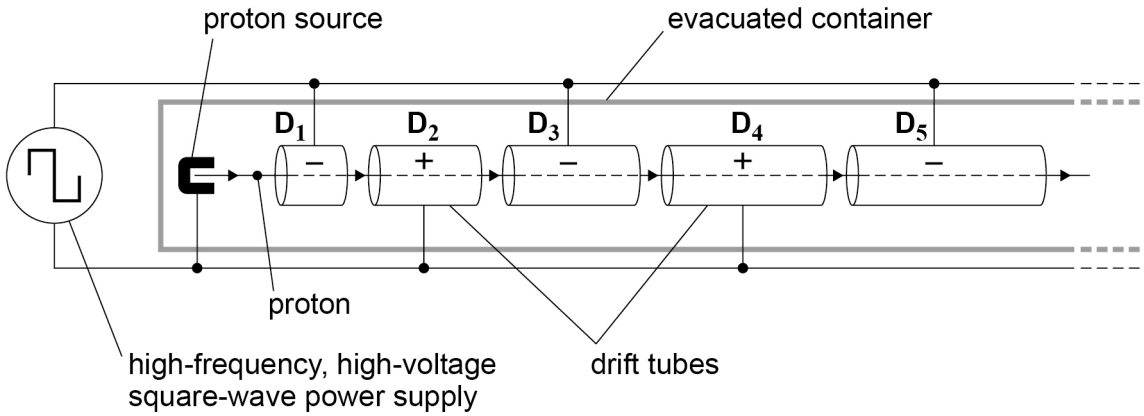
Do not write outside the box

0 7 **Figure 13** shows a linear accelerator that accelerates protons.

Protons pass through a series of hollow electrodes called drift tubes.
Drift tubes $\mathbf{D_1}$ to $\mathbf{D_5}$ are shown in **Figure 13**.

The drift tubes are connected to a high-frequency, high-voltage square-wave power supply so that adjacent drift tubes always have opposite polarities.
The periodic time of the supply is T.

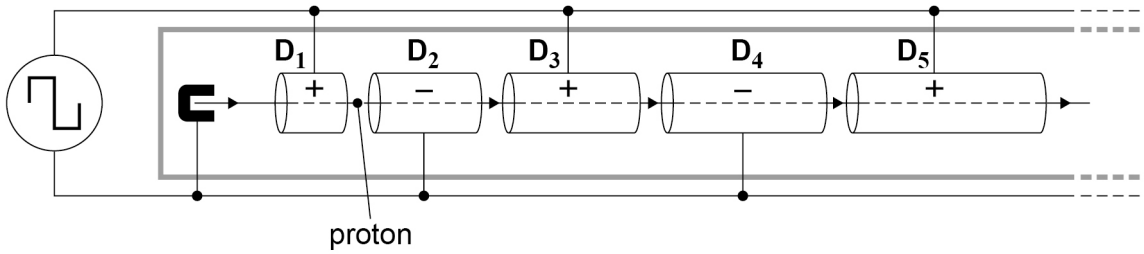
Figure 13



A proton with negligible energy is emitted from the proton source.

$\mathbf{D_1}$ is negative and the proton accelerates towards it. The proton enters $\mathbf{D_1}$ and travels at constant speed through it.
As the proton leaves $\mathbf{D_1}$, $\mathbf{D_2}$ becomes negative and $\mathbf{D_1}$ becomes positive. The proton accelerates towards $\mathbf{D_2}$, as shown in **Figure 14**.

Figure 14



Do not write outside the box

The proton only accelerates in the gaps between the drift tubes and travels at constant speeds within the drift tubes.

0 7 . 1 Suggest why the proton travels at constant speed when inside any drift tube.

[1 mark]

When the proton crosses a gap, the potential difference between adjacent drift tubes is $42\ \mathrm{kV}$.
The linear accelerator has 30 drift tubes $\mathbf{D_1}$ to $\mathbf{D_{30}}$.

0 7 . 2 Show that each proton has an energy of approximately $2 \times 10^{-13}\ \mathrm{J}$ when it reaches the end of the linear accelerator.

[2 marks]

Question 7 continues on the next page

Do not write outside the box

0 7 . 3 The frequency of the power supply is $5.0\ \text{MHz}$.

The proton spends a time $\frac{T}{2}$ in each drift tube.

