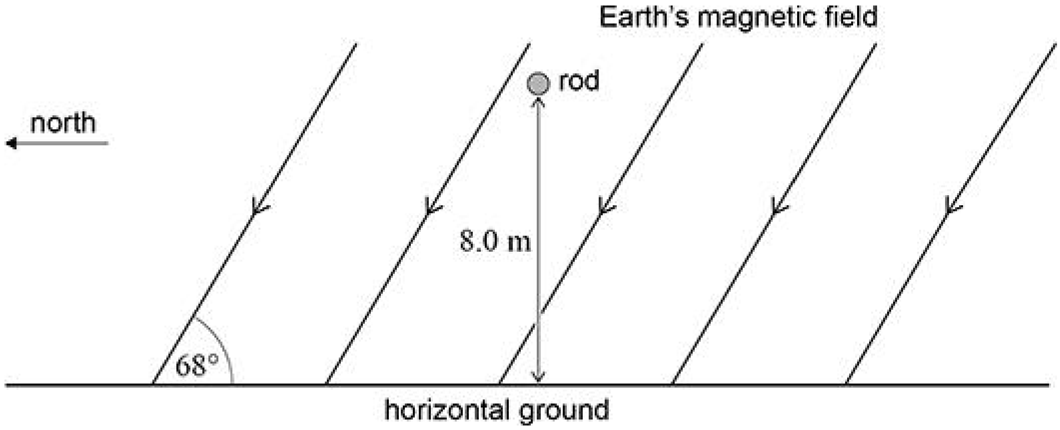
**Q1.**

A conducting rod is held horizontally in an east–west direction.
The magnetic flux density of the Earth's magnetic field is $4.9 \times 10^{-5}$ T and is directed at an angle of 68° to the ground.

(a) **Figure 1** shows the arrangement. The rod has a length of 2.0 m.

**Figure 1**




The rod is released and falls 8.0 m to the ground. It remains in a horizontal east–west direction as it falls.

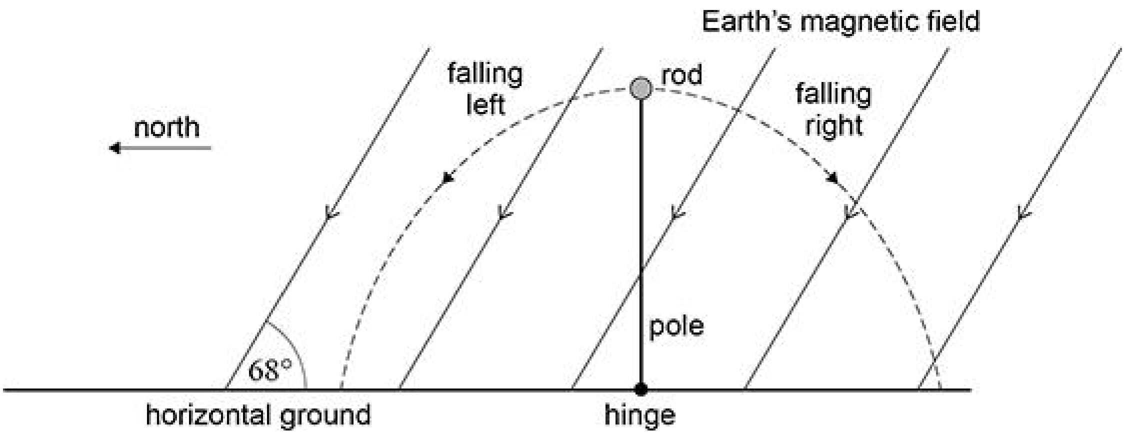
Determine the average emf across the rod during its fall to the ground.
Assume that air resistance is negligible.

average emf = ____________________ V

**(3)**

(b) The rod is returned to its original position. It is now supported by a non-conducting pole that is hinged on the ground as shown in **Figure 2**. The pole is initially vertical and is then released. The rod and pole can fall to the ground to the left or to the right.

