A-Level Physics

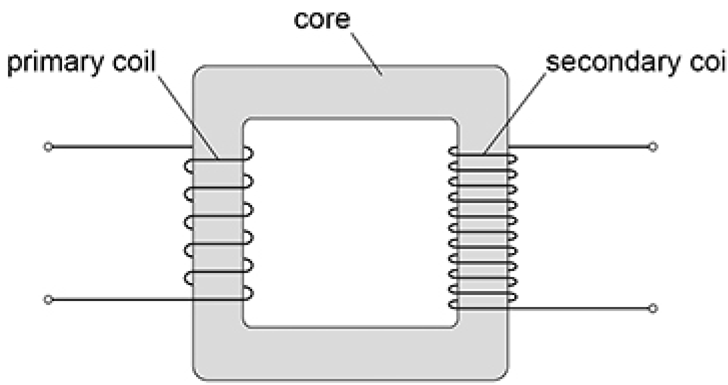
Magnetic Fields

Question Paper

Time available: 74 minutes
Marks available: 50 marks

1. **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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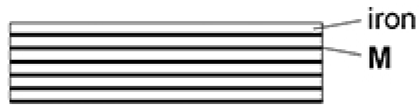
(3)

(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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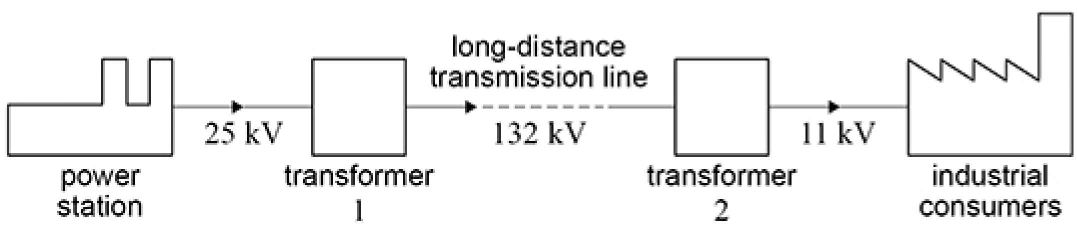
(3)

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.

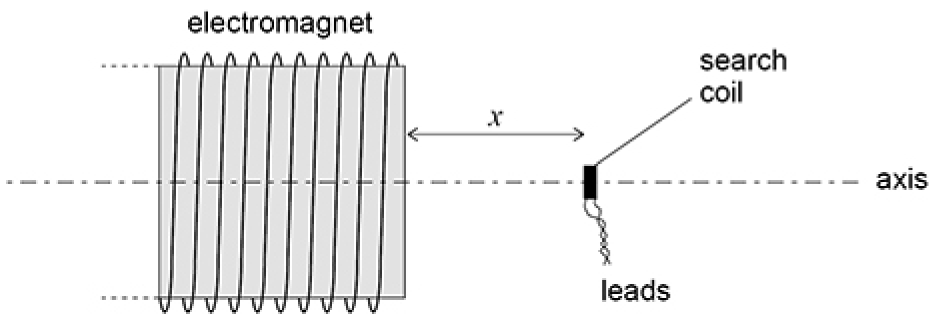
current = ________________ A

(3)

(Total 11 marks)

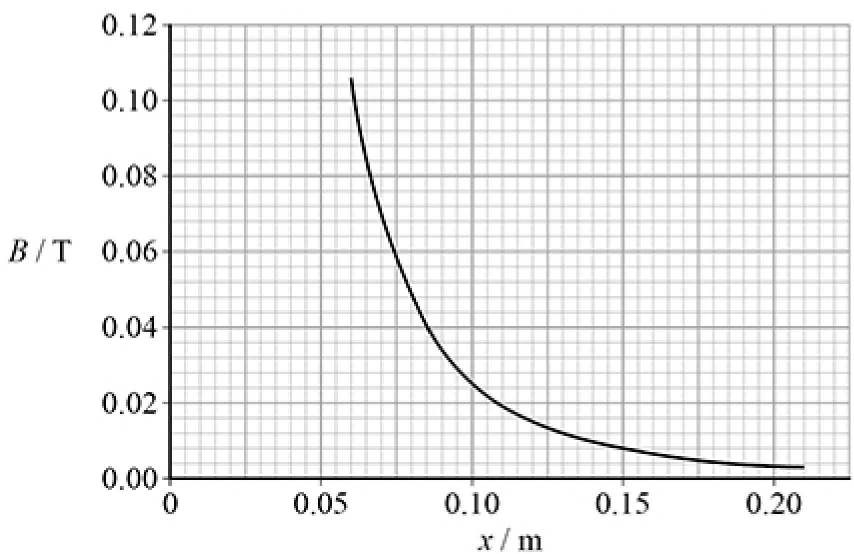
2. **Figure 1** shows a search coil positioned on the axis of an electromagnet, with the plane of the search coil perpendicular to the axis. A magnetic field is produced by a constant current in the electromagnet.
Assume that the magnetic flux density inside the search coil is uniform.