Calculate the length of the final drift tube $\mathbf{D_{30}}$.

[3 marks]

length = _____ m

0 7 . 4 A proton leaving the linear accelerator collides with an antiproton.

Describe the outcome of the collision, giving details of any products of the interaction.

rest energy of a proton = 1.51×10^{-10} J

[2 marks]

_____

_____

8

END OF SECTION A

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 An object performs simple harmonic motion described by:

$$x = A\cos\omega t$$

The velocity of the object is given by

[1 mark]

A $-A\sin\omega t$

B $-\omega A\sin\omega t$

C $A\sin\omega t$

D $\omega A\sin\omega t$

Turn over for the next question

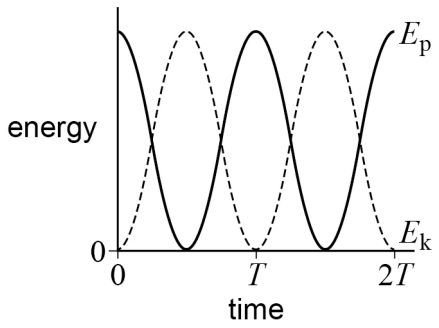
Do not write outside the box

0 9 A mass is suspended from a spring.
The mass is lifted a short distance above its equilibrium position and released at time $t = 0$
The mass performs simple harmonic motion with periodic time T.

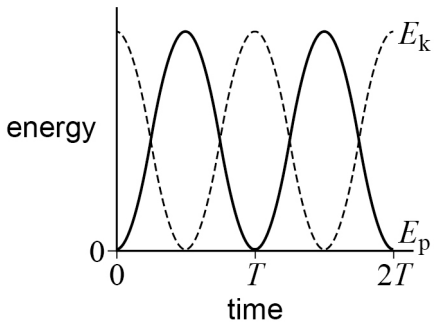
Which graph shows the variations with time of the kinetic energy E_k and the potential energy E_p of the mass–spring system?

[1 mark]

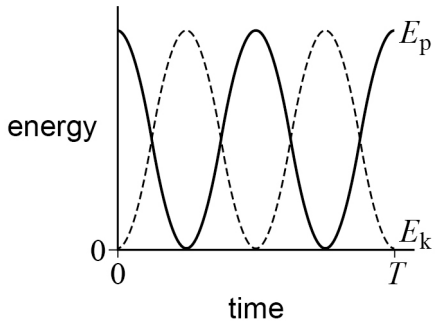
A



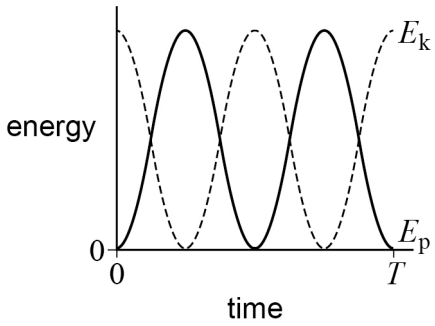
B



C



D



A ⬭

B ⬭

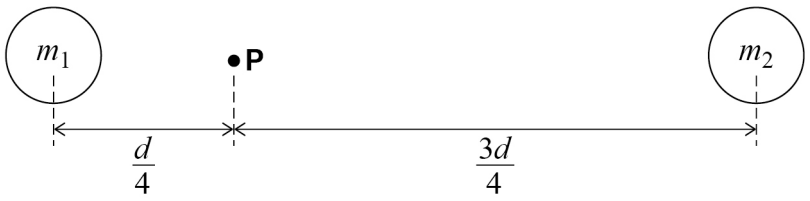
C ⬭

D ⬭

Do not write outside the box

1 0 Two isolated masses m_1 and m_2 are separated by a distance d.

The gravitational field strength at point **P** is zero.



What is the relationship between m_1 and m_2?

[1 mark]

A $m_1 = \frac{m_2}{9}$

B $m_2 = \frac{m_1}{9}$

C $m_1 = \frac{m_2}{3}$

D $m_2 = \frac{m_1}{3}$

1 1 P is the gravitational force between two protons in a nucleus.
Q is the electrostatic force between two protons in a nucleus.
R is the gravitational force between an electron and the nucleus in an atom.

Which is correct?

