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

Wednesday 10 January 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	
7–21	
TOTAL	

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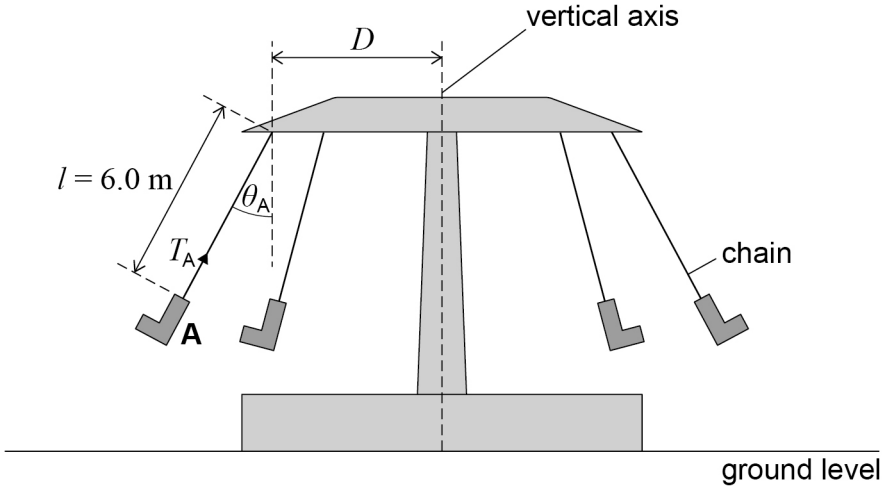
Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows a fairground ride moving at a constant angular speed about a vertical axis.
The ride makes a complete rotation in $6.8\ \mathrm{s}$ and the seats move in horizontal circles.

Ignore air resistance throughout this question.

Figure 1



Seat **A** acts as a point mass of $25\ \mathrm{kg}$ attached to a light chain. This chain has a length l of $6.0\ \mathrm{m}$ and is fixed to the top of the ride at a distance D from the vertical axis. The chain makes an angle θ_A to the vertical.
For this angular speed, θ_A is $40°$.

0 1 . 1 Show that the tension T_A in the chain is $320\ \mathrm{N}$.

[1 mark]

Do not write outside the box

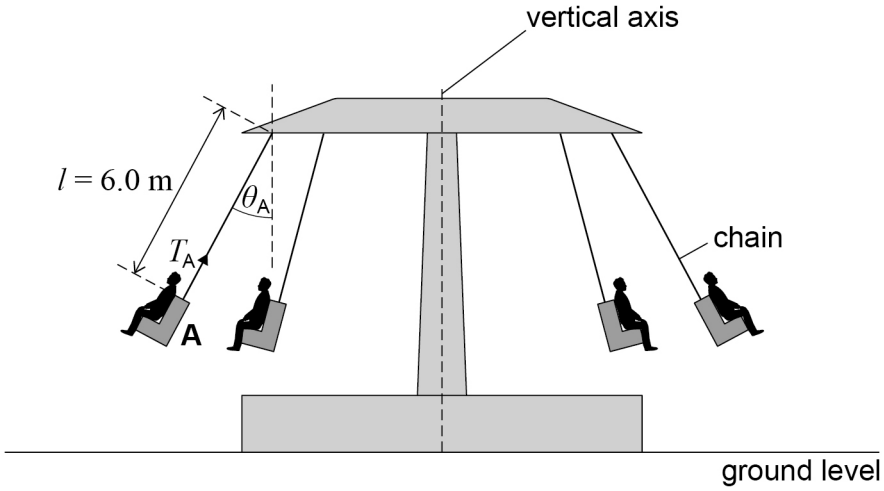
0 1 . 2 Calculate D.

[4 marks]

$D =$ _____ m

0 1 . 3 **Figure 2** shows the ride with a rider in each seat.
The angular speed of the ride has not changed.
The seat and rider act as a point mass at the end of the chain.

Figure 2



Show, by resolving forces horizontally and vertically, that θ_A does not depend on the mass of the rider in seat **A**.

[2 marks]

Question 1 continues on the next page

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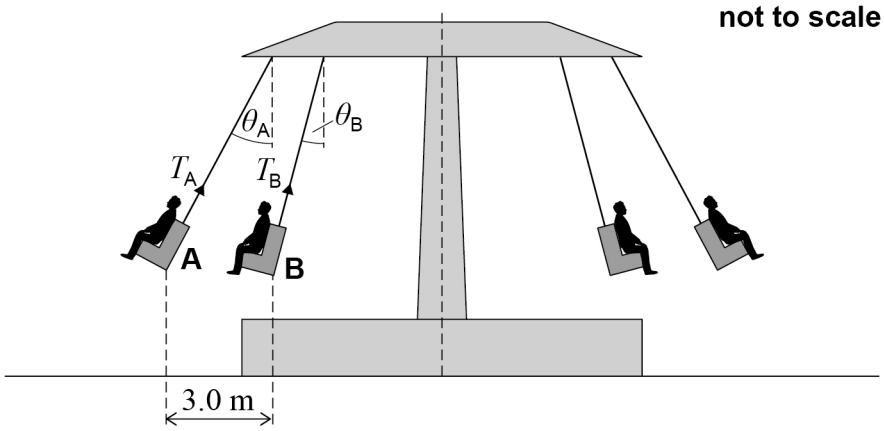
0 1 . 4 **Figure 3** shows the horizontal distance between seat **A** and seat **B**.