**Figure 2**




During each fall there are changes in the magnitude and direction of the induced emf. These changes differ depending on whether the rod falls to the left or to the right.

Explain any changes in the magnitude and direction of the induced emf as the rod falls:

- to the left
- to the right.

left ______________________________________________

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right ______________________________________________

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**(4)**

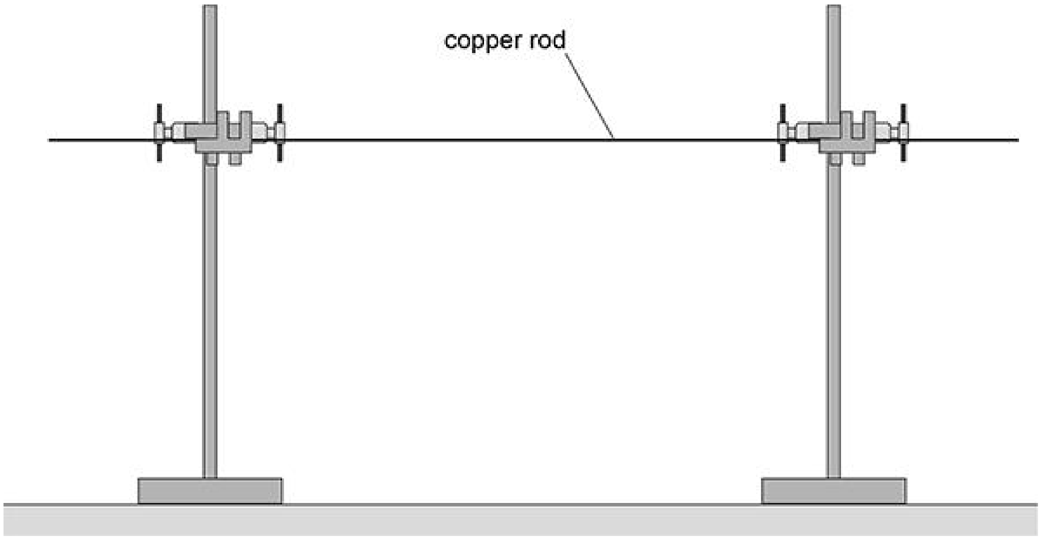
**(Total 7 marks)**

## Q2.

This question is about a method to investigate how the force on a conductor varies with flux density and current (required practical activity 10).

**Figure 1** shows a copper rod clamped above a horizontal bench.

**Figure 1**




(a) Describe a method to show that the copper rod is horizontal.
Your method must include the use of a metre ruler.
You may annotate **Figure 1**.

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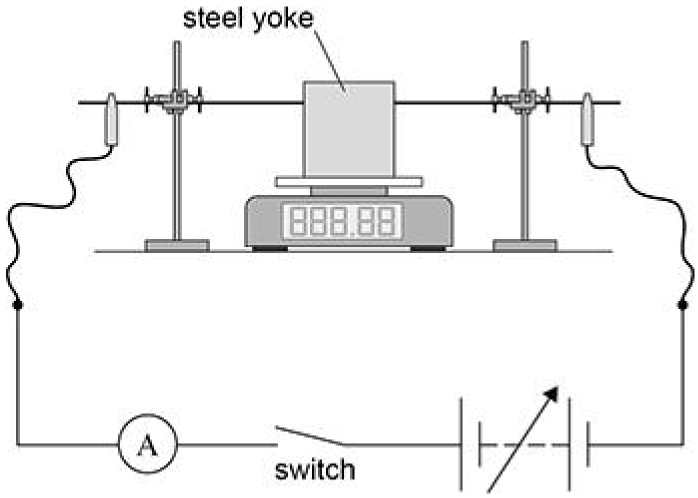
**(3)**

**Figure 2** shows the copper rod positioned above a digital balance.

Two identical magnets are mounted on a steel yoke with their opposite poles facing each other.
The balance is zeroed.
The yoke is then placed on the balance so that a horizontal uniform magnetic field is applied perpendicular to the copper rod.
The ends of the rod are connected as shown.