Figure 1



The distance between the search coil and the end of the electromagnet is x. **Figure 2** shows how the magnetic flux density B of the field varies with x.

Figure 2



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

(a) The search coil is placed at $x = 0.070$ m.

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

(2)

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

(b) Explain what happens to the value of the emf as the search coil moves.

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(2)

(c) The search coil passes through the position where x = 0.10 m.

Deduce whether the emf can exceed 5 mV for values of x greater than 0.10 m.

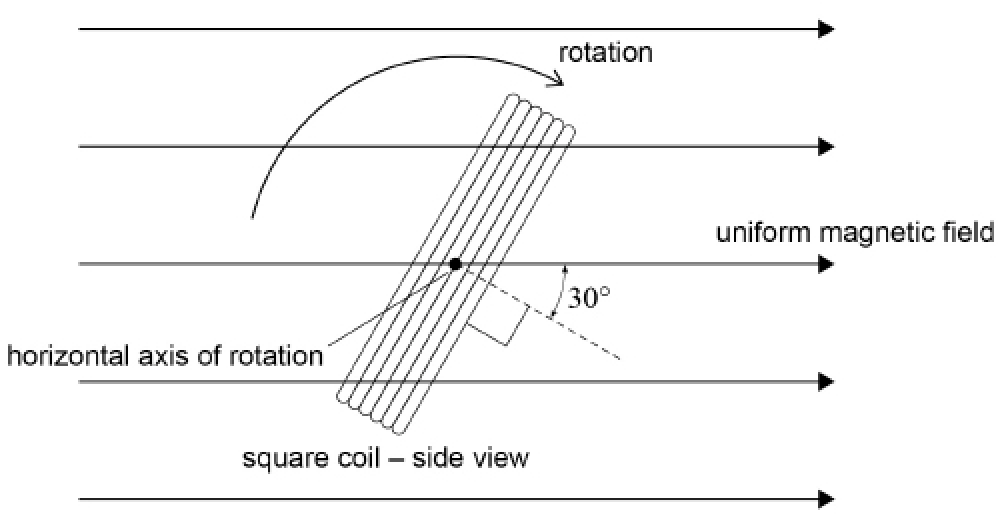
(4)

(Total 8 marks)

3. A square coil of wire is rotating at a constant angular speed about a horizontal axis.

Figure 1 shows the coil at one instant when the normal to the plane of the coil is at 30° to a magnetic field.

Figure 1



The area of the coil is 5.0×10^{-4} m^2 and the flux density of the uniform magnetic field is 2.5×10^{-2} T.

(a) The maximum flux linkage of the coil during its rotation is 1.5×10^{-3} Wb turns.

Calculate the number of turns in the coil.

number of turns = ____________________

(2)

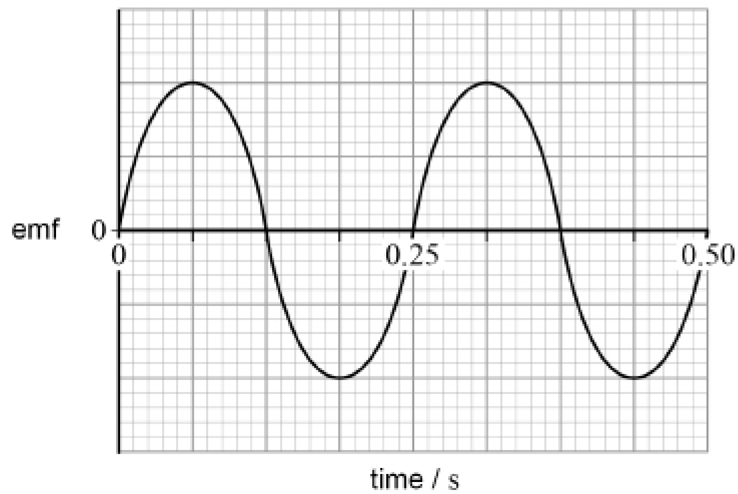
(b) Calculate the flux linkage of the coil at the instant shown in **Figure 1**.

flux linkage = ____________________ Wb turns

(2)

(c) The coil forms part of an electrical generator. **Figure 2** shows the emf generated by the coil.

