1 A flat circular coil P carrying a current produces a magnetic field. When a second coil Q is placed with its centre a distance x from the centre of coil P, as shown in Fig. 1.1, an e.m.f. V may be induced in coil Q.

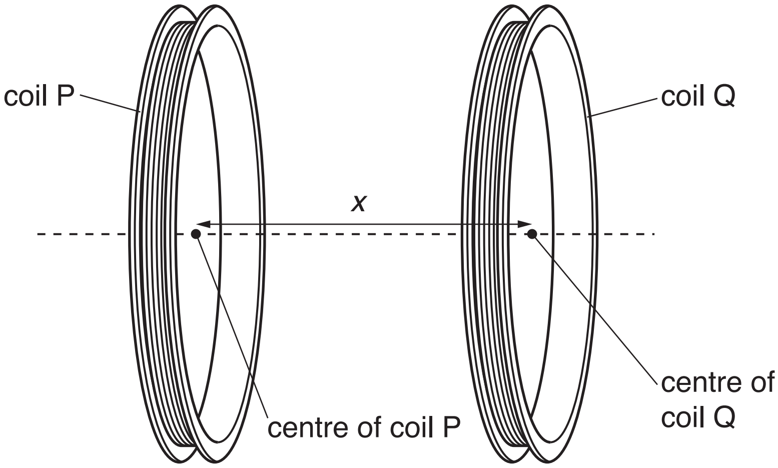

Fig. 1.1

It is suggested that V is related to x by the relationship

$$V = V_0 e^{-kx}$$

where V_0 and k are constants.

Design a laboratory experiment to test the relationship between V and x. Explain how your results could be used to determine a value for k. You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to

- the procedure to be followed,
- the measurements to be taken,
- the control of variables,
- the analysis of the data,
- any safety precautions to be taken.

[15]

Diagram

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[Turn over

[Total: 15]

2 Fig. 1.1 shows a coil (coil X).

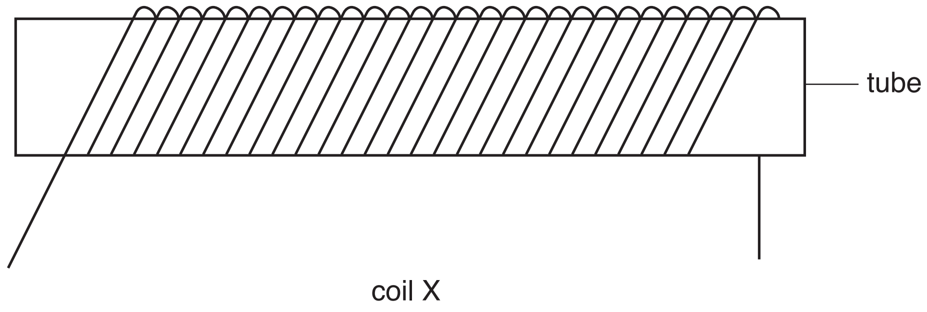

Fig. 1.1

A student winds another coil (coil Y) tightly around coil X.

A changing e.m.f. in coil X induces an e.m.f. in coil Y.

The student wishes to investigate how the e.m.f. *V* in coil Y depends on the frequency *f* of the current in coil X.

It is suggested that *V* is directly proportional to *f*.

Design a laboratory experiment to investigate the suggested relationship. You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken.

[15]

Diagram

For Examiner's Use

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For Examiner's Use

For Examiner's Use	Defining the problem	Methods of data collection	Method of analysis	Safety considerations	Additional detail

3 As a bar magnet is dropped through a coil, an e.m.f. is induced in the coil. The maximum e.m.f. E is induced as the magnet leaves the coil with speed v.

For Examiner's Use

It is suggested that E is directly proportional to v.

Design a laboratory experiment to test the relationship between E and v. You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken.

[15]

Diagram

For Examiner's Use

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For Examiner's Use

For Examiner's Use	Defining the problem	Methods of data collection	Method of analysis	Safety considerations	Additional detail

4 A thin card is inserted between two separate iron cores. A coil is wound around one core as shown in Fig. 1.1.

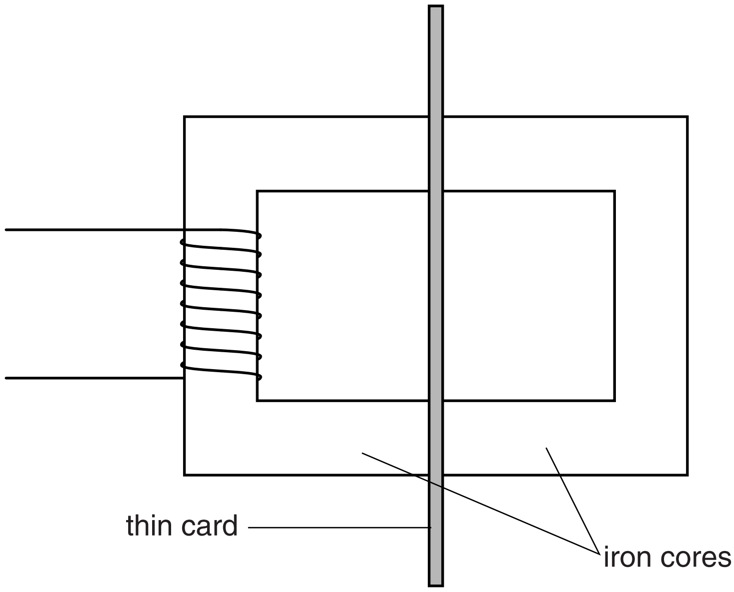

Fig. 1.1

A current in the coil may induce an e.m.f. in another coil wound on the other core. The induced e.m.f. V depends on the thickness t of the card.

A student suggests that

$$V = V_0 e^{-\sigma t}$$

where V_0 is the induced e.m.f. without card between the cores and σ is a constant.

Design a laboratory experiment to test the relationship between V and t and determine the value of σ. You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken.