**Figure 2**




(b) When the switch is open, the reading on the balance shows the mass of the yoke and the two magnets.
When the switch is closed, the reading on the balance decreases.

Explain, with reference to **Figure 2**, the direction of the horizontal magnetic field.

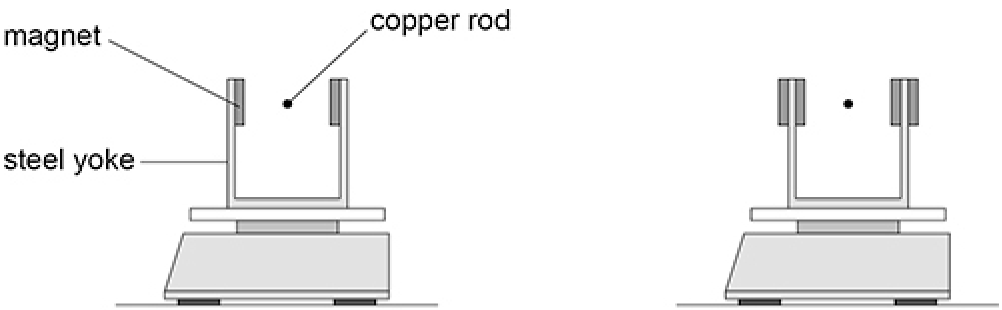
**(3)**

The current $I$ in the rod is varied.
The balance reading $M_1$ is recorded for different values of $I$.

The switch is now opened.
Two additional magnets, identical to those used before, are attached to the yoke.