Figure 3



The rider in seat **B** has the same mass as the rider in seat **A**.
The angular speed has not changed.

Deduce how:

- the value of θ_A compares with the value of θ_B
- the value of T_A compares with the value of T_B.

[3 marks]

θ_A and θ_B

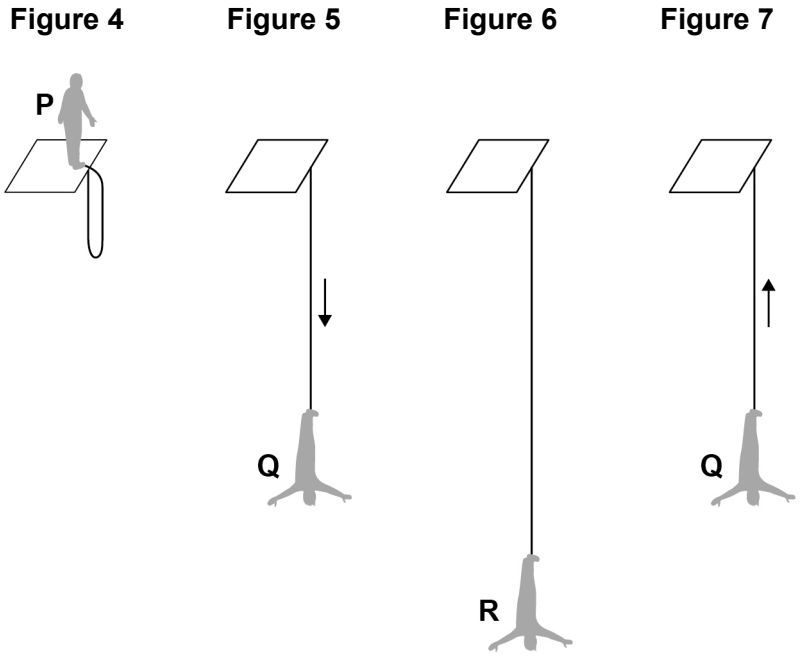
T_A and T_B

10

Do not write outside the box

0 2 A bungee jumper is attached to a platform by a light elastic rope. The rope obeys Hooke's law. Assume that air resistance is negligible.

Figure 4 shows the jumper at point **P** before she leaves the platform.
Figure 5 shows the jumper passing through her equilibrium position **Q** where the tension in the rope is equal to her weight.
Figure 6 shows the jumper at the lowest point **R** when she stops moving for an instant before moving upwards.
Figure 7 shows the jumper when she has moved back to her equilibrium position **Q**.



0 2 . 1 Draw and label arrows on **Figure 6** to show the forces acting on the jumper at **R**.
[1 mark]

Question 2 continues on the next page

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The spring constant of the rope is $161\ \mathrm{N\ kg^{-1}}$. The mass of the jumper is $58\ \mathrm{kg}$.

0 2 . 2 The rope has an extension of $19\ \mathrm{m}$ when the jumper is at **R**.

Calculate the jumper's acceleration at **R**.

[2 marks]

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

Consider the movement of the jumper from **Q** to **R** and back up to **Q** as simple harmonic motion for one half of an oscillation.

0 2 . 3 Calculate the maximum amplitude of this oscillation.

[2 marks]

maximum amplitude = _____ m

0 2 . 4 Calculate the time taken for the jumper to move from **Q** to **R** and back to **Q**.

[3 marks]

time = _____ s

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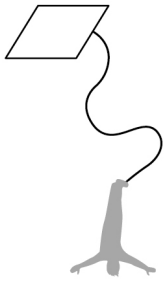
Figure 8 shows the jumper when she has moved far enough above **Q** for the tension in the rope to be zero.

Figure 8



0 2 . 5 Explain why the jumper is **not** in simple harmonic motion when she is travelling upwards and the tension in the rope is zero.

[2 marks]