[15]

Diagram

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Defining the problem	Methods of data collection	Method of analysis	Safety considerations	Additional detail

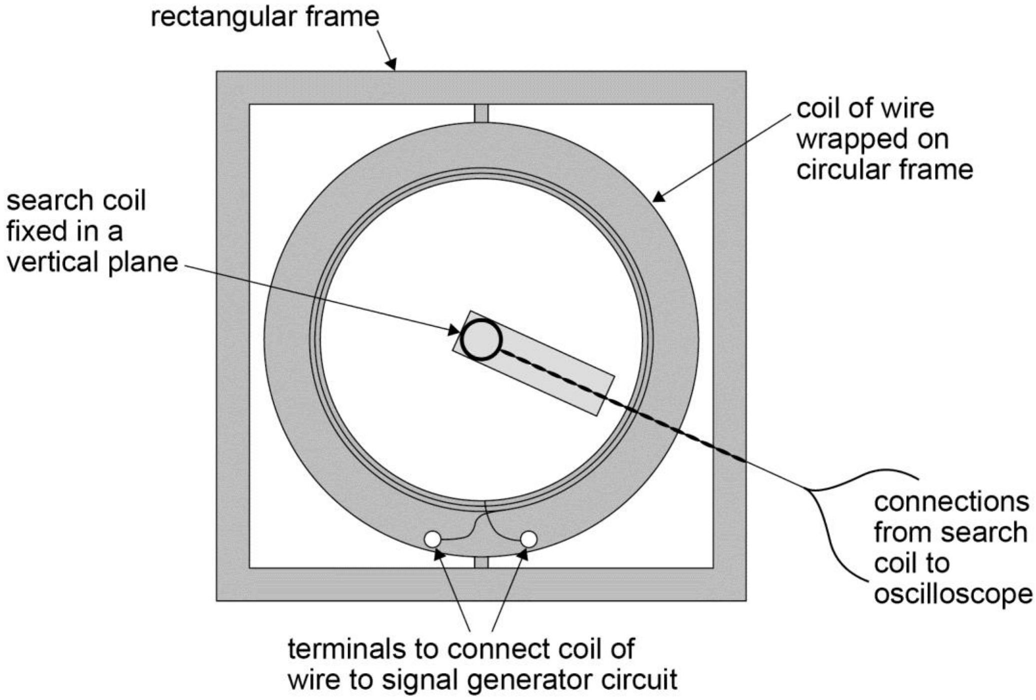
Section B

Answer **all** question(s) in this section.

0 1 This question is about experiments to investigate the magnetic flux density around a current-carrying conductor.

A student is provided with apparatus shown in **Figure 1**.

Figure 1



The apparatus consists of a circular frame on which is wound a coil of wire. This arrangement is mounted inside a rectangular frame.

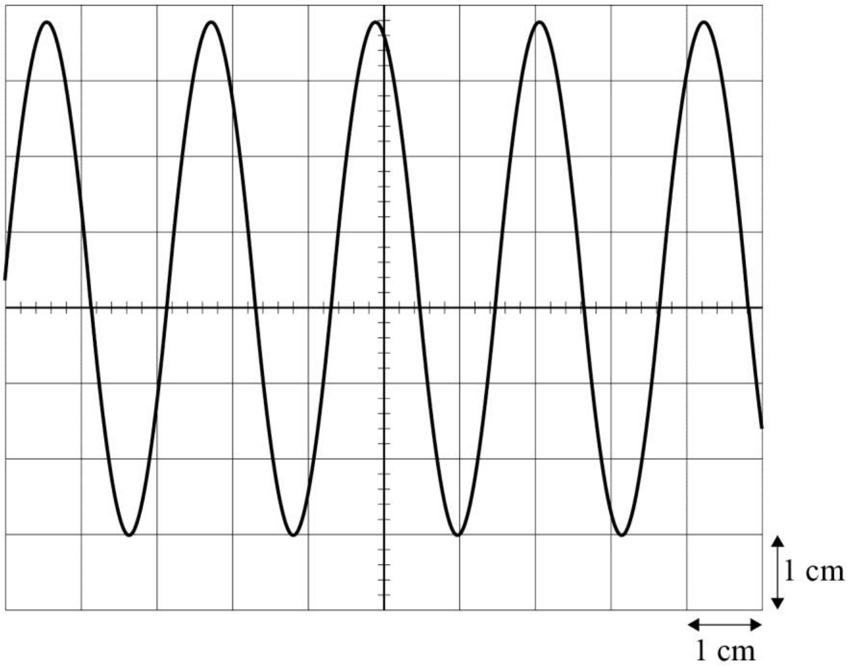
The student clamps a search coil so it is co-axial with the circular coil then arranges the apparatus so that both frames and the search coil lie in the same vertical plane.

The coil of wire is connected to a signal generator and the search coil is connected to an oscilloscope. When a sinusoidal alternating current is passed through the coil an alternating emf is induced in the search coil.

The induced emf displayed on the oscilloscope is shown in **Figure 2**.

Question 1 continues on the next page

Figure 2



0 1 . 1 Determine, using **Figure 2**, the frequency of the current in the coil.

Time-base setting of the oscilloscope is $0.2\ \text{ms cm}^{-1}$.

[2 marks]

frequency = ______________ Hz

0 1 . 2 Determine, using **Figure 2**, the root mean square (rms) voltage of the emf induced in the search coil.

y-voltage gain of the oscilloscope $= 10\ \text{mV cm}^{-1}$

[2 marks]

rms voltage = ______________ V

0 1 . 3 **Figure 3** and **Figure 4** show the search coil and B_{peak}, the peak magnetic flux density produced by the current in the circular coil, when the apparatus is viewed from above.

Figure 3 shows the direction of B_{peak} when the search coil is arranged as in **Figure 1**.

Figure 4 shows the direction of B_{peak} when the circular frame is rotated through an angle θ.

The shaded area in these diagrams shows how the flux linked with the search coil changes as the circular coil is rotated.