**Figure 3** shows how this new arrangement compares with the arrangement in **Figure 2**.

**Figure 3**




use of two magnets for the arrangement in **Figure 2**

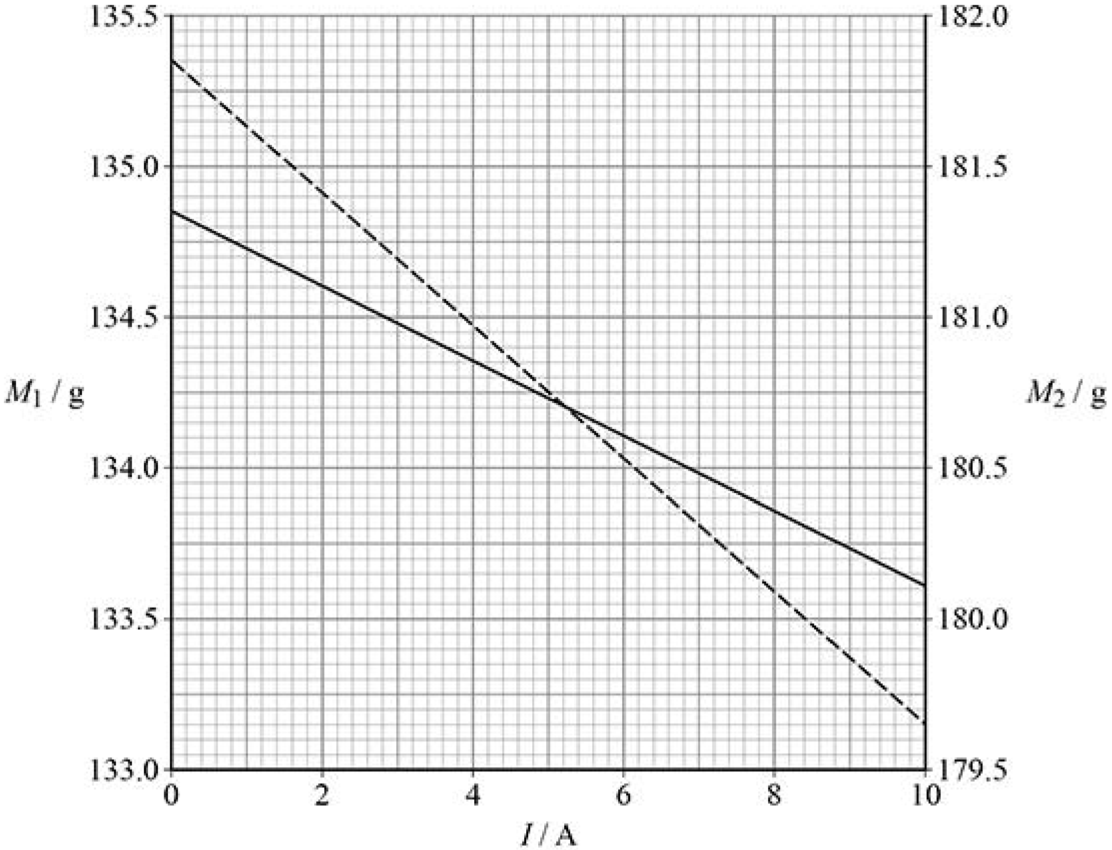
new arrangement using four magnets

The balance reading with four magnets attached to the yoke is $M_2$.
With the switch open, $M_2$ is the mass of the yoke and the four magnets.

The switch is now closed.
$M_2$ is recorded for different values of $I$.

**Figure 4** shows data from both experiments.
Values of $M_1$ and $M_2$ are plotted using different vertical axes.

**Figure 4**




The solid line ——— shows the variation of $M_1$ with $I$

The dashed line ----- shows the variation of $M_2$ with $I$

It can be shown that

$$M = kBI + nZ + Y$$

where

$M$ = balance reading when the current is $I$
$B$ = magnetic flux density of the horizontal uniform magnetic field
$n$ = number of magnets attached to the yoke
$Z$ = mass, in g, of each magnet
$Y$ = mass, in g, of the yoke
$k$ is a constant.

(c) Deduce the fundamental base units for $k$.

fundamental base units = ______________________

**(3)**

(d) Determine $Y$.

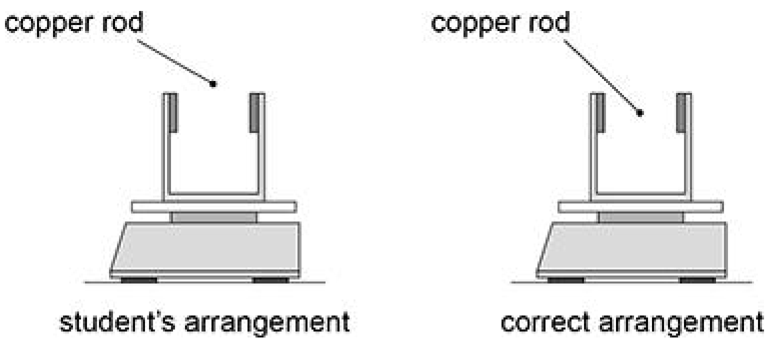
$Y$ = ______________________ g

**(3)**

(e) A student sets up the apparatus with the copper rod positioned incorrectly.

**Figure 5** shows how the student's arrangement compares with the correct arrangement.

**Figure 5**




The student produces a graph of $M_1$ against $I$.

Compare the student's graph with the graph of $M_1$ against $I$ (the solid line) in **Figure 4**.
Explain your answer.