Figure 2



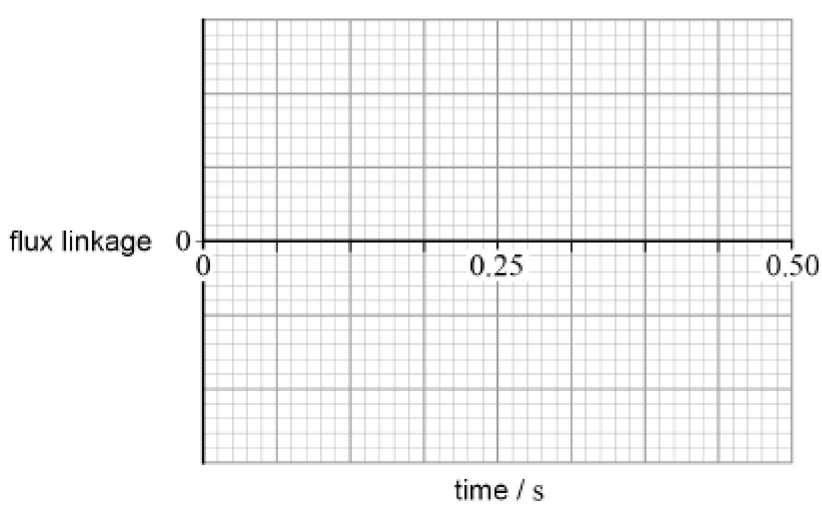
Calculate the peak value of the emf generated.

emf = ____________________ V

(2)

(d) Sketch on **Figure 3** the variation with time of flux linkage for the same time interval as **Figure 2**.

Figure 3

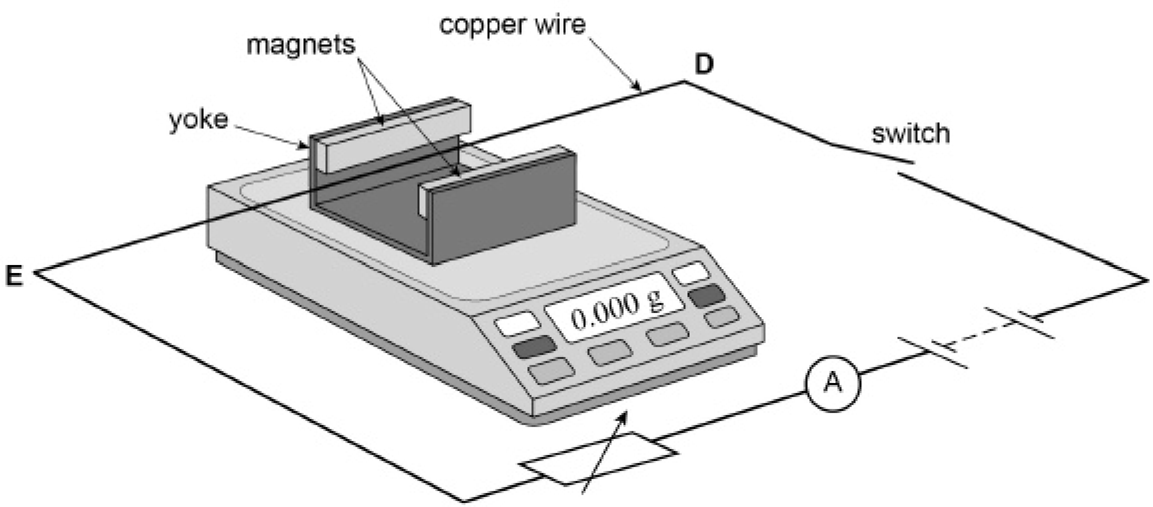


(1)

(Total 6 marks)

4. **Figure 1** shows two magnets, supported on a yoke, placed on an electronic balance.

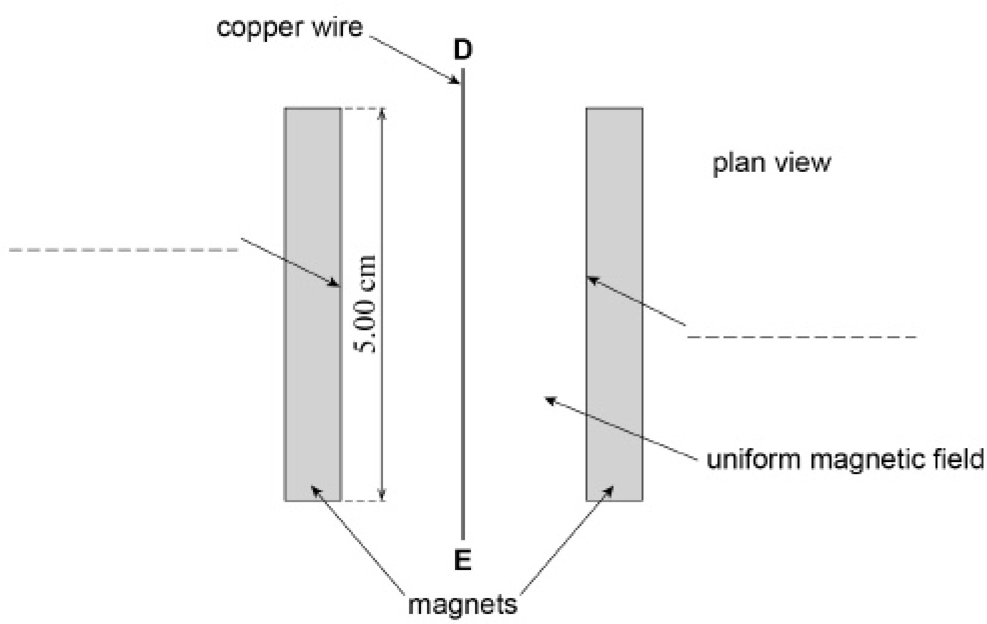
Figure 1



The magnets produce a uniform horizontal magnetic field in the region between them. A copper wire **DE** is connected in the circuit shown in **Figure 1** and is clamped horizontally at right angles to the magnetic field.