Figure 3

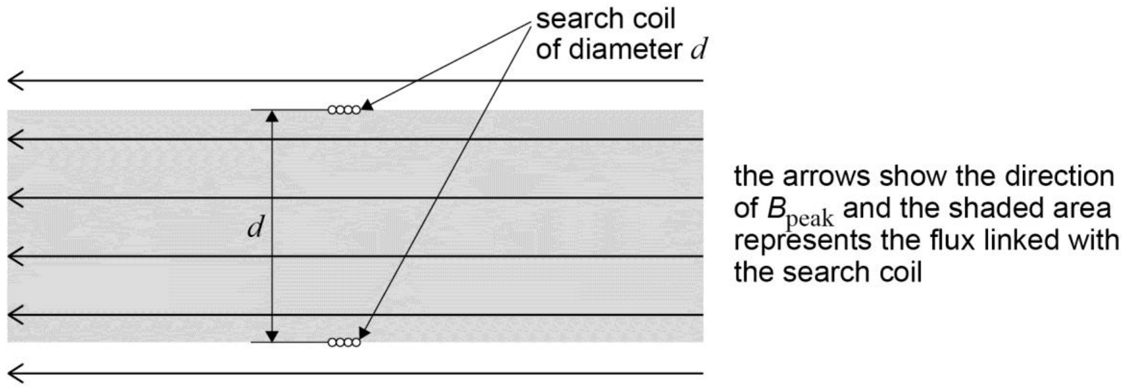
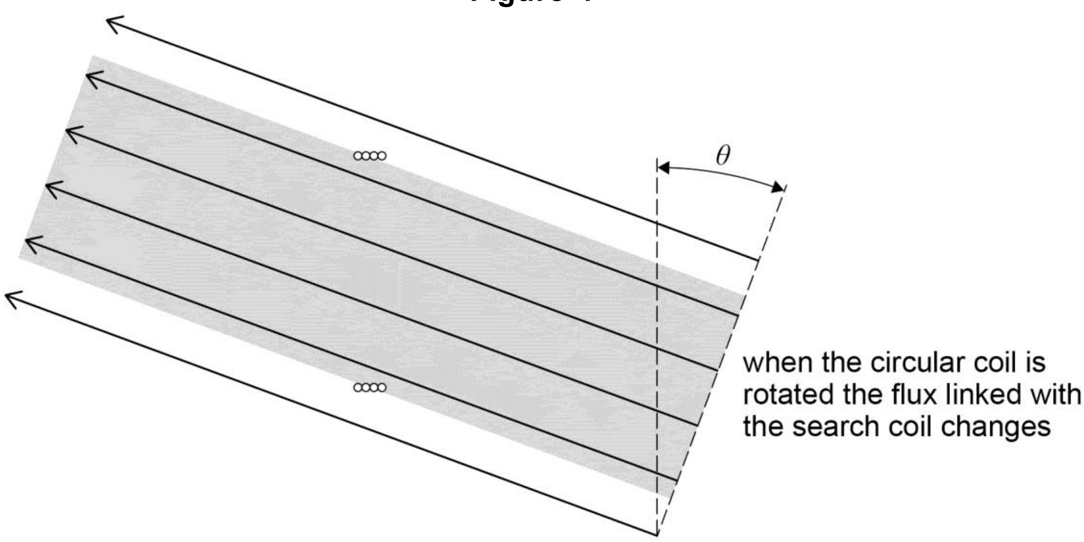


Figure 4

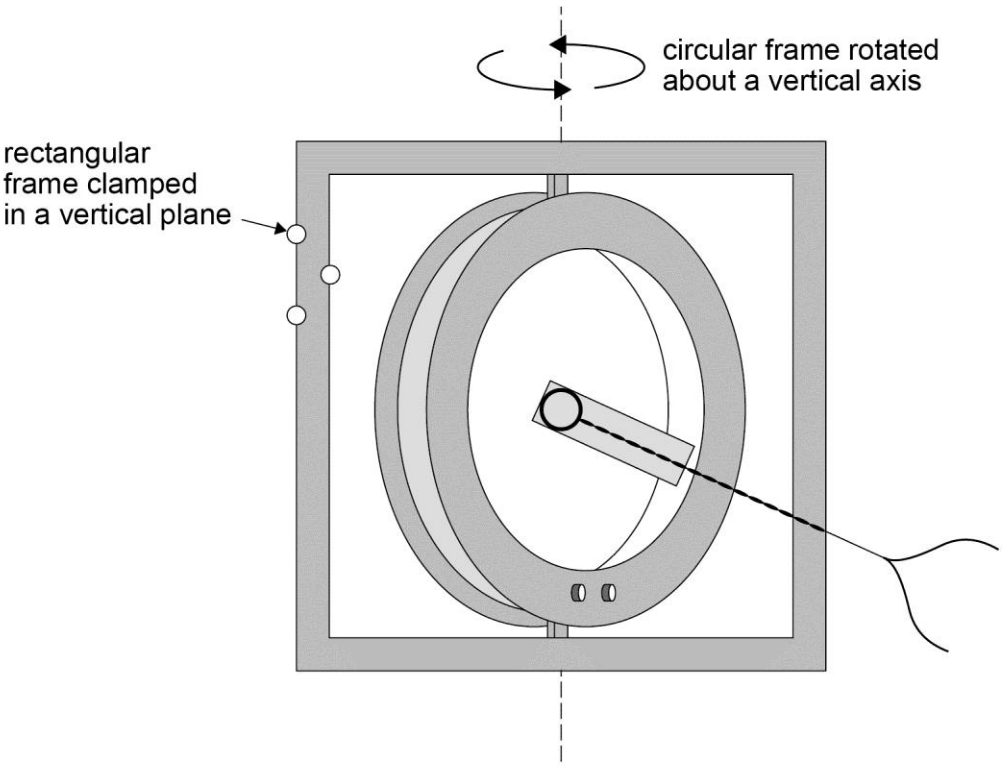


Explain why the flux linked with the coil is directly proportional to $\cos\theta$.

[2 marks]

0 1 . 4 The student clamps the rectangular frame so that it remains in a vertical plane. Without changing the position of the search coil she rotates the circular frame about a vertical axis so that it is turned through an angle, as shown in **Figure 5**.

Figure 5



She turns off the time-base on the oscilloscope so that a vertical line is displayed on the screen. Keeping the y-voltage gain at $10\,\text{mV cm}^{-1}$ she records the length l of the vertical line and the angle θ through which the circular frame has been rotated. She measures further results for l as θ is increased as shown in **Table 1**.