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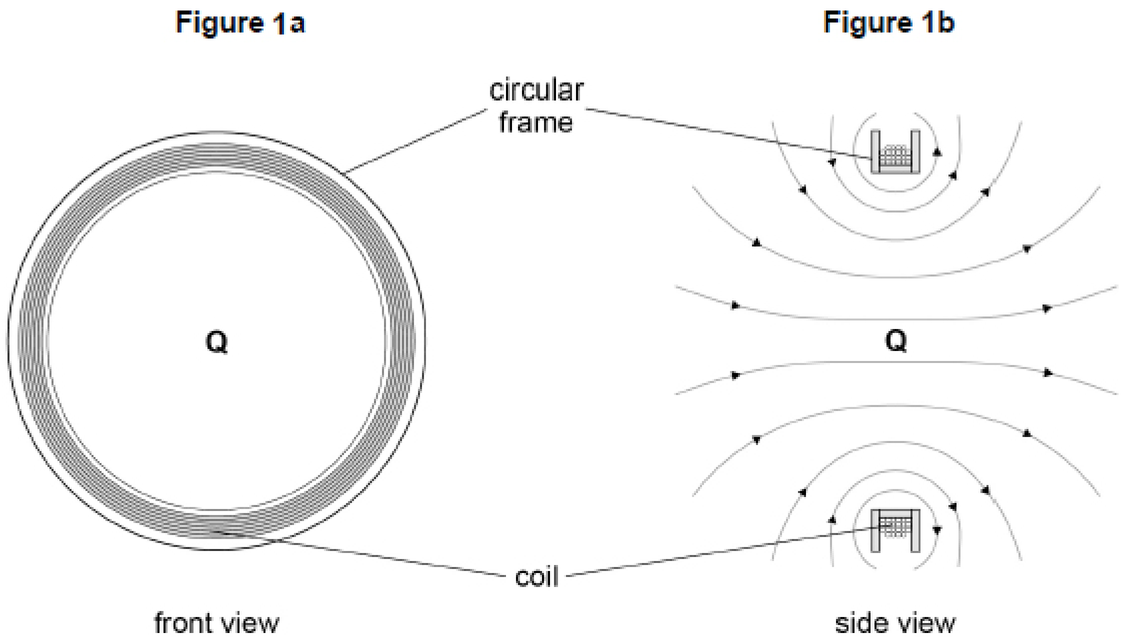
**(3)**
**(Total 15 marks)**

## Q3.

**Figure 1** shows the front view of a vertical coil mounted on a circular frame.

**Figure 1** is a side view showing a section through the frame and coil.
A constant direct current in the coil produces magnetic flux represented by the magnetic field lines on this diagram.




Point **Q** is at the centre of the coil.

A sensor placed at **Q** detects $B_H$, the horizontal component of the magnetic flux density.

The effect of the Earth's magnetic field at **Q** is negligible.

(a) Discuss whether a search coil is a suitable sensor to detect $B_H$.

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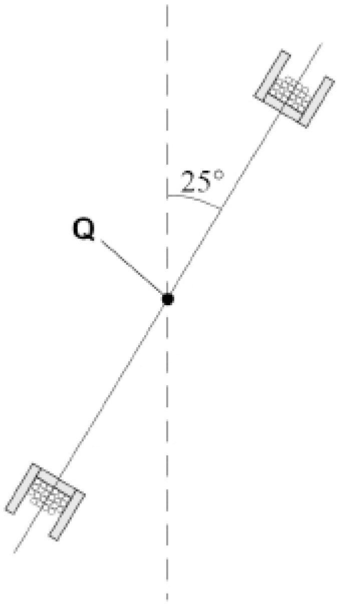
**(2)**

$B_H$ is measured at **Q** with the coil vertical.

The coil is now rotated about **Q** through 25° as shown in **Figure 2**.
The current in the coil does not change.

**Figure 2**




A new measurement of $B_H$ is made with the coil fixed in this new position.