Question 2 continues on the next page

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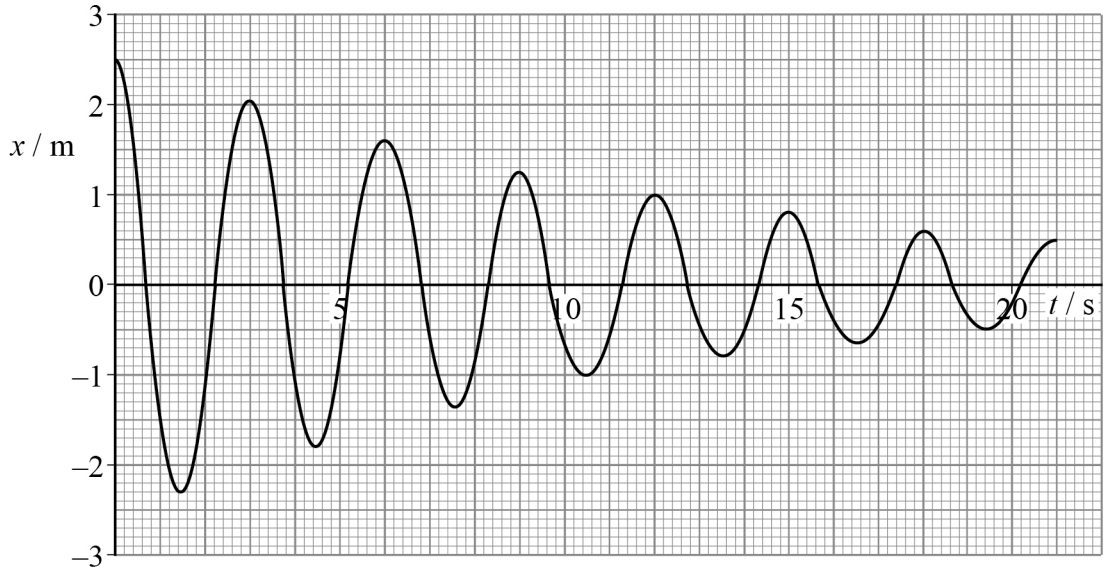
Another jumper of mass $38\ \text{kg}$ now performs the bungee jump.
At time $t = 0$, the amplitude of her oscillations begins to decrease.

Figure 9 shows the variation with t of the jumper's displacement x from her equilibrium position.

Figure 9



0 2 . 6 Explain why the amplitude of the oscillations for the jumper decreases.
Assume that air resistance is negligible.

[1 mark]

_____

_____

_____

0 2 . 7 Determine the mean rate at which energy is dissipated from the oscillation during the period covered by the graph in **Figure 9**.

[3 marks]

mean rate of energy dissipation = _____ W

14

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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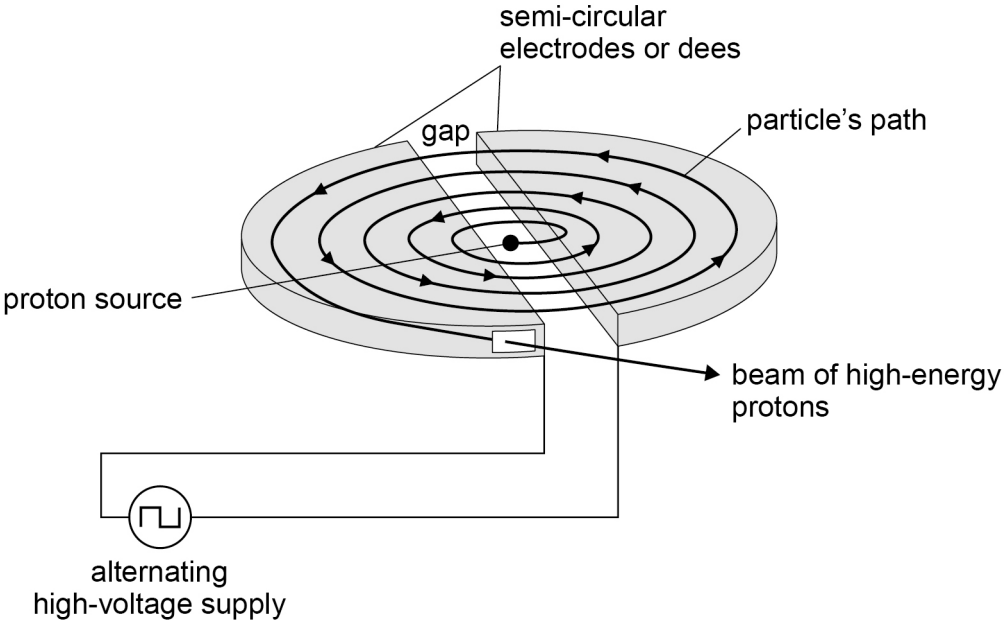
0 3 **Figure 10** shows a cyclotron that is used to accelerate protons to high energies.

Figure 10



The cyclotron has two hollow semi-circular electrodes called dees. These dees are in a uniform magnetic field.
The dees are connected to an alternating square-wave high-voltage supply.

Protons are released from the proton source. At the instant of release, the right-hand dee in **Figure 10** is negative and the protons are initially attracted to it. They then follow the horizontal path shown and leave the cyclotron as a beam of high-energy protons.

0 3 . 1 Determine the direction of the magnetic flux density inside the dees.

[1 mark]

_____

_____

Do not write outside the box

0 3 . 2 Discuss the motion of the protons in the cyclotron.

You should consider:
- the forces acting on the protons
- the acceleration of the protons.

[6 marks]

Question 3 continues on the next page

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The alternating voltage has a constant frequency.
Assume that a proton spends a negligible time in the gap between the dees.
Ignore relativistic effects.

0 3 . 3 State and explain any change to the angular velocity of a proton as it moves through the cyclotron.

[1 mark]

One cyclotron has dees with a diameter of $0.36\ \mathrm{m}$.
The protons leave the cyclotron $3.45 \times 10^{-6}\ \mathrm{s}$ after leaving the source and each proton has an energy of $1.92\ \mathrm{pJ}$.