Figure 2 shows a simplified plan view of the copper wire and magnets.

Figure 2



When the apparatus is assembled with the switch open, the reading on the electronic balance is set to 0.000 g. This reading changes to a positive value when the switch is closed.

(a) Which of the following correctly describes the direction of the force acting on the wire **DE** due to the magnetic field when the switch is closed?

Tick (✓) the correct box.

towards the left magnet in **Figure 2**	☐
towards the right magnet in **Figure 2**	☐
vertically up	☐
vertically down	☐

(1)

(b) Label the poles of the magnets by putting **N** or **S** on each of the two dashed lines in **Figure 2**.

(1)

(c) Define the tesla.

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(1)

(d) The magnets are 5.00 cm long. When the current in the wire is 3.43 A the reading on the electronic balance is 0.620 g.

Assume the field is uniform and is zero beyond the length of the magnets.

Calculate the magnetic flux density between the magnets.

magnetic flux density = ____________________ T

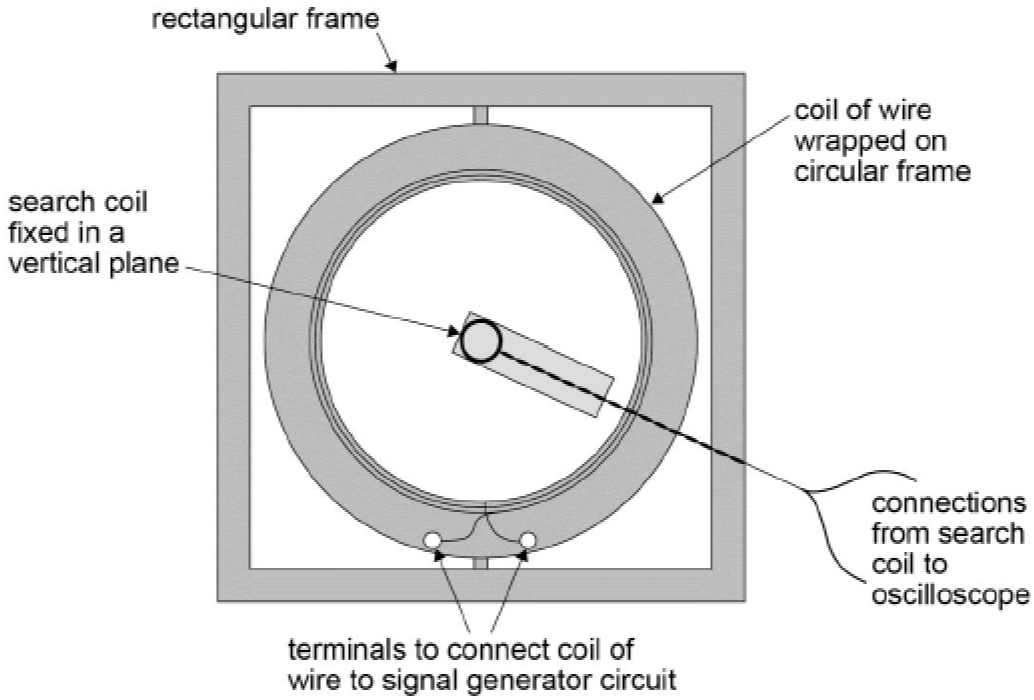
(2)

(Total 5 marks)

5. 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



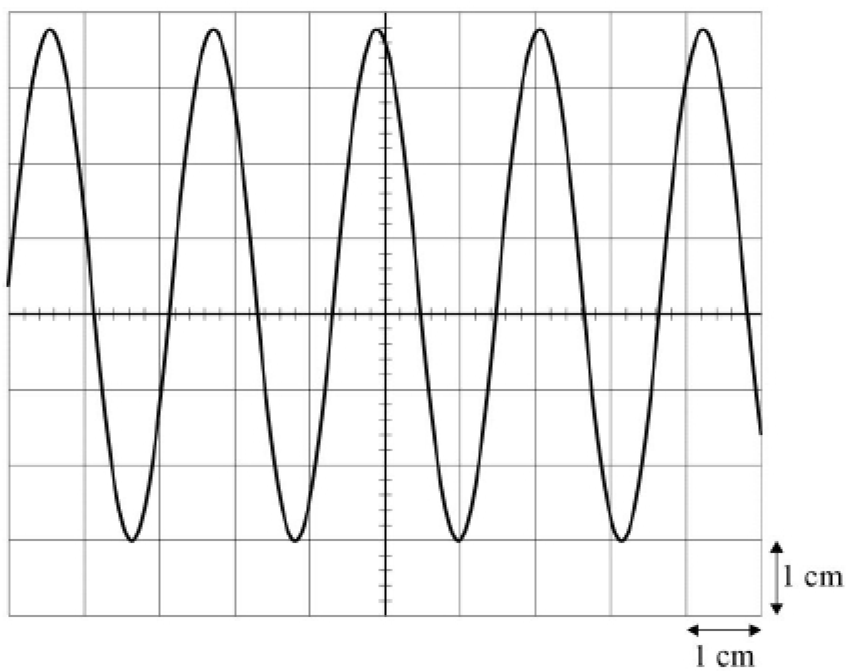
The apparatus consists of a circular frame on which is wound a coil of wire. This arrangement is mounted inside a rectangular frame.