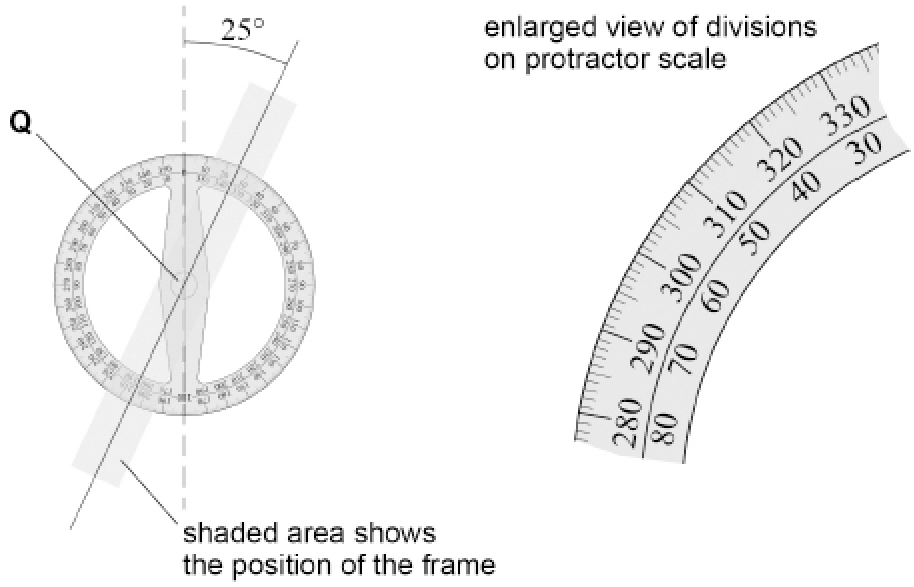
(b) Determine the percentage change in $B_H$ produced by this rotation of the coil.
Show your working.

percentage change = ____________________ %

**(2)**

(c) **Figure 3** shows a protractor being used to measure the angle through which the coil is rotated.

**Figure 3**




Estimate the percentage uncertainty in this result.
Justify your answer.

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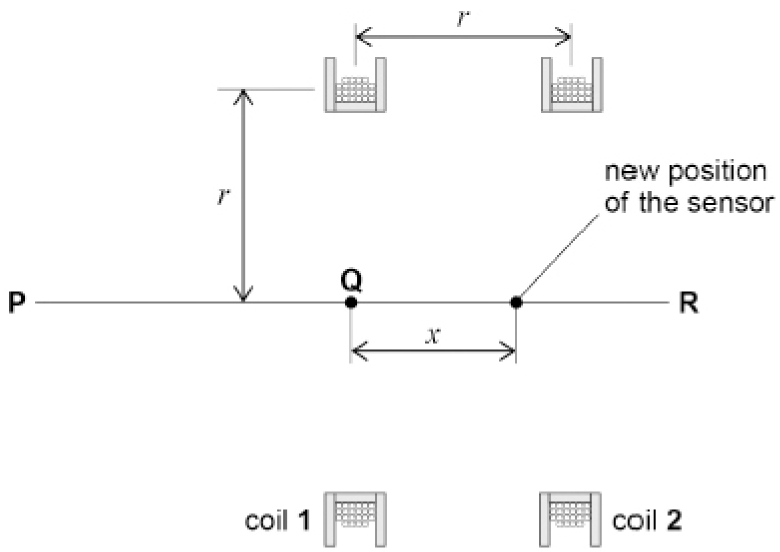
percentage uncertainty = ____________________ %

**(3)**

**Figure 4** shows an arrangement of two vertical coils.
Four experiments are done using this arrangement.

**Figure 4**




Coil **1** and coil **2** are identical and have a radius $r$.
The coils are separated by a distance $r$ and have a common axis **PR**.
**Q** is at the centre of coil **1**.