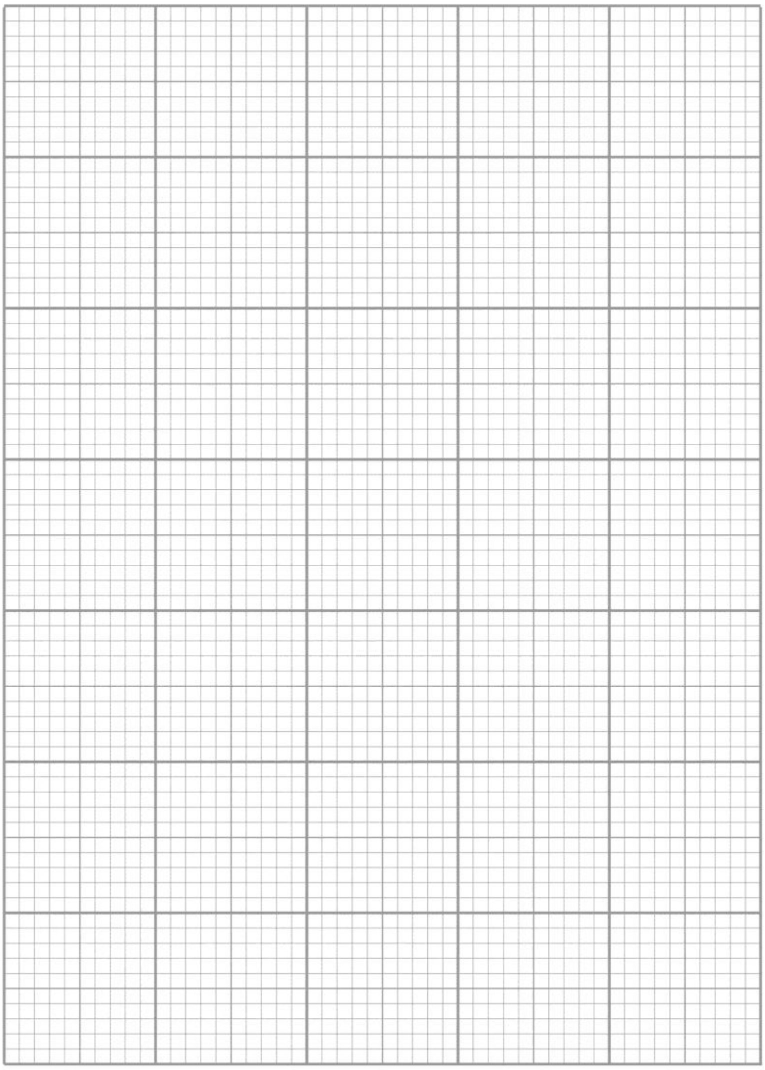
Table 1

θ/degree	l/cm	$\cos\theta$
10	6.7	
34	5.6	
50	4.4	
60	3.4	
72	2.1	
81	1.1	

Plot on **Figure 6** a graph to test if these data confirm that l is directly proportional to $\cos\theta$. Use the additional column in **Table 1** to record any derived data you use.

[4 marks]

Figure 6



0 1 . 5 State and explain whether the graph you have drawn confirms the suggestion that l is directly proportional to $\cos\theta$.

[1 mark]

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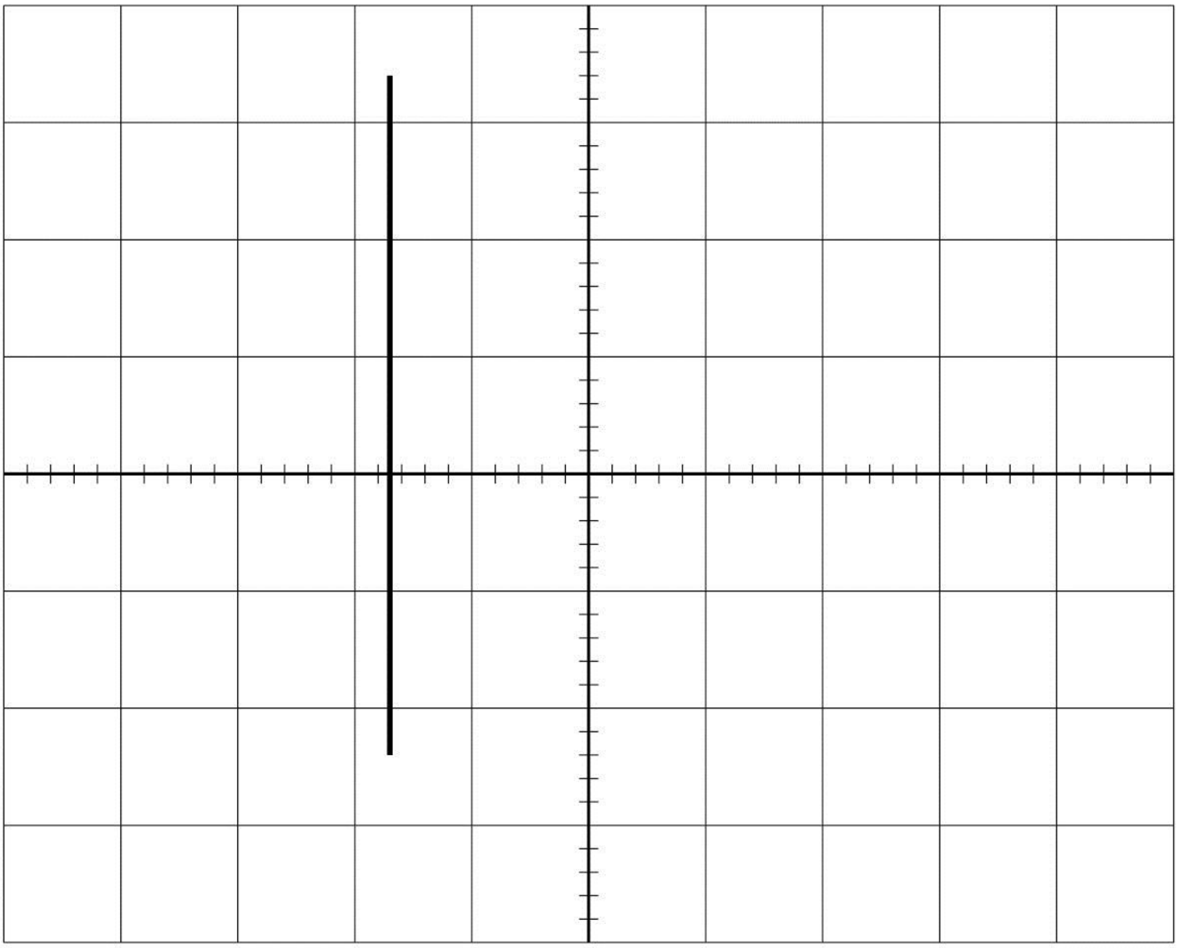
Question 1 continues on the next page

0 1 . 6 When the time-base is switched off, the trace on the oscilloscope appears as shown in **Figure 7**.

Figure 7



Describe **two** adjustments the student should make to the trace to reduce the uncertainty in l.

You should refer to specific controls on the oscilloscope. You may use **Figure 7** to illustrate your answer.

[4 marks]

0 1 . 7 The student adjusts the signal generator so that the frequency of the current in the circular coil is doubled.

State and explain any changes she should make to the settings of the oscilloscope in **Question 1.6** so that she can repeat the experiment.