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**.

Figure 2



(a) Determine, using **Figure 2**, the frequency of the current in the coil.

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

frequency = ____________________ Hz

(2)

(b) 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 mV cm^{-1}

rms voltage = __________________ V

(2)

(c) **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

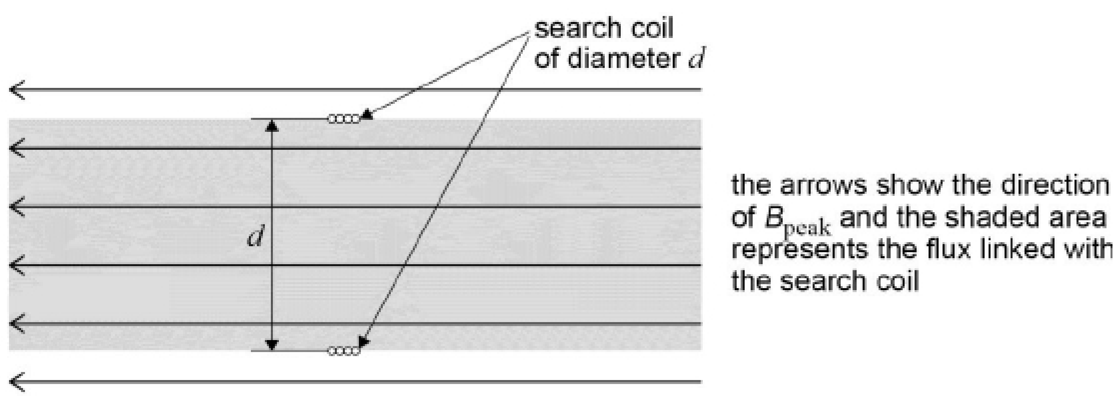
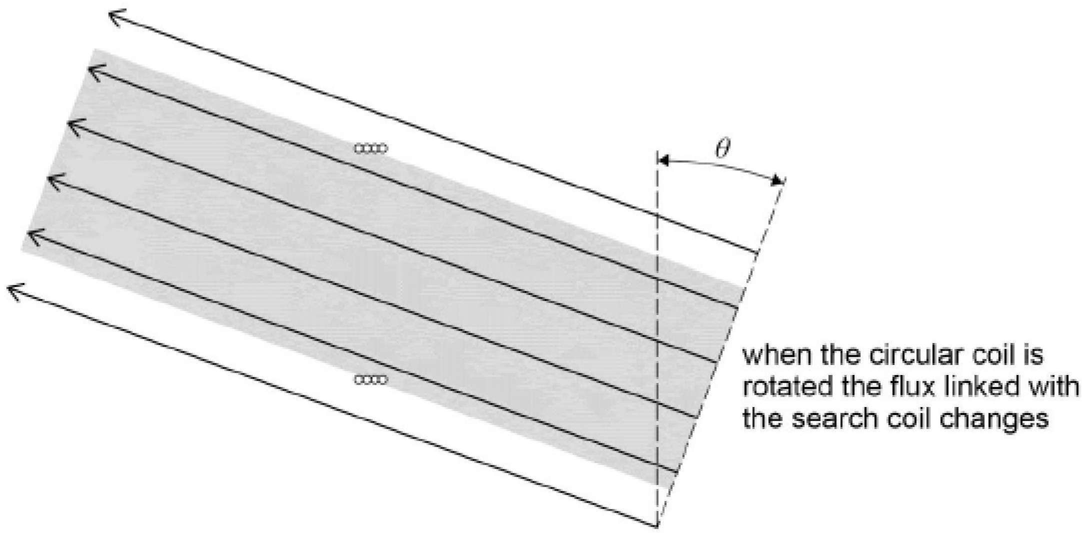