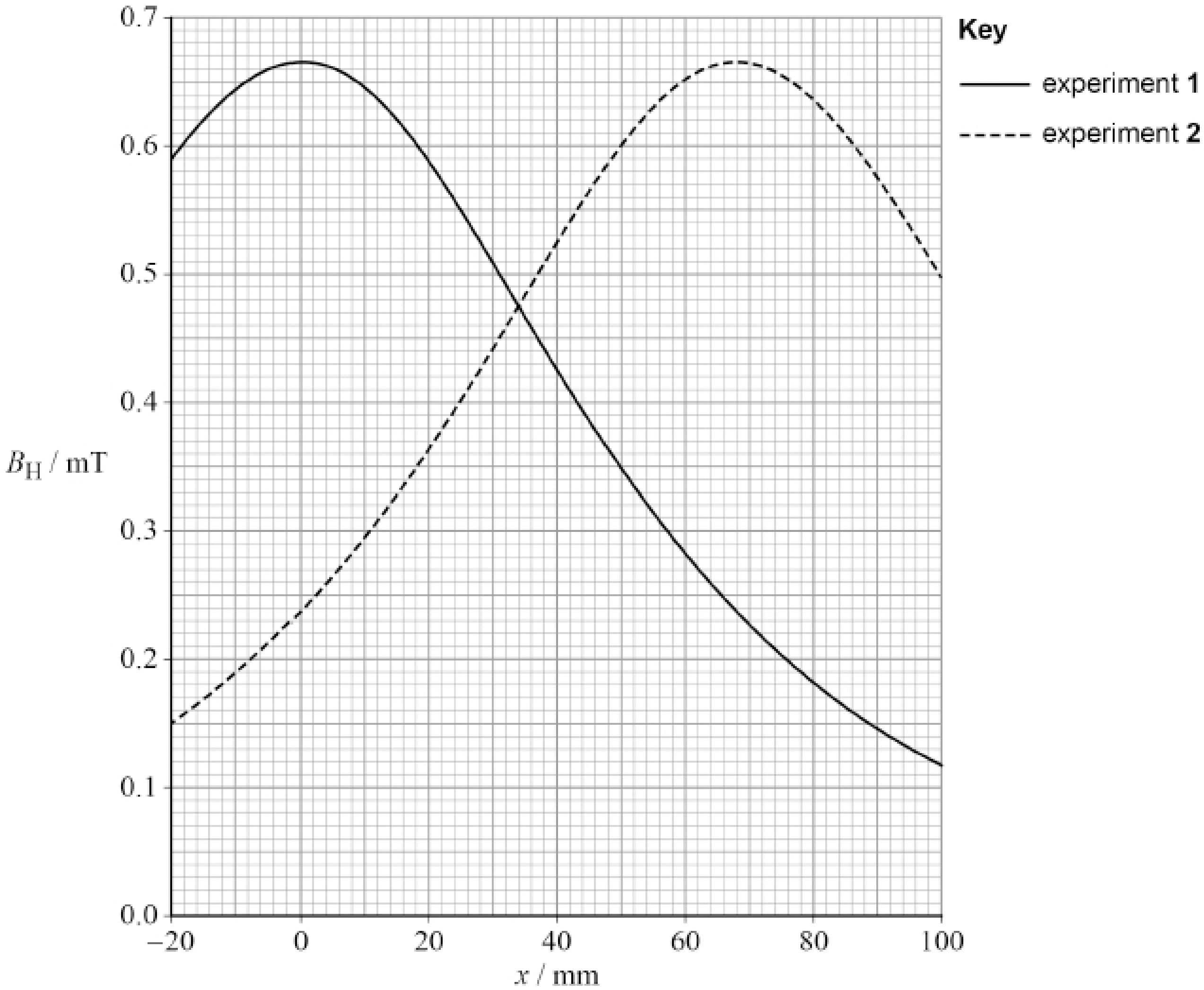
The four different experiments investigate how $B_H$ varies with $x$, the displacement of the sensor from **Q** along **PR**.

In experiment **1**, the current in coil **1** is 225 mA and the current in coil **2** is zero.

In experiment **2**, the current in coil **1** is zero and the current in coil **2** is 225 mA.