[3 marks]

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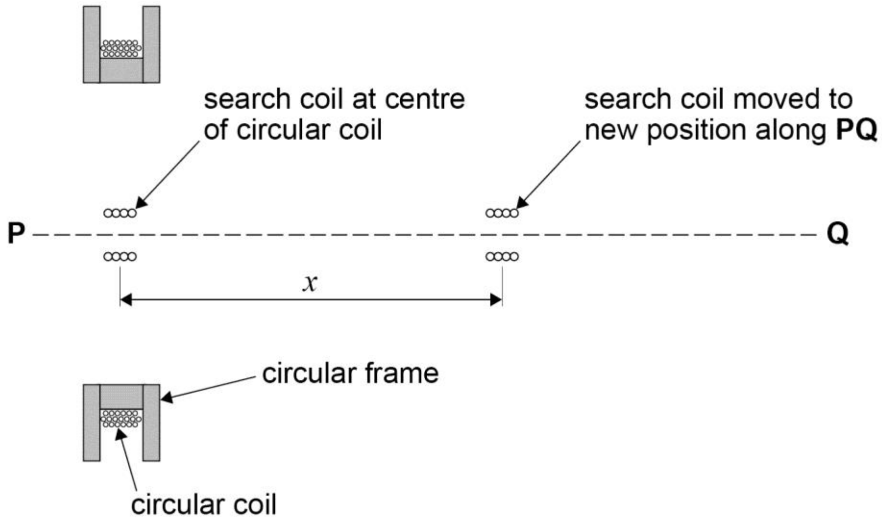
Question 1 continues on the next page

0 1 . 8 The apparatus is re-arranged as in **Figure 1** so that both coils lie in the same vertical plane and are co-axial along a line **PQ**.

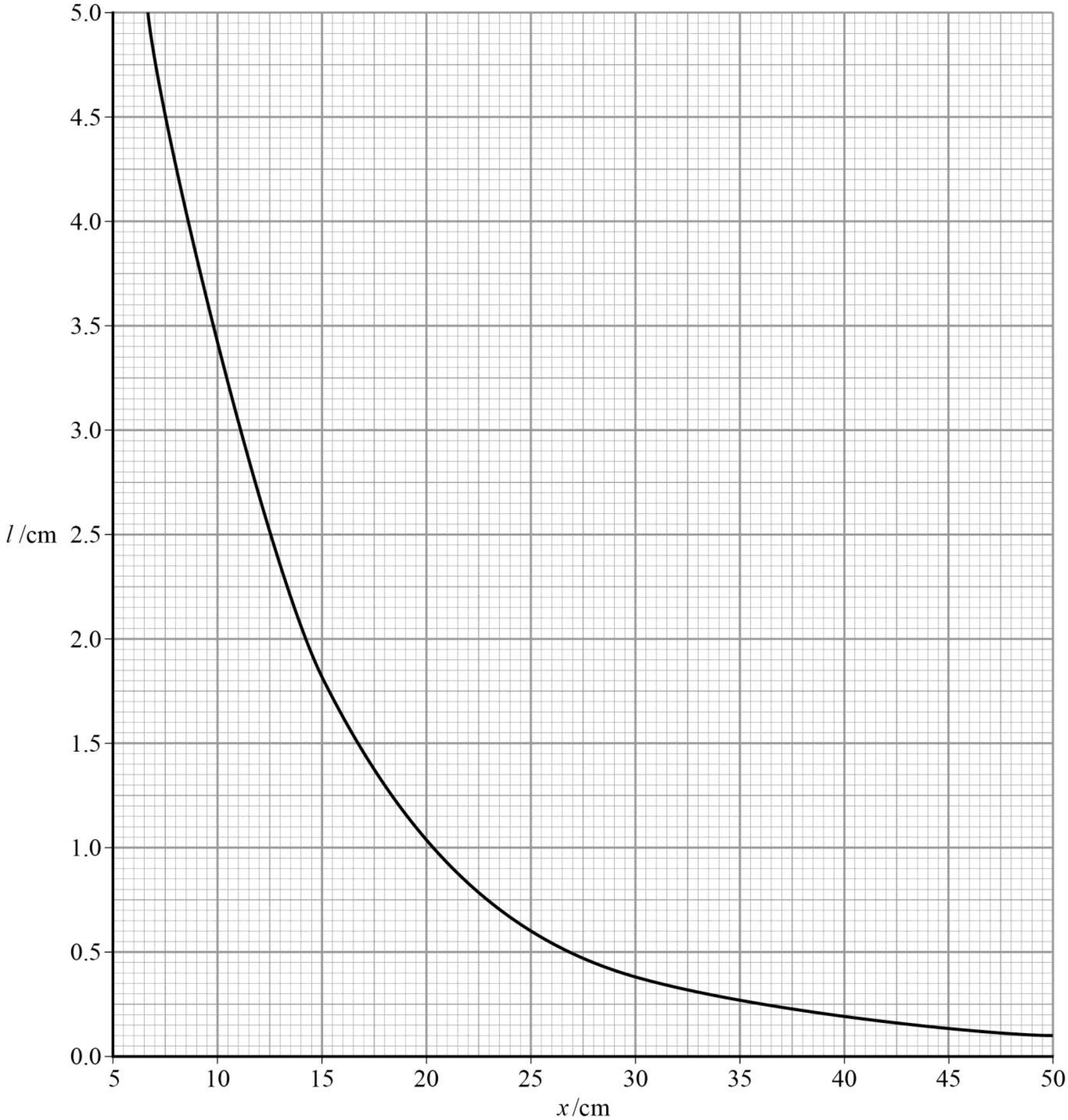
The search coil is then moved a distance x along **PQ**, as shown in **Figure 8**.

Figure 8



The values of l corresponding to different values of x are recorded. A graph of these data is shown in **Figure 9**.

Figure 9



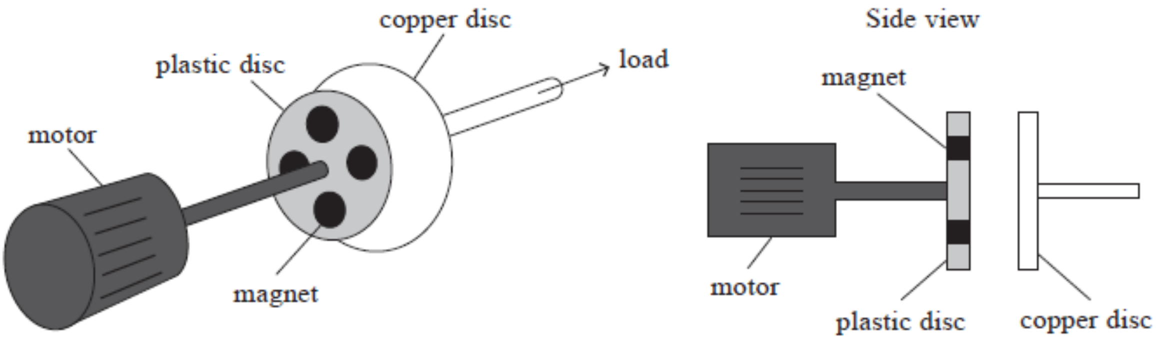
It is suggested that l decreases exponentially as x increases.

