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F-24

EXPERIMENT : No. 4

- **Aim:** To study the variation of magnetic field with distance along the axis of a circular coil carrying current.

- **Apparatus:** Circular box, compass box, ammeter, rheostat, commutator, cell, key, connection wires.

- **Theory:**

According to Biot-Savart's Law, the magnetic field (B) at a pt. due to an element of conductor carrying current is –

$$dB \propto i \quad , \text{ current}$$
$$\propto dl \quad , \text{ length}$$
$$\propto \sin\theta$$
$$\propto 1/r^2$$

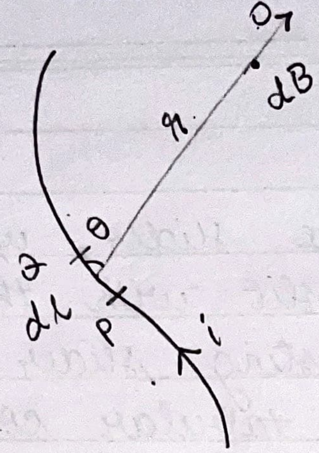
$$\therefore \boxed{d\vec{B} = \frac{\mu_0}{4\pi} \frac{i\, d\vec{l} \times \vec{r}}{r^3}} \quad (1) \qquad [\mu_0 = 4\pi \times 10^{-7} NA^{-2}]$$

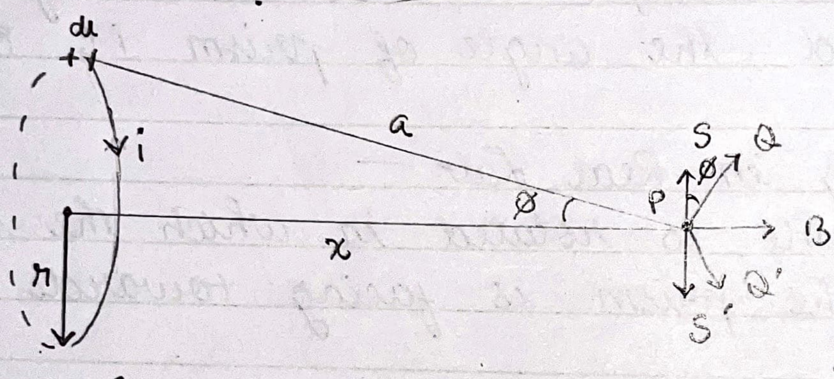
For the shown current coil, total magnetic field at pt. P →

$$B_x = \frac{\mu_0 n I r^2}{2 (x^2 + r^2)^{3/2}} \quad (2)$$

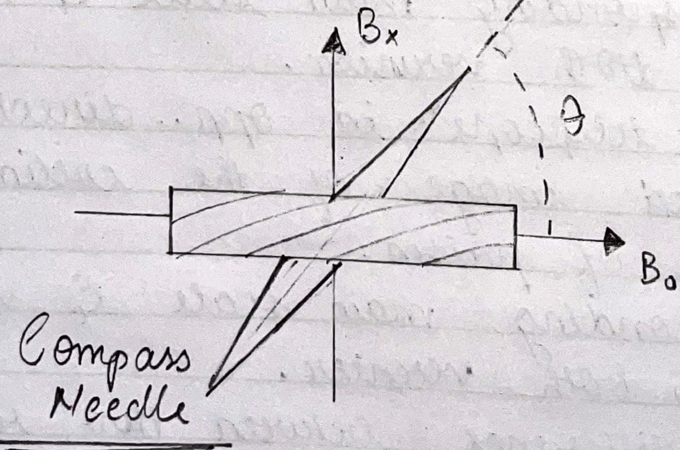
$\because$ B_x is $\perp$ to horizontal intensity of earth's magnetic field B_0 & the compass needle align at an angle θ with the vector sum of these fields