Figure 4



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

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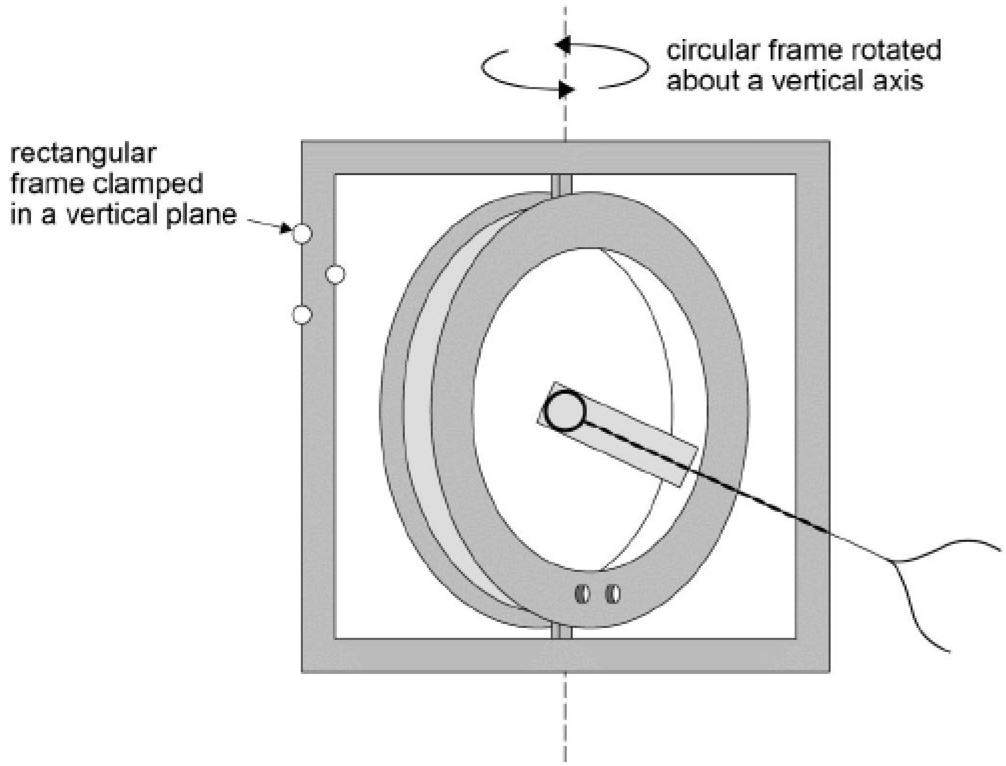
(2)

(d) 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

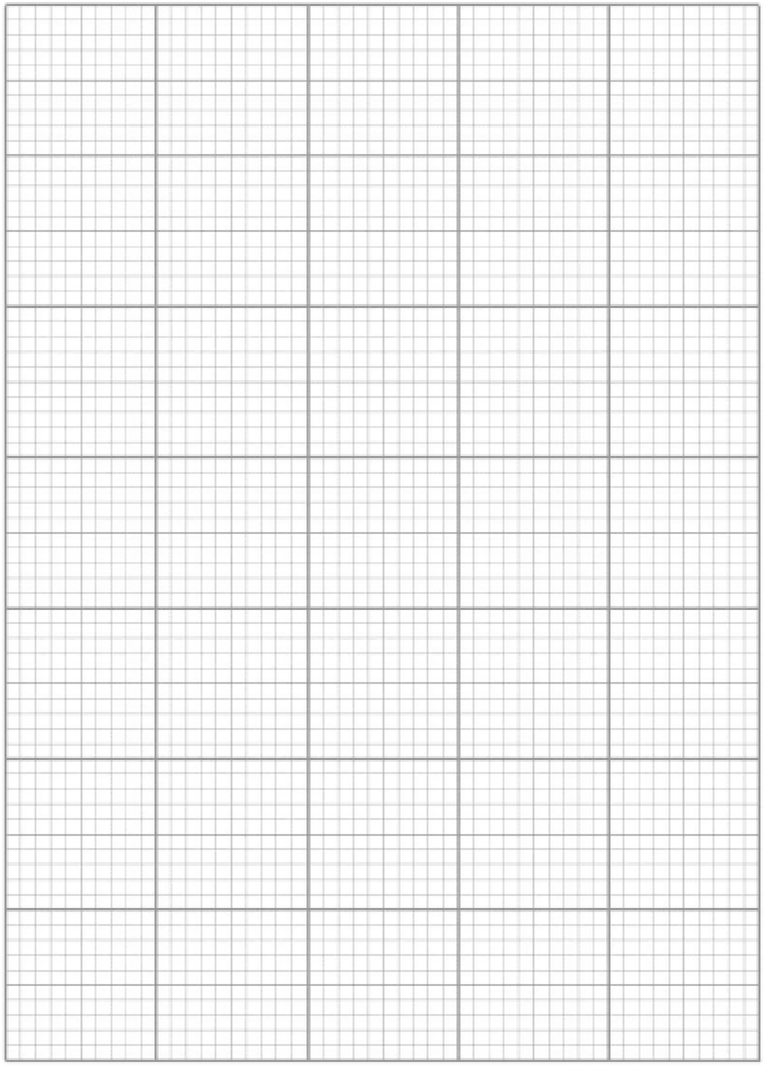


She turns off the time−base on the oscilloscope so that a vertical line is displayed on the screen. Keeping the y−voltage gain at 10 mV cm^{-1} she records the length l of the vertical line and the angle θ through which the circular frame has been rotated. She measures further results for l as θ is increased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

θ/degree	**l/cm**	**cosθ**
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 cosθ. Use the additional column in **Table 1** to record any derived data you use.