Explain whether **Figure 9** supports this suggestion.

[2 marks]

Q2.

A device called a clutch can be used to connect a motor to a load. The diagram shows a design called an eddy current clutch.



Several magnets are embedded in the plastic disc and it is rotated by the motor.

The table shows how the turning effect exerted on a load varies with ω for a particular distance between the copper disc and the plastic disc.

ω / rad s^{-1}	Turning effect / N cm
52.4	1.0
104.7	2.0
157.1	2.8

Explain the trend shown by the data.

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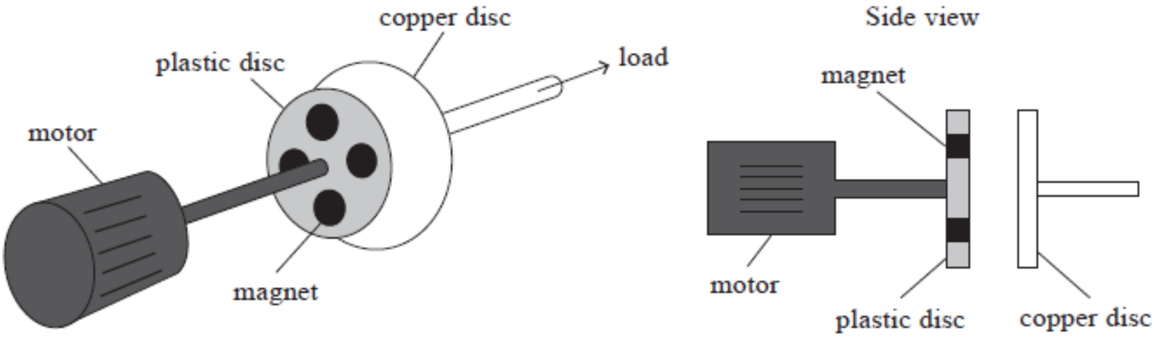
(Total for question = 4 marks)

Q3.

A device called a clutch can be used to connect a motor to a load. The diagram shows a design called an eddy current clutch.



Several magnets are embedded in the plastic disc and it is rotated by the motor.

(i) Explain why a current is induced in the copper disc when the motor is switched on.

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(ii) Explain, using Lenz's law, why the copper disc rotates.

(3)

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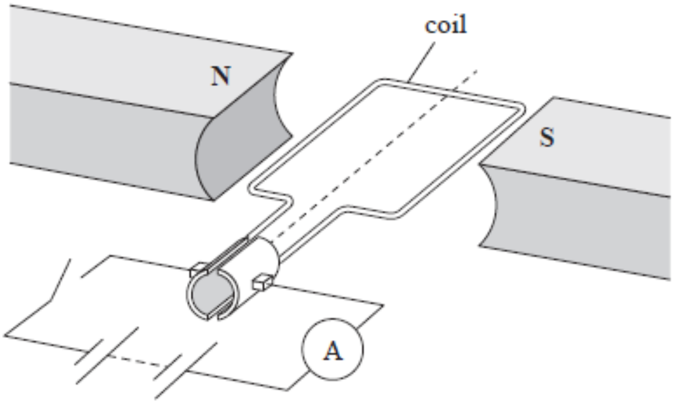
(Total for question = 5 marks)

Q4.

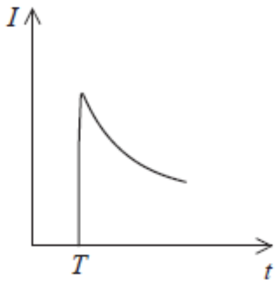
* A simple electric motor consists of a coil that is free to rotate in a magnetic field.

A student connects the motor to an ammeter and a battery.



The graph shows how the current *I* in the coil varies with time *t*. The switch is closed at time *T*.

Explain why the current rises to a maximum then decreases.
Your answer should include a reference to Faraday and Lenz's laws.



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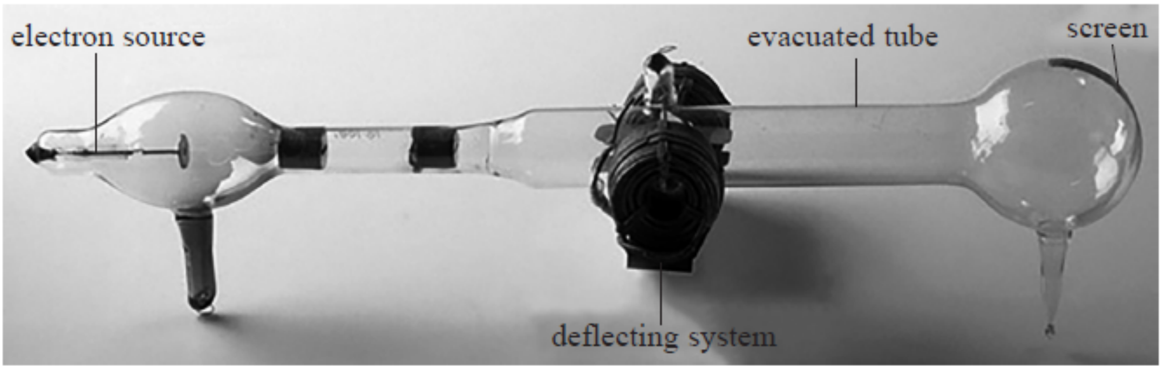
(Total for question = 6 marks)

Q5.

At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.



Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

In a modern version of Thompson's experiment, a uniform electric field of electric field strength E is applied so that the electric and magnetic forces on the electrons are equal and in opposite directions.

(i) Show that for electrons to be undeflected their velocity must be given by

$$v = \frac{E}{B}$$

where B is the magnetic flux density of the magnetic field.

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(ii) The beam is produced by accelerating electrons through a potential difference of 250 V.

The electric field strength is 1.4×10^4 V m^{-1}. The magnetic flux density is 1.5×10^{-3} T.

Calculate the value of the specific charge e/m for the electron using this data.