0 3 . 4 Calculate the speed of a proton as it leaves the cyclotron.

[2 marks]

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

Do not write outside the box

0 3 . 5 Show that a proton completes approximately 150 revolutions inside the cyclotron.

[2 marks]

0 3 . 6 Calculate the peak voltage of the high-voltage source.

[3 marks]

peak voltage = _____ V

15

Turn over for the next question

Do not write outside the box

0 4 Used fuel from a nuclear reactor contains many different radioactive isotopes.

A fuel rod is stored until it is cool enough to be handled safely.

After 10.0 years the activity of caesium-134 in the rod is 1.80×10^4 GBq.
Assume that no caesium-134 is produced during this period.
Caesium-134 is a β^- emitter with a half-life of 2.06 years.
0.829 MeV is released in each caesium-134 decay.

1 year = 3.16×10^7 s

0 4 . 1 Show that the initial activity of the caesium-134 is approximately 5×10^{14} Bq.

[2 marks]

0 4 . 2 Calculate, in g, the mass of caesium-134 initially present in the rod.

[3 marks]

mass = _____ g

Do not write outside the box

0 4 . 3 Calculate, in W, the initial rate of energy release caused by caesium-134 β^- decay in the rod.

[2 marks]

rate of energy release = _____ W

0 4 . 4 The energy released in each decay is 0.829 MeV.

Discuss how:

- some of the decay energy causes heating of the fuel rod
- some of the decay energy does not heat the fuel rod.

[2 marks]

_____

_____

_____

_____

_____

_____

9

Turn over for the next question

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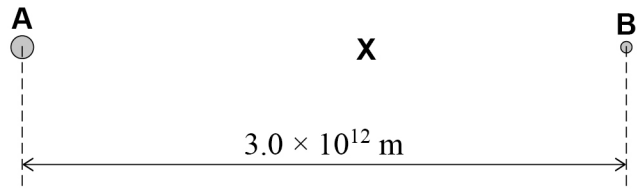
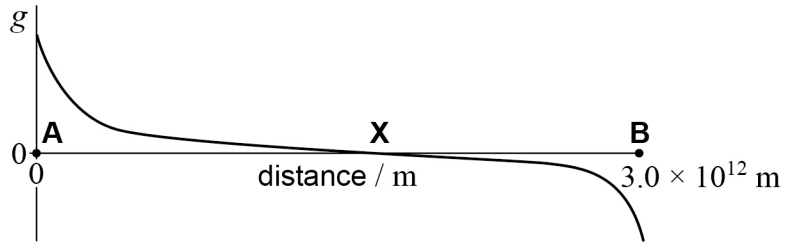
0 5 **Figure 11** shows two stars **A** and **B** separated by a distance of 3.0×10^{12} m. The gravitational field strength at point **X** is zero.

Figure 11



0 5 . 1 **Figure 12** shows the variation of gravitational field strength g with distance from **A** to **B**.

Figure 12



X is further from **A** than it is from **B**.

Explain the variation in g over the distance shown in **Figure 12**.

[3 marks]

Do not write outside the box

0 5 . 2 **A** has a mass of 4.0×10^{30} kg.
X is 1.76×10^{12} m from **A**.

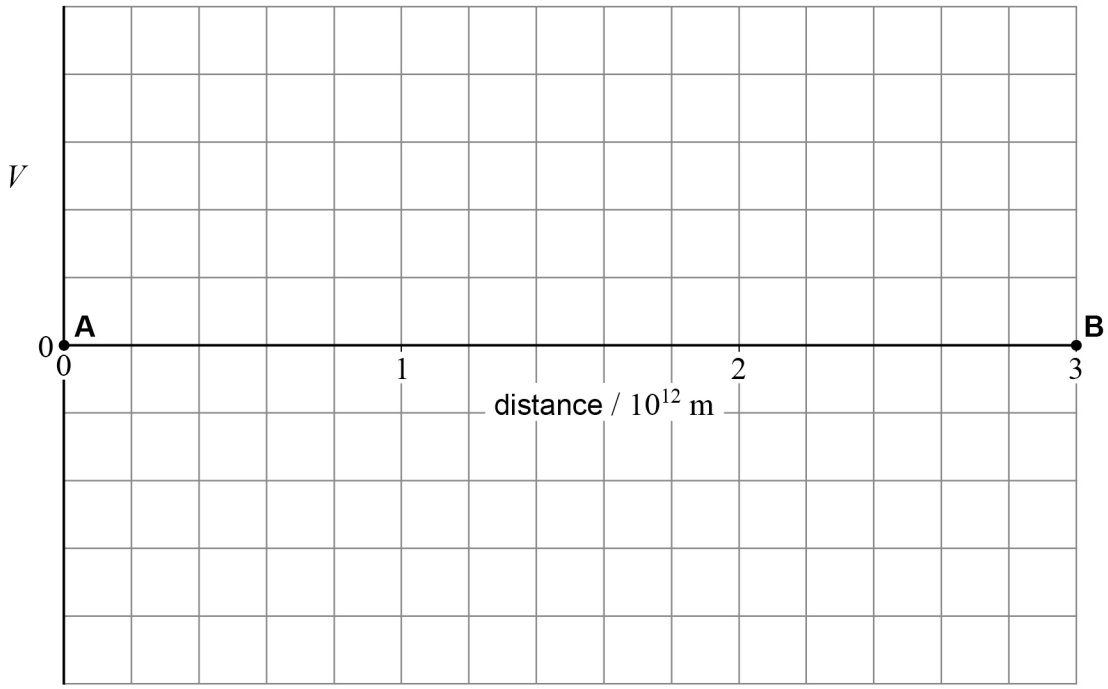
Calculate the mass of **B**.