[1 mark]

A $P < R < Q$

B $R < P < Q$

C $Q < R < P$

D $Q < P < R$

Do not write outside the box

1 2 The electric field around a negative point charge is represented using lines of equipotential and electric field lines.

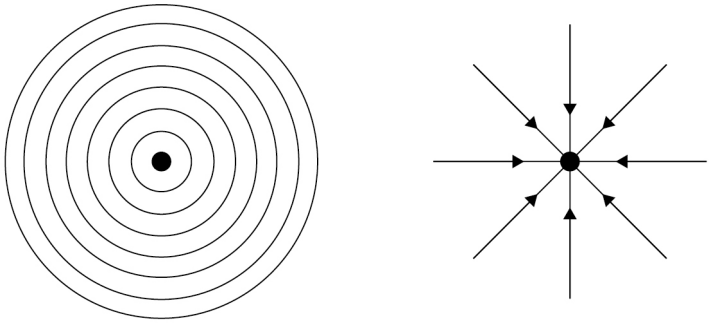
The potential difference between adjacent lines of equipotential is constant.

Which pair of drawings is correct?

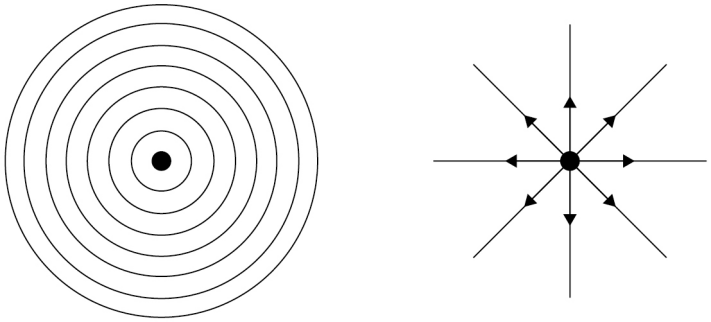
[1 mark]

lines of equipotential **electric field lines**

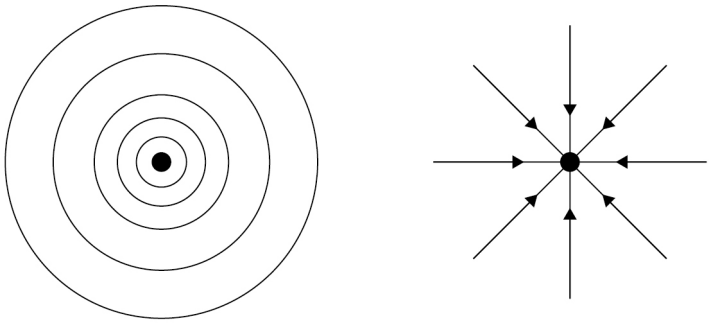
A



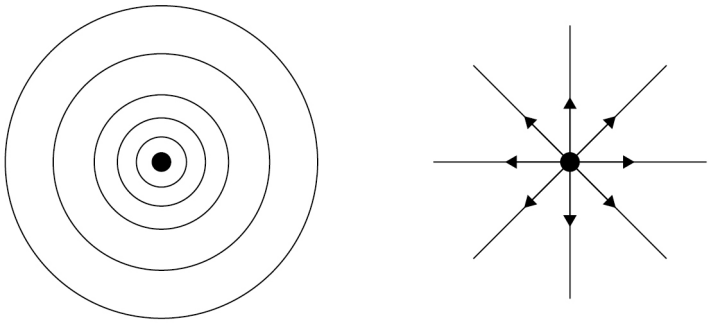
B



C



D



Do not write outside the box

1 3 An alpha particle α enters a region where there is a uniform magnetic field and a uniform electric field.

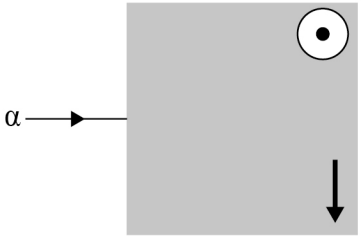
The direction of the magnetic flux density is either into the page ⊗ or out of the page ⊙

The direction of the electric field strength is given by one of the following arrows ↑ ↓ →

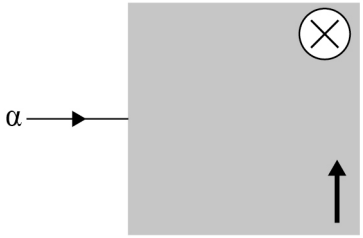
Which diagram shows a combination of flux density and electric field strength that can result in the alpha particle travelling through this region at a constant velocity?

