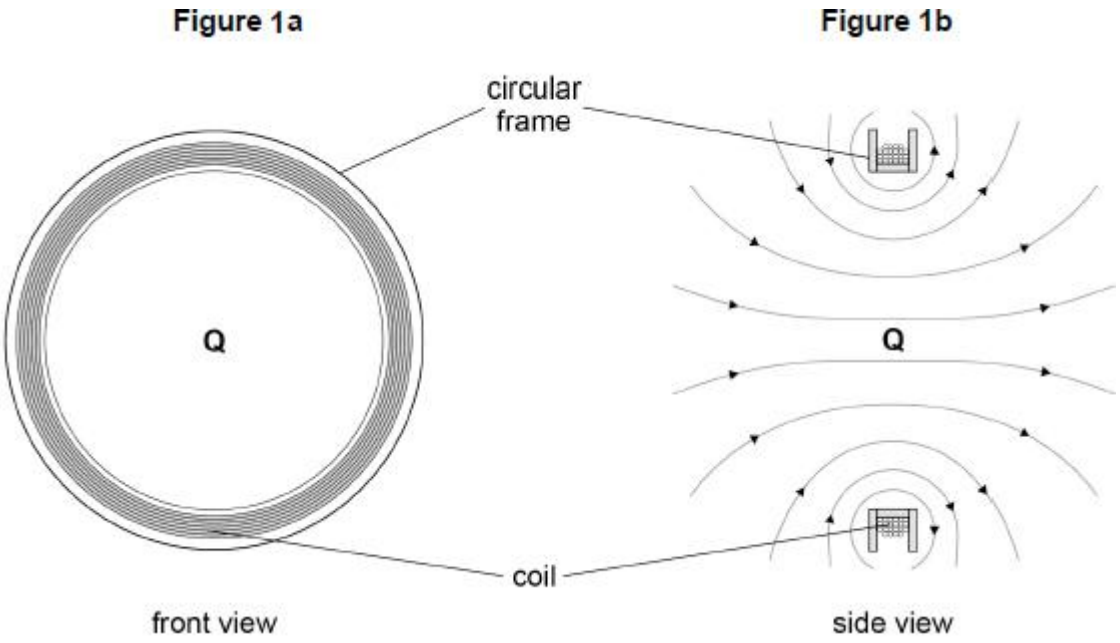
Name of the Student:_____
Max. Marks : 24 Marks **Time : 24 Minutes**

Q1.

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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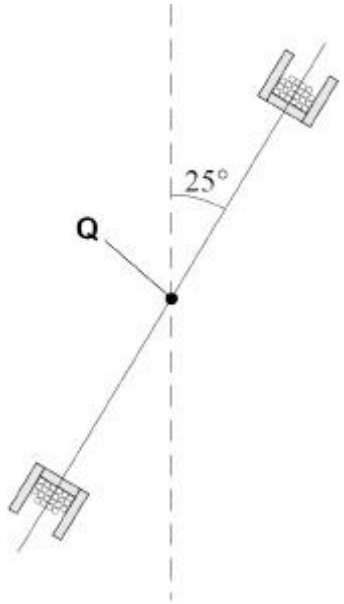
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(2)

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.

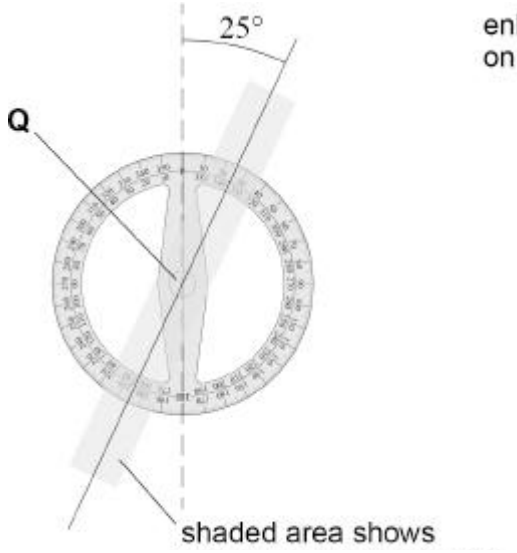
percentage change = _____ %

(2)

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

Figure 3

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

_____

_____

_____

_____

_____

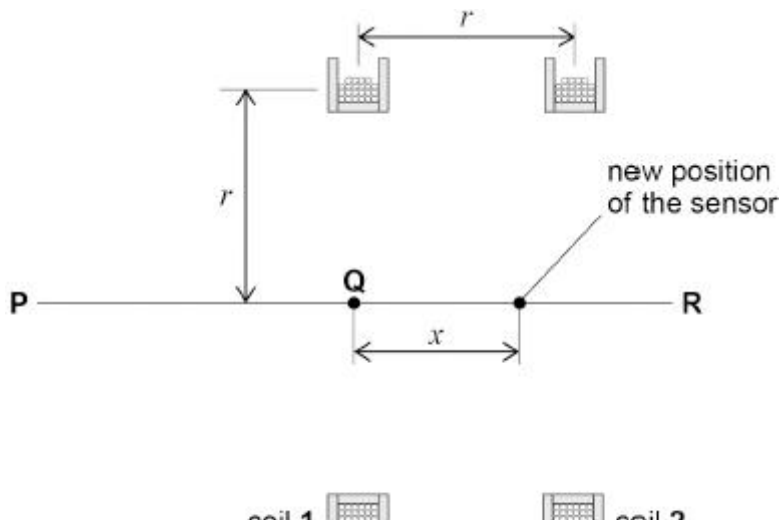
percentage uncertainty = _____ %

(3)

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

Figure 4

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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**.