[3 marks]

mass of **B** = _____ kg

0 5 . 3 Sketch, without performing any calculations, the variation of gravitational potential V with distance from **A** to **B**.

[2 marks]



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0 6 Many car engines need a spark from a spark plug to ignite the fuel in the cylinder.

Figure 13 shows a spark plug with a spark crossing the gap.
The spark occurs when a large emf ε is applied across the spark gap.

Figure 13

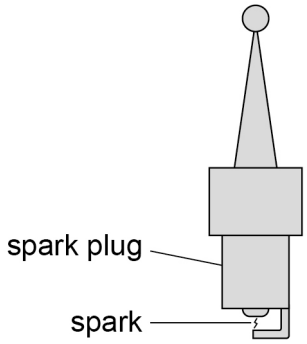
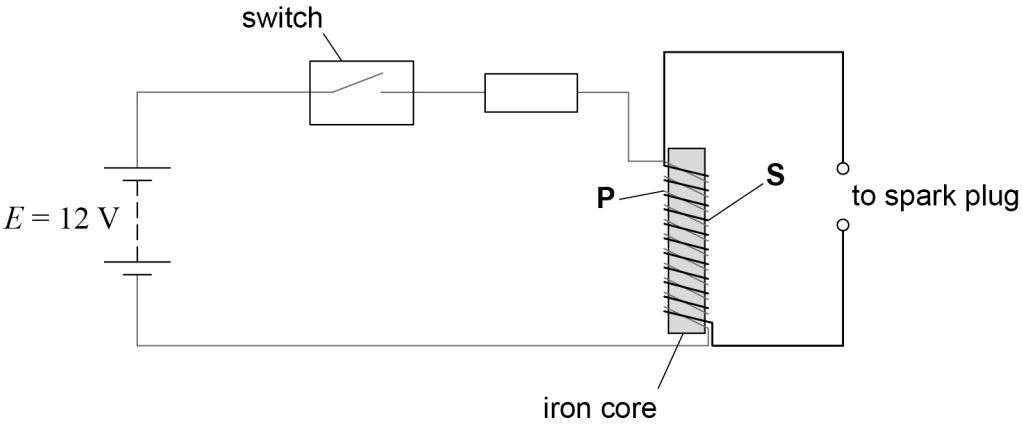


Figure 14 shows the main parts of the system for creating the large emf ε.

Figure 14



The system contains a coil **P** wrapped around an iron core. An insulated coil **S** is wrapped around **P**.
When the switch is in the closed position, there is a current in **P**.
The current in **P** creates a magnetic field that links with **S**.

When the switch opens, the current in **P** stops, causing the emf ε to be induced in **S**.

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0 6 . 1 Explain how an emf is induced in **S** when the switch opens.

[1 mark]

_____

_____

_____

0 6 . 2 Explain **two** features of the system in **Figure 14** that will result in a large emf ε being produced.

[2 marks]

1 _____

_____

_____

2 _____

_____

_____

Question 6 continues on the next page

Do not write outside the box

When there is a current in **P**, the flux linkage in **S** is given by:

$$\Phi_S = \mu N_P N_S A \frac{E}{R}$$

where

μ	= a constant	$= 1.26 \times 10^{-6}$ V s A^{-1} m^{-1}
N_P	= the number of turns on **P**	= 180
N_S	= the number of turns on **S**	= 20 000
A	= the cross-sectional area of each coil	$= 6.0 \times 10^{-4}$ m^2
E	= the emf of the battery	= 12 V
R	= the resistance of the primary circuit	= 2.4 Ω

0 6 . 3 Derive an expression for B, the magnetic flux density due to the current in **P** when the switch is in the closed position.

[2 marks]

Do not write outside the box

0 6 . 4 The switch is opened and the current in **P** decreases to zero. The magnetic flux density due to the current in **P** decreases uniformly to zero in a time t.
An emf ε of $30\ \mathrm{kV}$ is induced in **S** during the time t.

Calculate t.

[2 marks]

$t =$ _____ s

0 6 . 5 An engineer suggests reducing the resistance R of the primary circuit.

Explain the effect that this reduction would have on the emf induced in **S** when the switch is opened.

[2 marks]

_____

_____

_____

_____

_____

_____

9

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 7 What is the unit for the gravitational constant G in SI fundamental (base) units?

