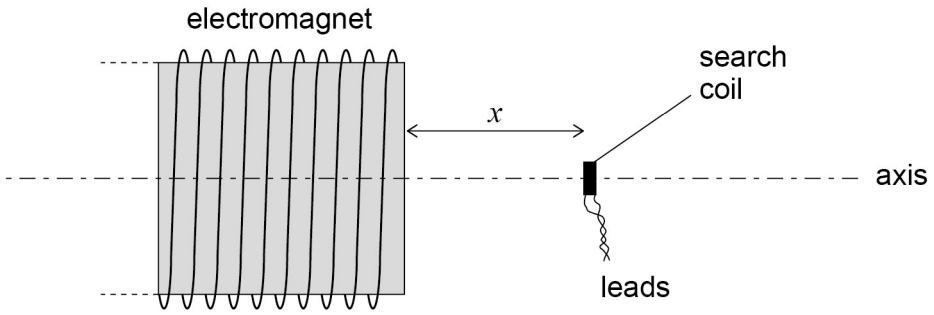
Do not write outside the box

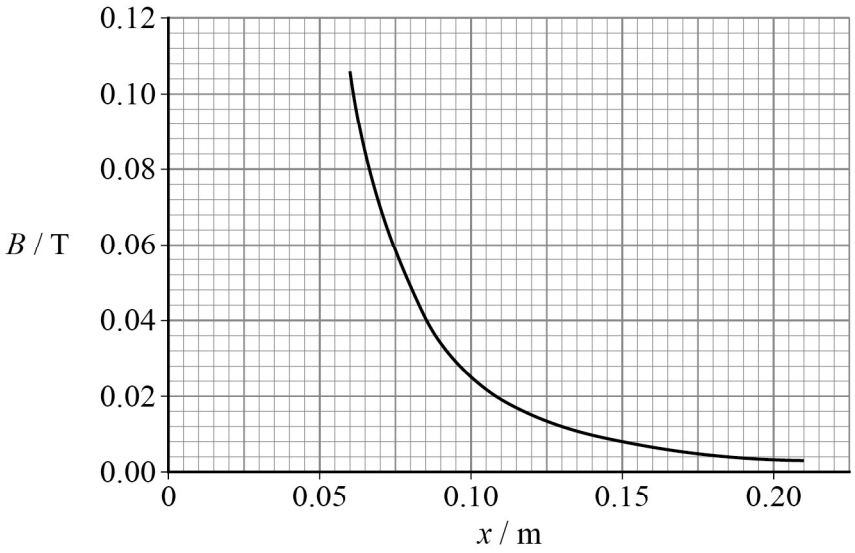
0 4 **Figure 7** shows a search coil positioned on the axis of an electromagnet, with the plane of the search coil perpendicular to the axis. A magnetic field is produced by a constant current in the electromagnet.
Assume that the magnetic flux density inside the search coil is uniform.

Figure 7



The distance between the search coil and the end of the electromagnet is x.
Figure 8 shows how the magnetic flux density B of the field varies with x.

Figure 8



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The search coil has 200 turns and a cross-sectional area of $3.5 \times 10^{-5}\ \text{m}^2$.

0 4 . 1 The search coil is placed at $x = 0.070\ \text{m}$.

Show that the magnetic flux linkage through the search coil is about $5 \times 10^{-4}\ \text{Wb}$.

[2 marks]

Question 4 continues on the next page

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The search coil is now moved at a constant speed of $0.80\ \text{m s}^{-1}$ along the axis so that x is increasing. An emf is induced across the terminals of the search coil.

0 4 . 2 Explain what happens to the value of the emf as the search coil moves.

[2 marks]

0 4 . 3 The search coil passes through the position where $x = 0.10\ \text{m}$.

Deduce whether the emf can exceed $5\ \text{mV}$ for values of x greater than $0.10\ \text{m}$.