**Figure 5** shows the results of experiment **1** and experiment **2**.

**Figure 5**




(d) During experiment **1**, $B_H$ is measured with the sensor at **Q**.
The sensor is then moved along **PR** until the value of $B_H$ is halved.
The distance from **Q** to the sensor is $x_{0.5}$

Determine $\frac{x_{0.5}}{r}$

$\frac{x_{0.5}}{r}$ = ____________________

**(2)**

In experiment **3**, the current in both coils is 225 mA so that the magnetic fields produced by coil **1** and coil **2** are combined.

The resultant $B_H$ has a constant maximum value in the region between $x = \frac{r}{4}$ and $x = \frac{3r}{4}$

(e) Deduce, in mT, the value of $B_H$ in this region.

$B_H$ = ____________________ mT

**(2)**

(f) State **two** characteristics of the magnetic field lines in this region.

1 ______________________________________________________________

______________________________________________________________

2 ______________________________________________________________

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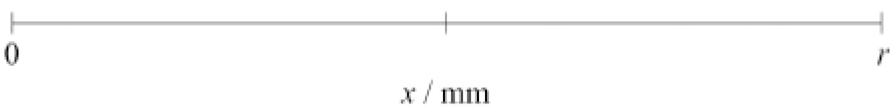
**(2)**

(g) In experiment **4**, the current in coil **2** is reversed so that the direction of the magnetic field produced by coil **2** is also reversed.
The magnitudes of the currents in coil **1** and coil **2** are still 225 mA.

Sketch a graph to show how $B_H$ varies between $x = 0$ and $x = r$.
The $x$-axis has been provided for you.

Your graph should include numerical values on your $B_H$ axis that correspond to $x = 0$ and $x = r$.



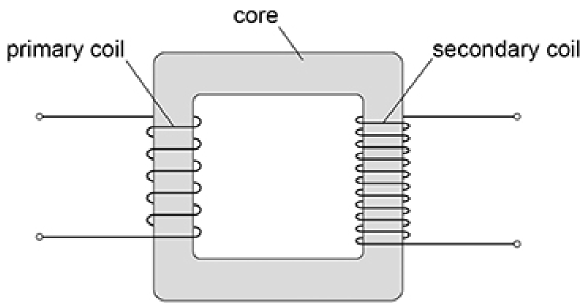

**(3)**

**(Total 16 marks)**

## Q4.

**Figure 1** shows a transformer.

**Figure 1**




(a) Explain the functions of the core and the secondary coil.

core ________________________________________

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secondary coil ________________________________________

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**(3)**

(b) **Figure 2** shows a cross-section through the transformer core. Thin iron sheets are separated by material **M**.
Explain how the efficiency of the transformer is increased by constructing the core in this way.

**Figure 2**


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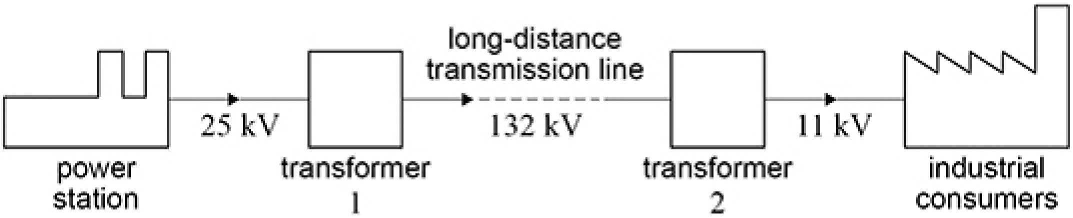
**(3)**

**Figure 3** shows a schematic diagram of a power transmission system.

**Figure 3**




(c) Voltages between 33 kV and 400 kV are used for long-distance transmission.

Suggest why engineers have chosen 132 kV for this system.

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**(2)**

(d) The industrial consumers use 72 MW of power.
Transformers 1 and 2 each have an efficiency of 98% and the transmission line has an efficiency of 94%.

Calculate the current in the 25 kV line from the power station.

current = ____________ A

**(3)**
**(Total 11 marks)**