[1 mark]

A $\mathrm{N\,m^2\,kg^{-2}}$

B $\mathrm{kg\,m^2\,s^{-2}}$

C $\mathrm{kg^{-1}\,m^3\,s^{-2}}$

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

Do not write outside the box

0 8 Two identical satellites **P** and **Q** are in circular orbits around the same planet.
The orbital radius of **P** is smaller than the orbital radius of **Q**.

Which row shows the satellite with the greater kinetic energy and the satellite with the greater gravitational potential energy?

[1 mark]

	Satellite with the greater kinetic energy	**Satellite with the greater gravitational potential energy**	
A	**P**	**P**	⬭
B	**P**	**Q**	⬭
C	**Q**	**P**	⬭
D	**Q**	**Q**	⬭

Turn over for the next question

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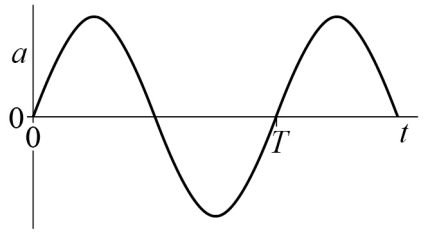
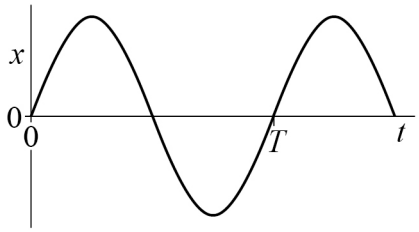
0 9 The graph shows the variation of acceleration a with time t for an object performing simple harmonic motion. The period of the oscillation is T.



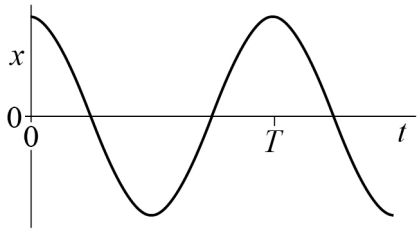
Which graph shows the variation of displacement x with t for the same object?

[1 mark]

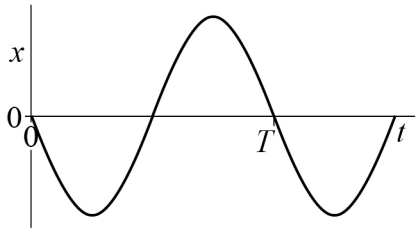
A



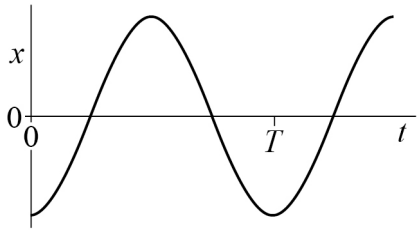
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

Do not write outside the box

1 0 In the Rutherford scattering experiment, an alpha particle is moving directly towards a nucleus. The alpha particle stops for an instant at its distance of closest approach to the nucleus.

A $4\ \mathrm{MeV}$ alpha particle is directed towards a zinc nucleus $\left({}^{64}_{30}\mathrm{Zn}\right)$.

Its distance of closest approach to the nucleus is d_{Z}.

An $8\ \mathrm{MeV}$ alpha particle is directed towards a thorium nucleus $\left({}^{232}_{90}\mathrm{Th}\right)$.

Its distance of closest approach to the nucleus is d_{T}.

What is the value of $\dfrac{d_{\mathrm{Z}}}{d_{\mathrm{T}}}$?

[1 mark]

A 0.67 ⬭

B 0.75 ⬭

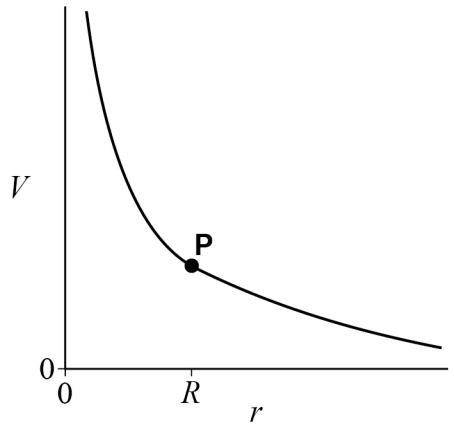
C 1.5 ⬭

D 1.8 ⬭

Turn over for the next question

Do not write outside the box

1 1 The graph shows the variation of absolute electrical potential V with distance r from an isolated point charge.



The point **P** is at a distance R from the point charge.

What is equivalent to the magnitude of the electric field strength at **P**?

[1 mark]

A $\dfrac{1}{\text{the gradient at } \mathbf{P}}$

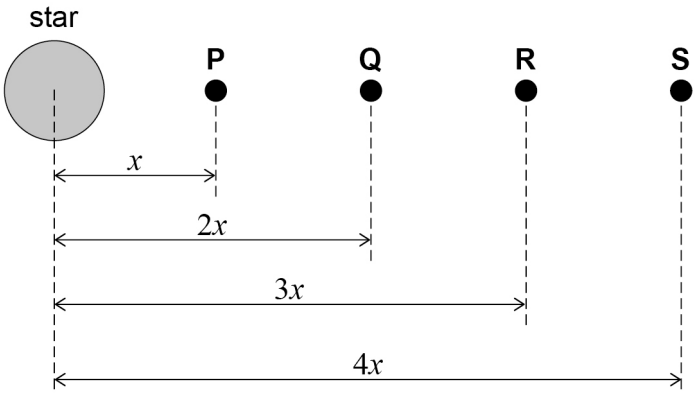
B the gradient at **P**

C the area under the curve from $r = 0$ to $r = R$

D the area under the curve from $r = R$ to $r = \infty$

Do not write outside the box

1 2 The diagram shows four planets **P**, **Q**, **R** and **S** in circular orbits about a star.
The orbital radii of **P**, **Q**, **R** and **S** are x, $2x$, $3x$ and $4x$ respectively.