[1 mark]

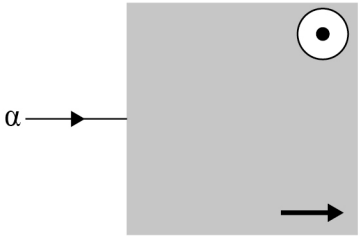
A



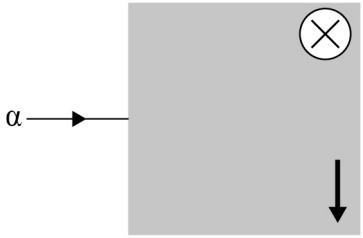
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

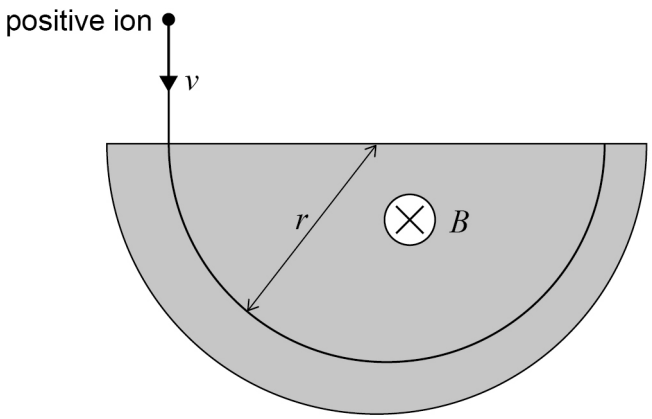
Turn over for the next question

Do not write outside the box

1 4 Positive ions of mass m and charge q have a velocity v when they enter a uniform magnetic field.

The magnetic flux density B is into the page ⊗

The ions move along a semi-circular path of radius r.



The time taken for an ion to complete the semi-circular path depends only on:

[1 mark]

A q, B and m. ⬭

B q, B and r. ⬭

C q, m and r. ⬭

D B, m and r. ⬭

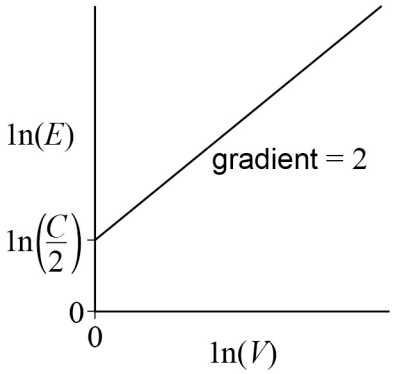
Do not write outside the box

1 5 E is the energy stored on a capacitor of capacitance C.
E changes when the potential difference V across the capacitor changes.

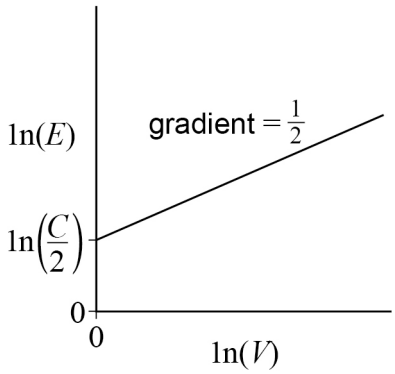
Which graph shows the variation of $\ln(E)$ against $\ln(V)$ for the capacitor?

[1 mark]

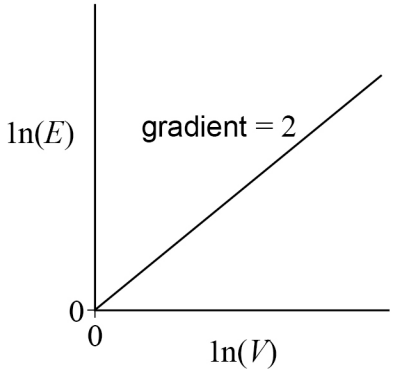
A



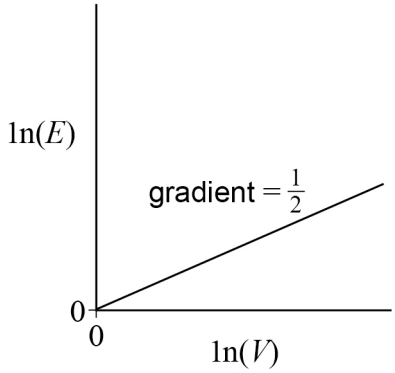
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