Figure 6



(4)

(e) State and explain whether the graph you have drawn confirms the suggestion that l is directly proportional to $\cos\theta$.

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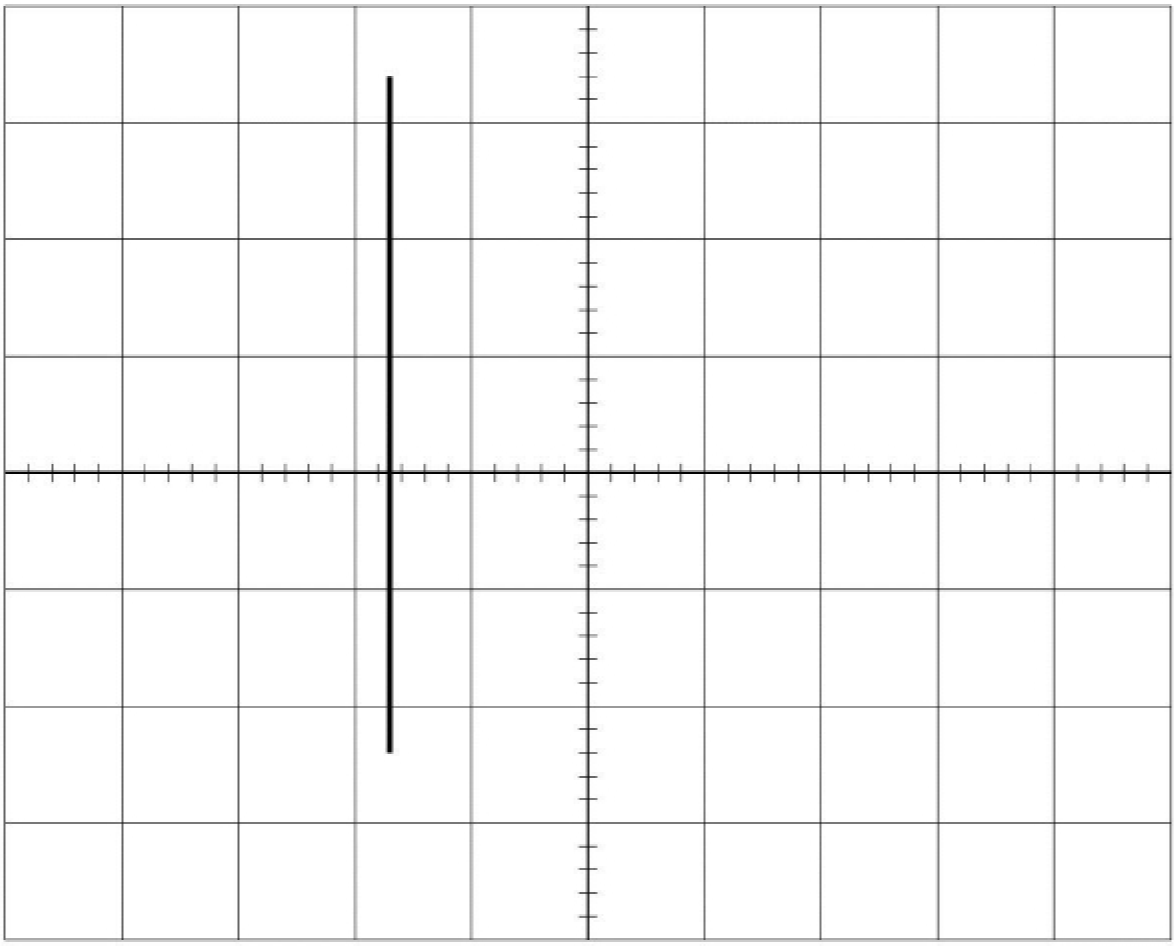
(1)

(f) 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)

(g) 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 part **(f)** so that she can repeat the experiment.