[4 marks]

8

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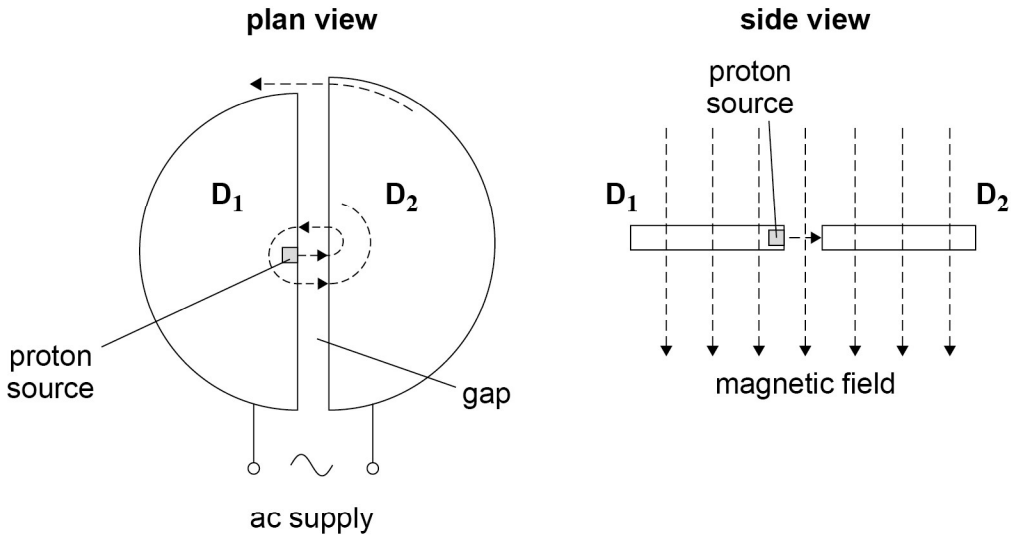
0 5 **Figure 9** shows a cyclotron. A proton is released from rest and is accelerated each time it reaches the gap between two horizontal 'dees' $\mathbf{D_1}$ and $\mathbf{D_2}$. Between these accelerations the proton moves at constant speed. A vertical magnetic field of flux density B acts over the dees so that the proton follows a semicircular path in each dee.

The dees are connected to an alternating potential difference (pd).
This pd is adjusted so that the proton is always accelerated by the peak electric field as it crosses the gap between the dees.

Figure 9



0 5 . 1 Explain why the proton travels in a semicircular path in a dee.

[2 marks]

Question 5 continues on the next page

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0 5 . 2 The peak pd of the alternating supply is $10.0\ \text{kV}$. The proton leaves the cyclotron with kinetic energy of $14\ \text{MeV}$.

Determine the number of times the proton moves across the gap before it leaves the cyclotron.

[1 mark]

number of times = _____

The radius of the outermost semicircular path of the proton is R and the proton leaves with a maximum kinetic energy E_k.

0 5 . 3 Show that E_k is given by

$$E_\text{k} = \frac{e^2 B^2 R^2}{2m_\text{p}}$$

[3 marks]

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0 5 . 4 A hospital decides to purchase a cyclotron in order to manufacture its own radioactive isotopes using high-speed protons.
The required minimum kinetic energy of the emerging protons is $11\ \text{MeV}$.
The cost of a cyclotron is approximately proportional to $E_k^{1.5}$.
The cost of a $10\ \text{MeV}$ cyclotron is about £2.3 million.
Table 1 gives information for three cyclotrons **X**, **Y** and **Z**.

Table 1

Cyclotron	B / T	R / m
X	1.3	0.38
Y	1.1	0.50
Z	0.5	0.60

Deduce which cyclotron **X**, **Y** or **Z** will satisfy the energy requirement for the lowest cost.
Go on to determine the approximate cost of this cyclotron.