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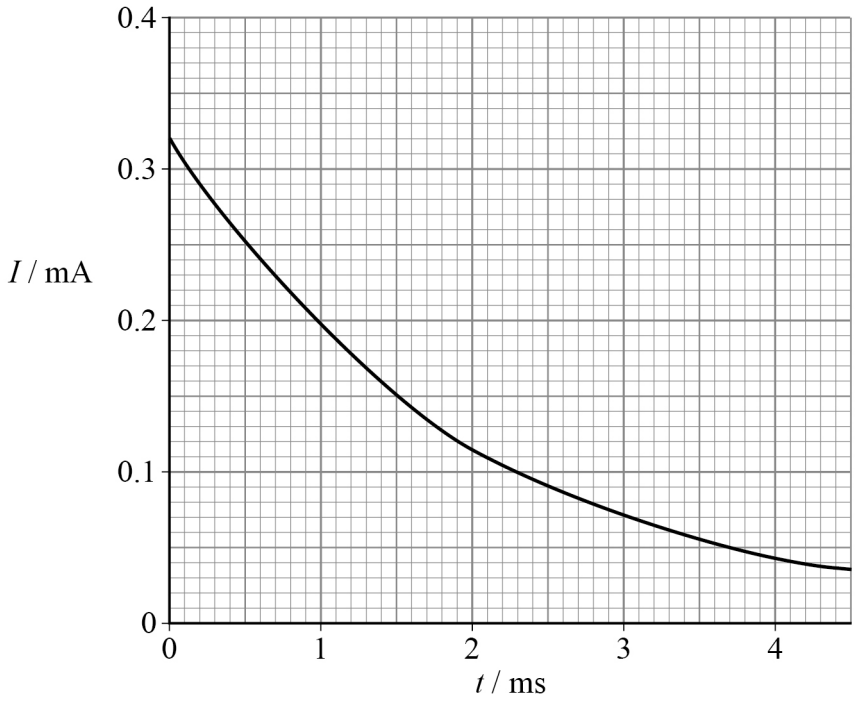
1 6 The graph shows the variation of current I with time t for a capacitor discharging through a 47 kΩ resistor.



What is the capacitance of the capacitor?

[1 mark]

A 66 nF ⬭

B 43 nF ⬭

C 66 pF ⬭

D 43 pF ⬭

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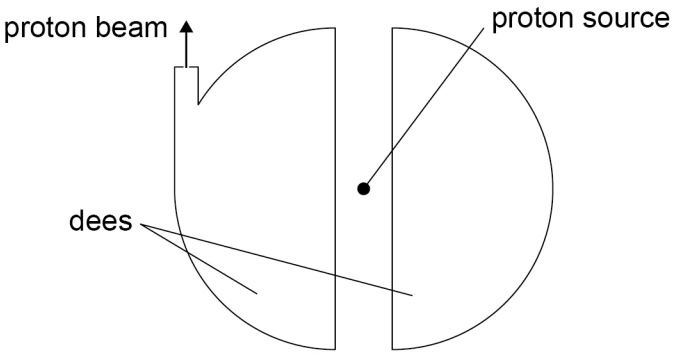
1 7 The diagram shows a cyclotron.



Which row describes the velocity of the protons **inside** the dees and **between** the dees?

[1 mark]

	Velocity of protons inside the dees	**Velocity of protons between the dees**	
A	changing	constant	⬭
B	changing	changing	⬭
C	constant	constant	⬭
D	constant	changing	⬭

Turn over for the next question

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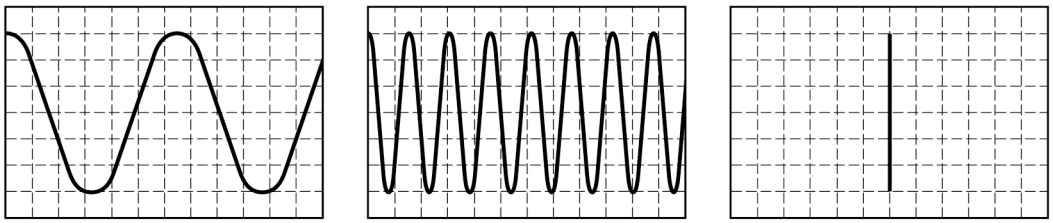
1 8 The diagrams show three oscilloscope traces of the same signal. The traces have different time-base settings.