Which of the following pairs of planets has the biggest difference in gravitational potential due to the star's gravitational field?

[1 mark]

A **P** and **R**

B **Q** and **S**

C **P** and **Q**

D **R** and **S**

1 3 An object moves with simple harmonic motion and has an amplitude A and a frequency f.

What is the speed of the object when its displacement from the equilibrium position is $\frac{A}{2}$?

[1 mark]

A $\frac{Af}{2}$

B πAf

C $\frac{\sqrt{6}}{2}Af$

D $\sqrt{3}\pi Af$

Turn over ►

Do not write outside the box

1 4 The electrostatic force between two protons in a nucleus is F.
The electrostatic force between the electron and the proton in a hydrogen atom is f.

What is the order of magnitude of $\frac{F}{f}$?

[1 mark]

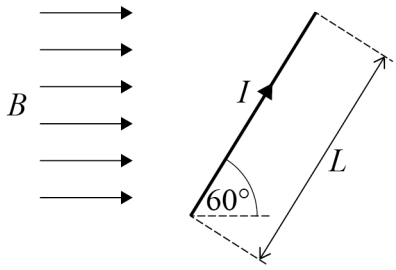
A 10^5

B 10^6

C 10^{10}

D 10^{15}

1 5 A wire of length L is placed at an angle of $60°$ to a magnetic field of magnetic flux density B. The wire carries a current I. The wire and the magnetic field are parallel to the plane of the page.



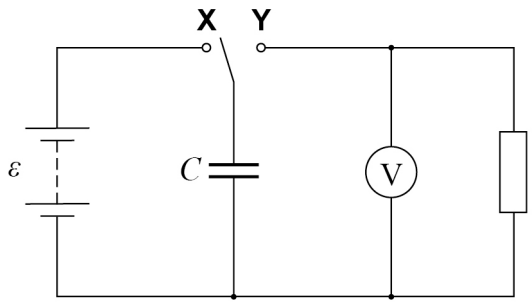
Which row shows the magnitude and the direction of the force experienced by the wire?

[1 mark]

	Magnitude of the force	Direction of the force
A	$\frac{\sqrt{3}}{2}BIL$	out of the page
B	$\frac{\sqrt{3}}{2}BIL$	into the page
C	$\frac{1}{2}BIL$	out of the page
D	$\frac{1}{2}BIL$	into the page

Do not write outside the box

1 6 A student uses this circuit to measure the capacitance C of a capacitor.
The voltmeter has a resistance R_V and the battery has an emf ε.



She charges the capacitor with the switch in position **X**. She moves the switch to position **Y** and records the voltmeter reading as the capacitor discharges through the resistor.
The student determines the time constant of the discharge and calculates C.

Her value of C is lower than expected.

Which changes to R_V and ε could lead to a more accurate determination of C?

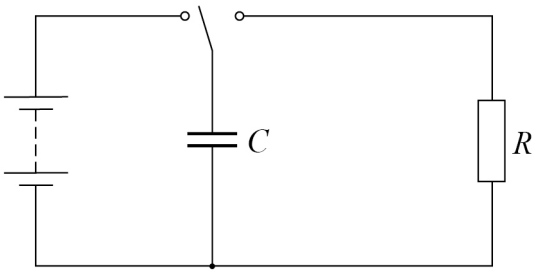
[1 mark]

	Change to R_V	Change to ε	
A	decrease	decrease	⬭
B	decrease	increase	⬭
C	increase	decrease	⬭
D	increase	increase	⬭

Turn over for the next question

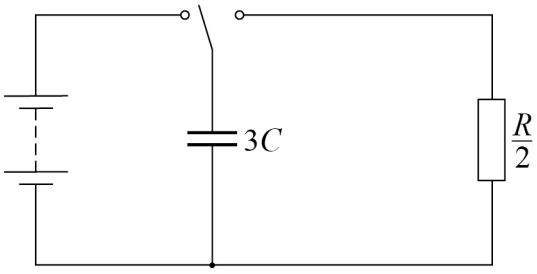
Do not write outside the box

1 7 A circuit contains a capacitor of capacitance C that is discharged through a resistor of resistance R.



The pd across the capacitor decreases from $10\ \text{V}$ to $2.5\ \text{V}$ in $35\ \text{s}$.

A second circuit contains a capacitor of capacitance $3C$ that is discharged through a resistor of resistance $\frac{R}{2}$.



What is the time taken for the pd across the capacitor to decrease from $10\ \text{V}$ to $5.0\ \text{V}$ in the second circuit?