[4 marks]

cyclotron = _____

cost = _____

10

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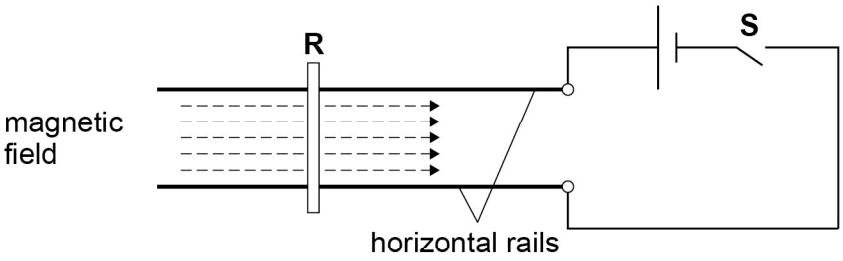
2 1 A short copper rod **R** is placed on a pair of thick horizontal parallel copper rails. A horizontal magnetic field exists in the direction shown by the dashed arrows. The diagram shows the apparatus when viewed from directly above.



When switch **S** is closed, **R** will tend to

[1 mark]

A lift upwards away from the rails. ⬭

B move to the left. ⬭

C move to the right. ⬭

D be pressed downwards onto the rails. ⬭

Turn over for the next question

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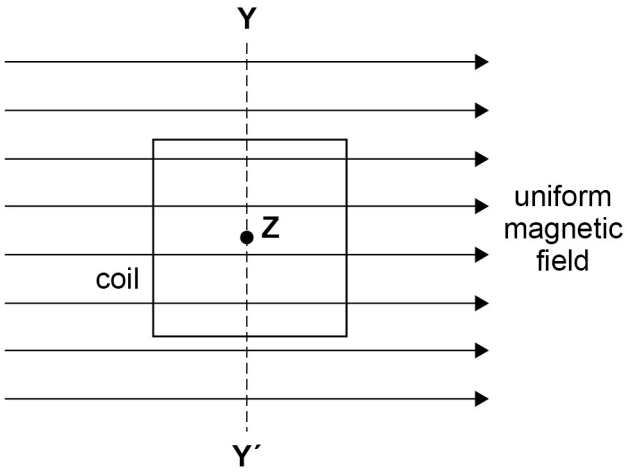
2 2 The diagram shows a square coil with its plane parallel to a uniform magnetic field.



The coil always remains within the magnetic field.
There are four possible changes to the position of the coil:

- moving it to the left
- moving it towards **Y**
- rotating it about the axis **YY´**
- rotating it about an axis **Z** that is at its centre and perpendicular to the plane of the coil.

How many of these changes will result in an induced emf in the coil while the change occurs?

[1 mark]

A one ⬭

B two ⬭

C three ⬭

D four ⬭

2 3 Mains electricity is rated 230 V in the UK.

Which is correct?

[1 mark]

A The mean voltage is 163 V. ⬭

B The peak voltage is 230 V. ⬭

C The root mean square voltage is 325 V. ⬭

D The peak-to-peak voltage is 650 V. ⬭

Do not write outside the box

2 4 In a resistor of resistance R, a steady current I dissipates a power P.

In a resistor of resistance $\frac{R}{2}$ there is an alternating current of root mean square value $3I$.

What is the mean power dissipated in the resistor of resistance $\frac{R}{2}$?

[1 mark]

A $9P$ ⬭

B $\frac{9}{2}P$ ⬭

C $\frac{9}{4}P$ ⬭

D $\frac{3}{2}P$ ⬭

2 5 The primary winding of a transformer has 200 turns and the secondary winding has 1600 turns.
A root mean square (rms) alternating voltage of $25\ \text{V}$ is applied to the primary winding causing a primary rms current of $4.0\ \text{A}$. The transformer is 90% efficient.

What are the rms values of the secondary voltage and the secondary current?

[1 mark]

	Secondary voltage / V	**Secondary current / A**	
A	200	0.50	⬭
B	200	0.45	⬭
C	180	0.50	⬭
D	3.1	29.0	⬭