1 **2** **3**

Which row shows the best alternative for determining the peak-to-peak voltage and the frequency of the signal?

[1 mark]

	Best trace for determining peak-to-peak voltage	Best trace for determining frequency	
A	**2**	**1**	⬭
B	**2**	**2**	⬭
C	**3**	**3**	⬭
D	**3**	**2**	⬭

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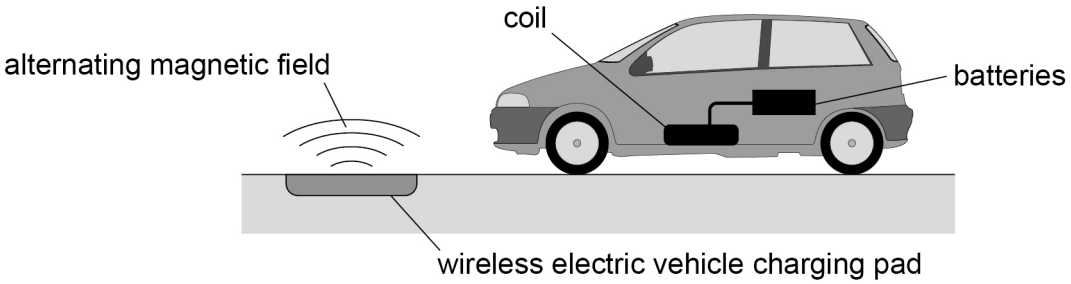
1 9 The diagram shows a system for recharging the batteries of moving electric vehicles.



The car passes through the alternating magnetic field.

An emf is induced in the coil, causing the car's batteries to charge.

Three suggestions for changes to the system are to:

1 increase the speed of the car
2 increase the area of the coil in the car
3 increase the frequency of the alternating magnetic field.

Which combination of suggestions will increase the energy supplied to the car battery as the car passes over the charging pad?

[1 mark]

A **1** and **2** only ⬭

B **1** and **3** only ⬭

C **2** and **3** only ⬭

D **1** and **2** and **3** ⬭

Turn over for the next question

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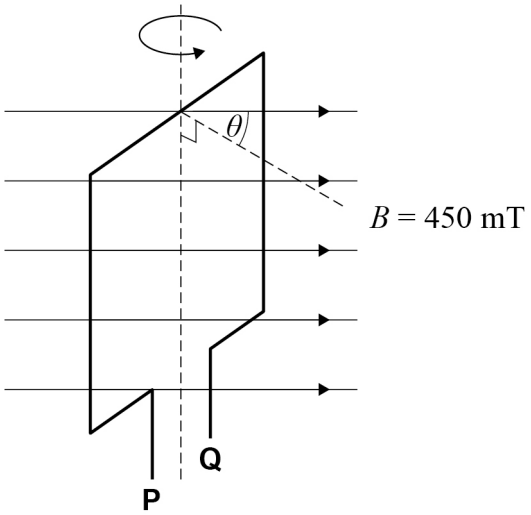
2 0 A rectangular coil rotates at a constant angular speed about its axis in a uniform magnetic field of flux density 450 mT.

The coil is 5.0 cm long and 3.0 cm wide. It completes 200 rotations every minute.



At one instant, the angle θ between the magnetic field and the normal to the coil is 30°.

What is the emf induced between **P** and **Q** when θ is 30°?

[1 mark]

A 120 V

B 0.73 V

C 0.012 V

D 0.0071 V

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2 1 A power station produces 1.25 GW of electrical power at 275 kV rms. The transmission lines are 99% efficient.

Which row shows the resistance of the transmission lines and the rms voltage drop across them?

[1 mark]

	Resistance / Ω	rms voltage drop / V
A	0.61	2750
B	0.61	27 500
C	6.1	2750
D	6.1	27 500

2 2 The power input to an ideal transformer is 7.2 MW at 132 kV rms.
The rms voltage output from the transformer is 230 V.

What is the peak secondary current?

[1 mark]

A 390 A

B 770 A

C 22 kA

D 44 kA

15

END OF QUESTIONS

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