.... **(3)**

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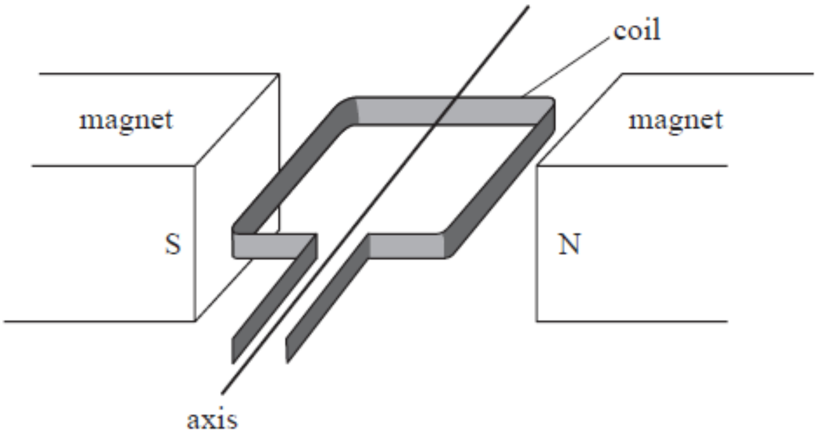
e/m = ...

(Total for question = 5 marks)

Q6.

Hybrid electric vehicles (HEV) use the same device both as a generator to charge the car battery and as an electric motor to support the propulsion system. A simplified diagram of the device is shown. The coil can rotate freely around the axis.



Describe how the device can be used as both a generator and an electric motor.

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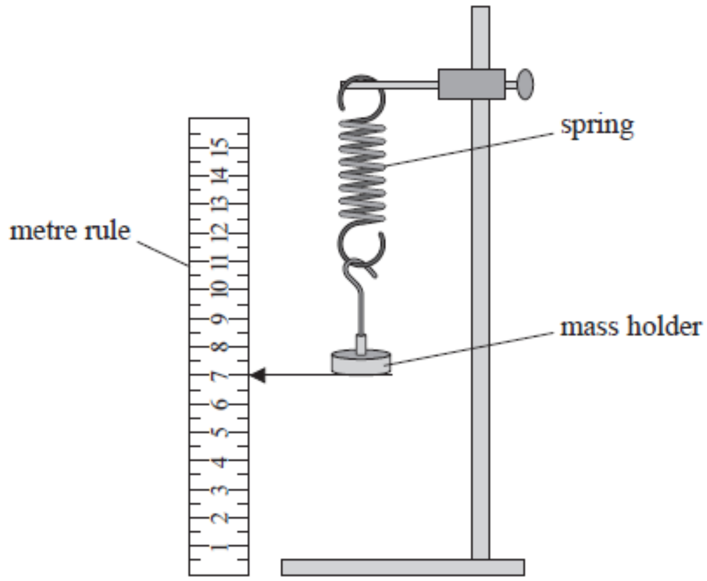
(Total for question = 6 marks)

Q7.

A student investigated the behaviour of a spring under tension. The spring was hung vertically with a mass holder attached.

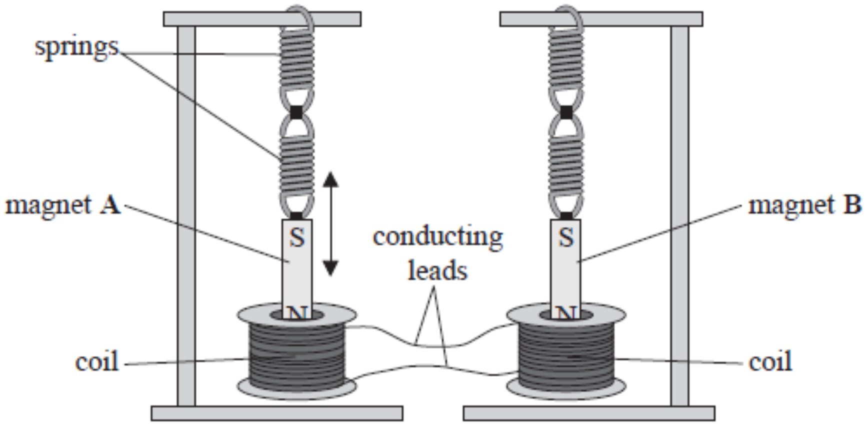


The position of the bottom of the mass holder was recorded. The spring was stretched by adding masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

The student produced the following table.

Mass added / g	Extension / cm	Stretching force / N
50	1.9	0.49
70	3	0.69
90	3.5	0.9
110	4.5	1.08
130	5.3	1.28
150	5.8	1.47

* Identical bar magnets are suspended from identical springs, with the North pole of each magnet inside a coil of wire as shown. The two coils are connected together with conducting leads.



Magnet A is displaced so that it oscillates vertically. The North pole of magnet A moves into and out of the coil of wire with simple harmonic motion. As this motion continues, magnet B starts to oscillate. The amplitude of oscillation of magnet B increases over time.

Explain why magnet B starts to oscillate with an increasing amplitude.

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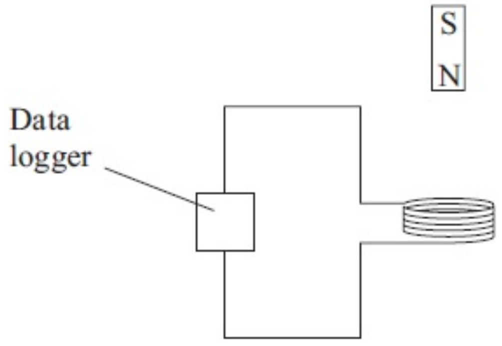
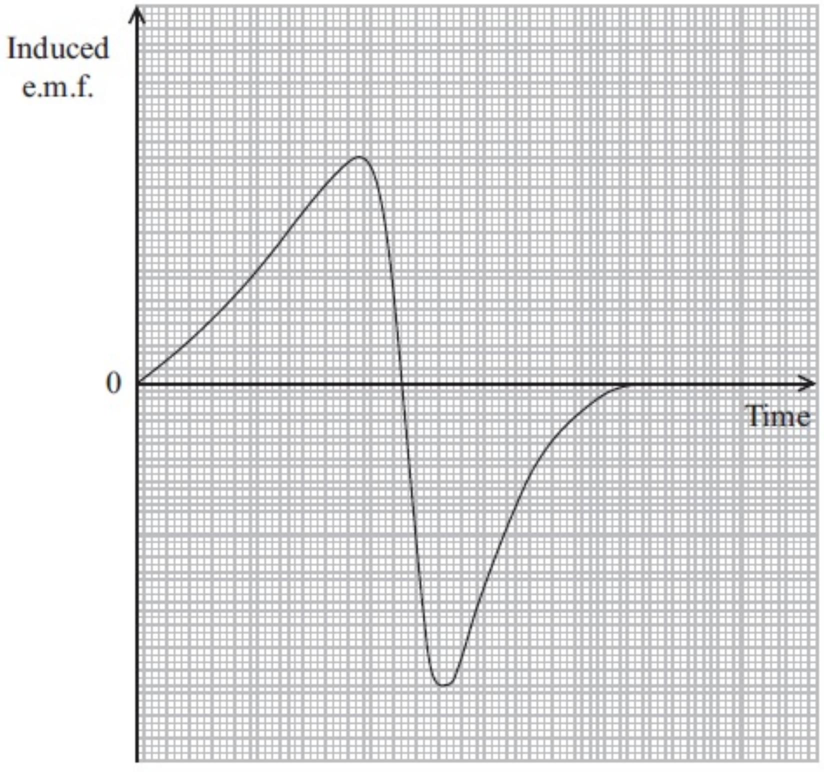
(Total for question = 6 marks)