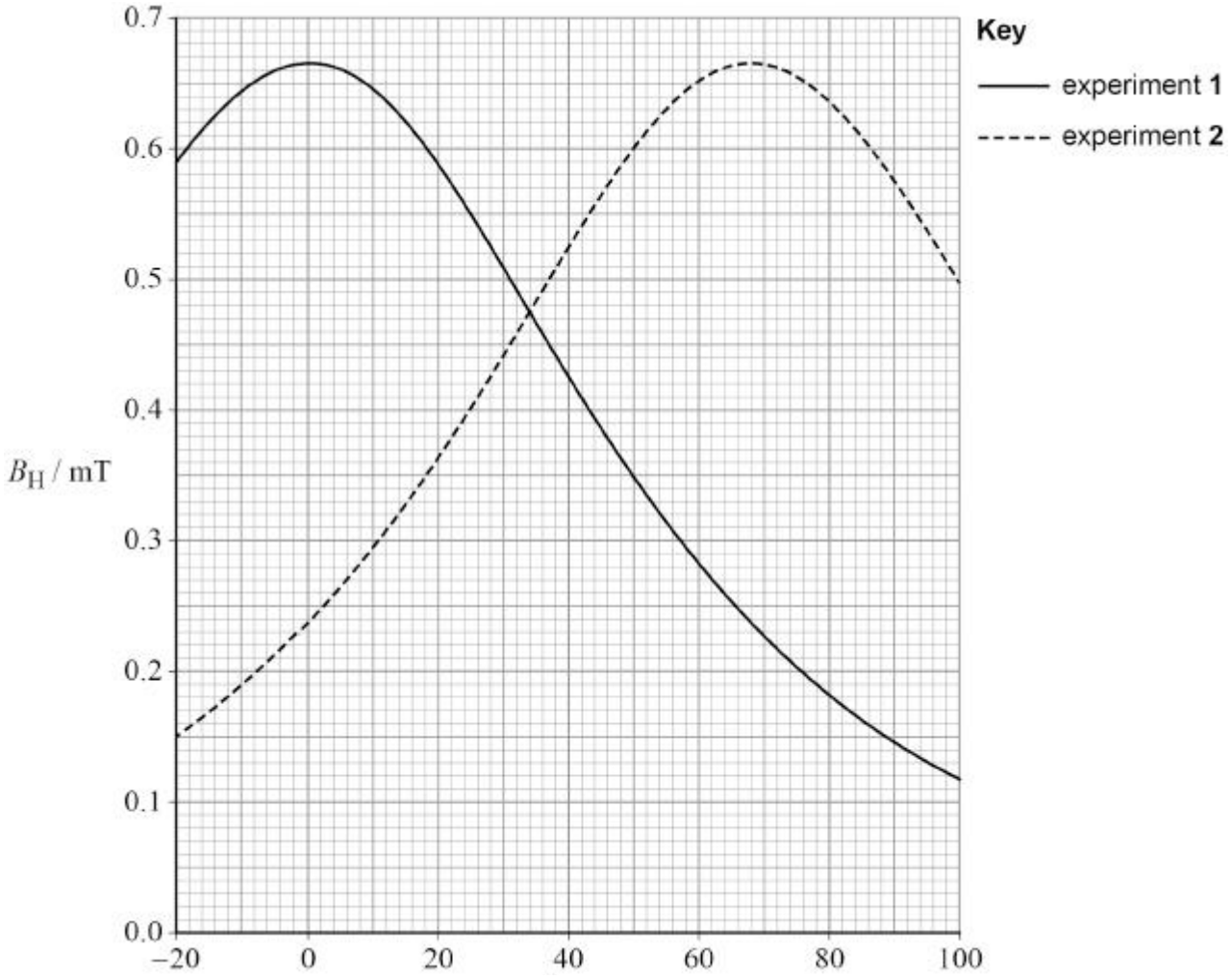
In experiment **1**, the current in coil **1** is 225 mA and the current in coil **2** is zero.

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

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(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 $x = \frac{3r}{4}$

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(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 _____

_____

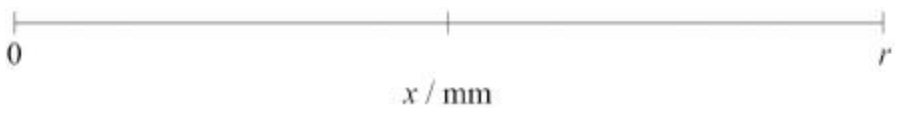
_____

(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)

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Q2.

(a) State the defining property of a black hole.

_____

_____

_____

(1)

(b) In 2019, astronomers linked several radio telescopes to produce a single telescope called the EHT. The resolution of the EHT is the same as the resolution that a telescope with an aperture equal to the diameter of the Earth could achieve.

The table below shows data about the EHT and the Hubble telescope.

	Aperture	**Operating wavelength**
EHT	1.3×10^7 m	1.3 mm
Hubble	2.4 m	410 nm

Galaxy M87 is 5.3×10^7 light years from Earth. The supermassive black hole at the centre of M87 has a mass 6.5×10^9 times the mass of the Sun.

The radius of the event horizon is R.

The astronomers propose to use either the EHT or the Hubble telescope to observe stars whose distance from the centre of the black hole is less than $1000R$.

Discuss, with calculations, which telescope is more suitable for this observation.

_____

_____

_____

_____

(4)

(c) A star is orbiting the black hole in M87. The star is observed in the plane of its orbit. The wavelength of a spectral line observed in the light emitted from the star varies between a maximum and a minimum value.

maximum value observed = 374.96 nm

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minimum value observed = 373.53 nm

Calculate the orbital speed of the star.

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

(3)

(Total 8 marks)

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