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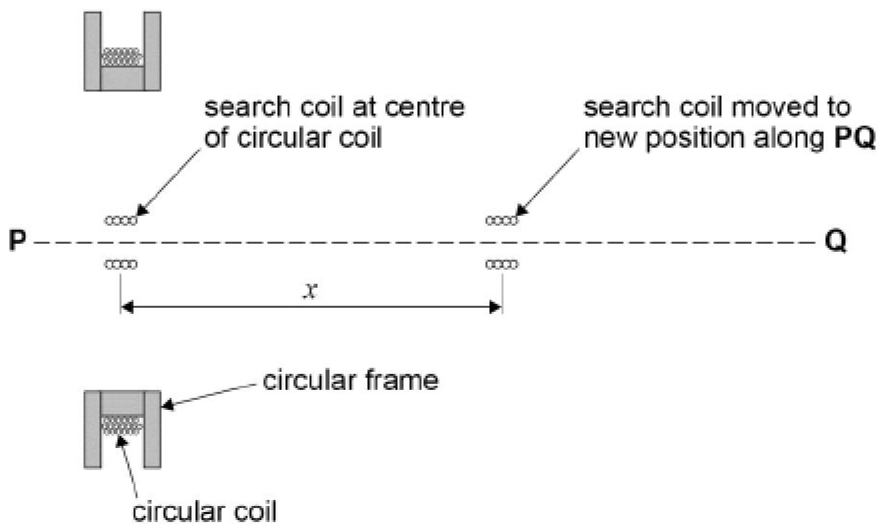
(3)

(h) 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**.

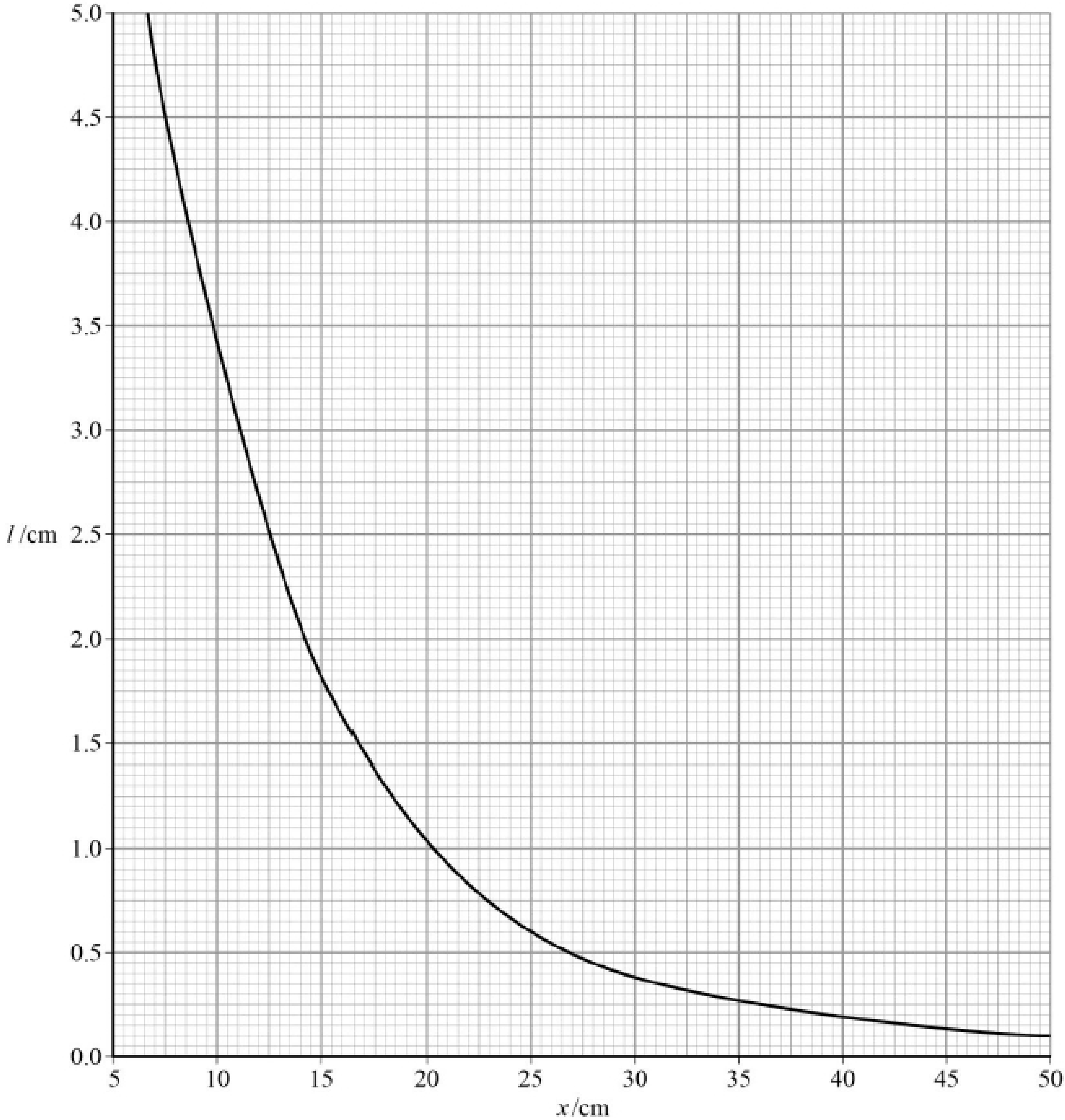
The search coil is then moved a distance x along **PQ**, as shown in **Figure 8**.

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)

(Total 20 marks)