Q8.

A teacher demonstrates electromagnetic induction by dropping a bar magnet through a flat coil of wire connected to a data logger.



The data from the data logger is used to produce a graph of induced e.m.f. across the coil against time.



*(a) Explain the shape of the graph and the relative values on both axes.

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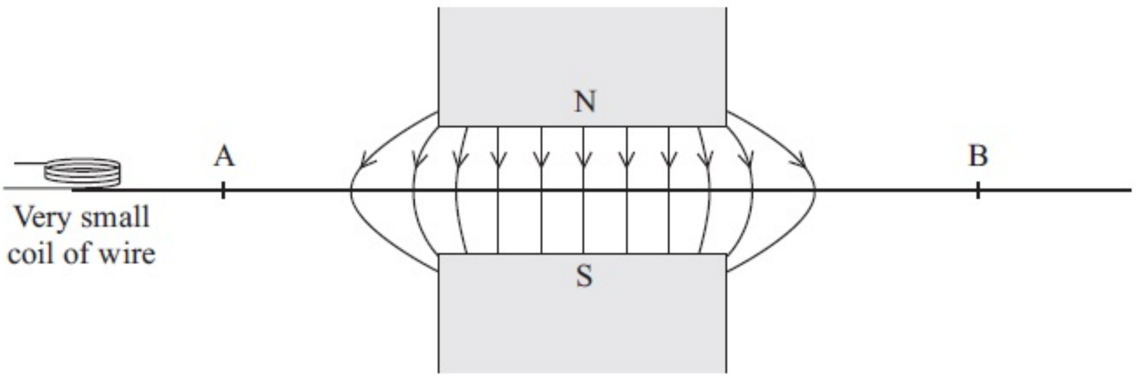
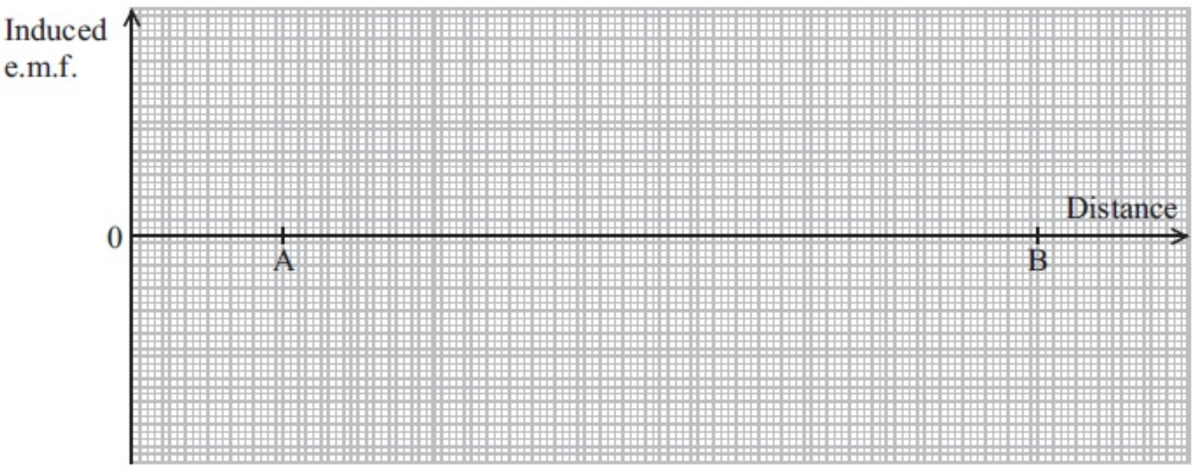
*(b) The teacher then sets up another demonstration using a large U-shaped magnet and a very small coil of wire which is again connected to a data logger.

The north pole is vertically above the south pole and the coil is moved along the line AB which is midway between the poles. The magnetic field due to the U-shaped magnet has been drawn. The plane of the coil is horizontal.



Sketch a graph to show how the e.m.f. induced across the coil varies as the coil moves from A to B at a constant speed.

(4)



(Total for question = 10 marks)

Q9.

(a) A magnetic field can be measured with a device called a Hall probe. The probe is connected to a voltmeter. When the probe is placed at right angles to a magnetic field, a potential difference is recorded on the voltmeter. The potential difference increases with increasing magnetic flux density.

A wire carries a constant current. A Hall probe is used to investigate how the magnetic flux density produced by the wire varies with distance from the wire.

The potential difference *V* was recorded for a range of distances *r*.

r/cm	*V*/V
1.0	0.725
1.5	0.483
2.0	0.363
2.5	0.29
3.0	0.242
3.5	0.21

(i) Criticise these results.

(2)

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(ii) It is suggested that *V* and *r* are related by the equation

$$V = \frac{k}{r}$$

where *k* is a constant.

(1) Determine by calculation whether this suggestion is valid.

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(2) A graph of $\frac{1}{V}$ is plotted against r.

State how the graph would indicate that the equation is correct.

(1)

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(b) The Hall probe can be replaced with a small coil of wire which is connected to a sensitive voltmeter. The plane of the coil is at right angles to the magnetic field produced by the current-carrying wire.

(i) Explain, with reference to Faraday's law, why the voltmeter reading would be zero.

(2)

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(ii) State **three** different ways in which an e.m.f. could be induced in this coil.

(3)

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(Total for question = 10 marks)