[1 mark]

A $53\ \text{s}$

B $26\ \text{s}$

C $23\ \text{s}$

D $12\ \text{s}$

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1 8 Some metals such as iron and steel are magnetic. Magnetic metals are attracted to magnets.
Other metals such as copper and aluminium are non-magnetic. Non-magnetic materials are not attracted to magnets.

A metal is at rest in a magnetic field.

Eddy currents are produced:

[1 mark]

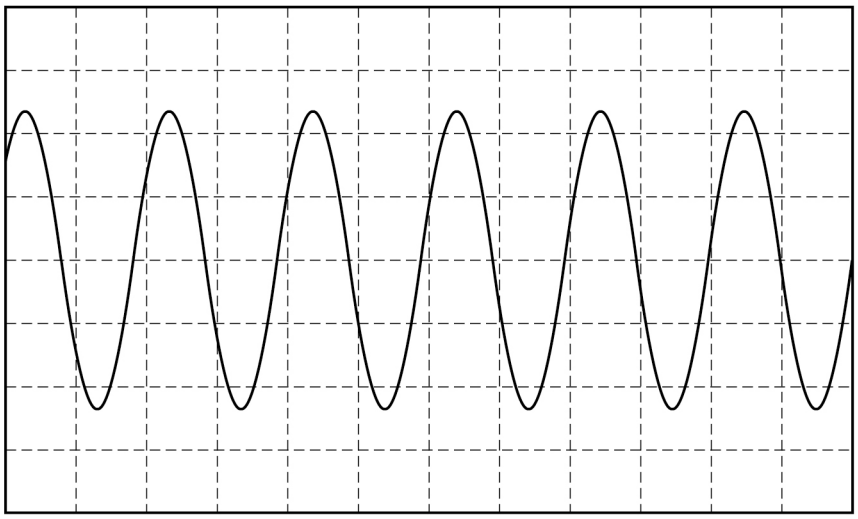
A only in a magnetic metal in a constant magnetic field. ⬭

B only in a magnetic metal in a changing magnetic field. ⬭

C in any metal in a constant magnetic field. ⬭

D in any metal in a changing magnetic field. ⬭

1 9 The diagram shows the oscilloscope trace for a signal of rms voltage 16 V.



What is the volts / division setting on the oscilloscope?

[1 mark]

A 5 V / division ⬭

B 7 V / division ⬭

C 10 V / division ⬭

D 20 V / division ⬭

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2 0 An ideal transformer at a power station supplies power to a factory through transmission lines of resistance R.

What is the rate of energy dissipation in the transmission lines?

[1 mark]

A $\frac{N_P^2}{N_S^2} I_P^2 R$ ⬭

B $\frac{N_S^2}{N_P^2} I_P^2 R$ ⬭

C $\frac{N_P^2}{N_S^2} \frac{V_P^2}{R}$ ⬭

D $\frac{N_S^2}{N_P^2} \frac{V_P^2}{R}$ ⬭

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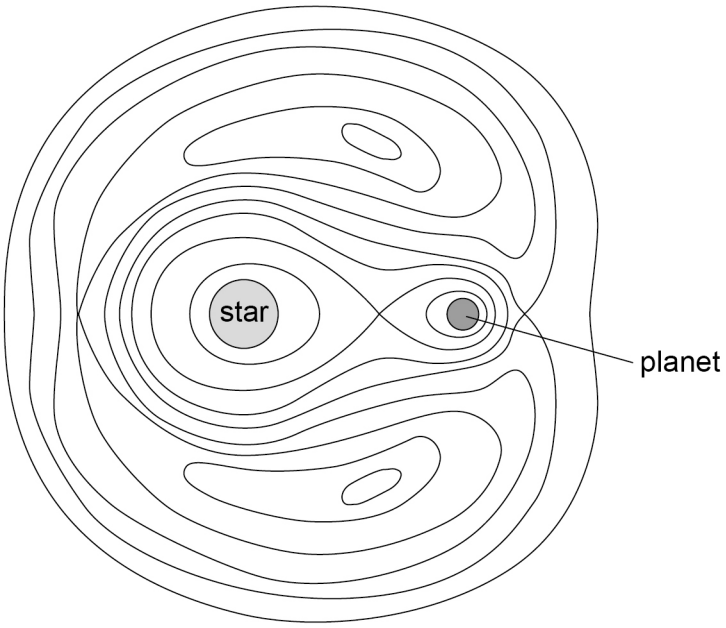
2 1 The diagram represents the gravitational field around a star and its planet.

Gravitational fields can be represented by gravitational field lines or by lines of equipotential.



A mass placed in the gravitational field experiences a force F. The magnitude of F varies with the position of the mass.

Which row describes the nature of the lines on the diagram and the positions where the magnitude of F is greatest?

[1 mark]

	The nature of the lines	**Positions where the magnitude of F is greatest**	
A	gravitational field lines	the lines are far apart	⬭
B	gravitational field lines	the lines are close together	⬭
C	lines of equipotential	the lines are far apart	⬭
D	lines of equipotential	the lines are close together	⬭

15

END OF QUESTIONS

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