$$\therefore \boxed{B_x = B_0 \tan\theta} \quad (3)$$





Current Coil (n turns) r- radius



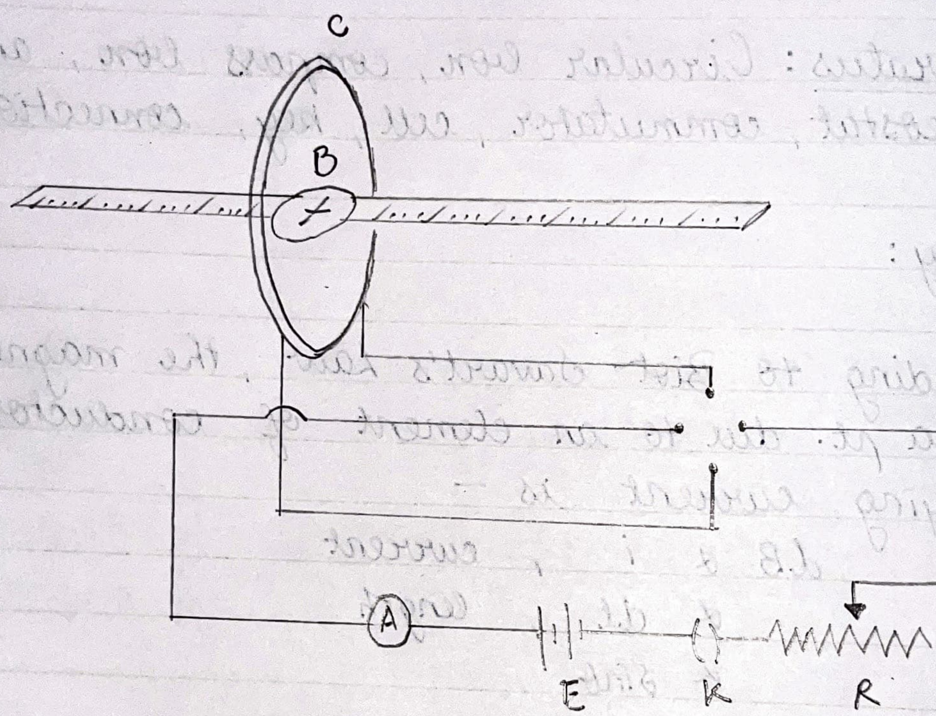
- **Procedure :**

REAL LAB

- To find the magnetic field –

1. First, the coil is fixed at the middle of the platform & the compass box is placed at the center of the coil.
2. The compass box is rotated till the 90-90 line becomes parallel to the plane of the coil.
3. Then the apparatus as a whole is rotated till the aluminium pointer reads 0-0.
4. Close the circuit.
5. Adjust the rheostat until the deflection lies between 30 & 60 degrees. Note down the deflection of the compass needle & the current.
6. Then current through the coil is reversed using the commutator & again the deflection & current are noted.
7. Average the magnitude of the two deflections & calculate the magnetic field at the center of the coil from the eq^n.
8. Without changing the current or the no. of turns, place the compass box at a particular distance from the center of the coil. Note the deflection. Again reverse the current & average the magnitude of the two deflections. Note the average, and the distance
9. ~~Take~~ Same procedure is repeated with the compass box at the same distance on the other

Circular Coil Apparatus



C - Circular Coil

R - Rheostat

A - Ammeter

E - Cell

B - Compass Box

side of the arm, keeping no. of turns & current constant.

10. Take the average of the two values of θ measured on opp. sides of the coil.
11. Then calculate the magnetic field B_x from the coil using eq^n. (3).
12. Repeat for various distances.
13. Draw ~~th~~ graph of B_x on the vertical axis vs distance x on theoretical axis.

SIMULATOR

1. First preliminary adjustments should be done in order to properly align the apparatus with the earth's magnetic field. The button "Initial Adjustment" is provided for this purpose. The experimental apparatus will be fully active only after the initial adjustments are done.
2. On clicking the initial adjustment button, a zoomed view of the compass ~~view~~ box will be displayed in the simulator. Two slider "Rotate Compass Box" and "Rotate apparatus" are provided.
3. Using the slider "Rotate Compass Box", the compass box can be rotated and its 90-90 reading ∥ to the plane of the coil. Fine adjustments can be made, if necessary, with the left-right arrow keys.
4. When the 90-90 alignment is exact, the slider "Rotate apparatus" will be active. Using this,

rotate the whole apparatus & make the aluminium pointer to read 0-0. Fine adjustments can be made with left-right arrow keys.

5. Using the "Show normal" button in the simulator, go back to the ~~the~~ experimental set-up.
6. Make the connections as shown in the figure. The user can drag the connection wires from the terminals of each components when a hand symbol appears there.
7. Close the circuit using the button "Insert Key".
8. "Zoom Compass Box" enables the user to view the reading of the pointer.
9. No. of turns of the coil: The user can select the no. of turns of the coil using this combo box.
10. Reverse current: Enables the user to reverse the direction of current through the circuit.
11. Using the slider Radius of the coil, the user can change the radius of the coil.
12. The slider along with the compass box can be moved along the arm of the apparatus using the slider Compass box position. The user can vary the distance x of the compass box from the center of the coil.
13. Adjust Rheostat slider can be used to adjust the current through the circuit.
14. Show ~~the~~ result button displays the result after doing the experiment.
15. A Reset button is provided to reset the

experimental set up.

16. The experiment can be repeated for different number of turns & radius of the coil & for different currents.

- **Result :**

Flux density due to Earth's Horizontal field at the place = 3.48×10^{-9} T

Observation Table :

Distance from the center (x)	Deflection with Compass box on Left side				Deflection with Compass box on Right side				Mean θ (deg)	B_x (T)	$B_0 = \frac{B_x}{\tan\theta}$
	Direct		Reversed		Direct		Reverse				
	θ_1	θ_2	θ_3	θ_4	θ_1	θ_2	θ_3	θ_4			
25	11	10	-10	-11	11	10	-10	-11	10.5	6.43×10^{-10}	3.46×10^{-9}
20	19	17	-18	-18	19	17	-18	-18	18	1.12×10^{-9}	3.44×10^{-9}
15	32	31	-31	-31	32	31	-31	-31	31.25	2.14×10^{-9}	3.52×10^{-9}
10	53	51	-52	-51	53	51	-52	-51	51.75	4.44×10^{-9}	3.5×10^{-9}
5	69	69	-69	-6.9	69	69	-69	-69	69	9×10^{-9}	3.45×10^{-9}
0	75	74	-75	-74	75	74	-75	-74	74.5	12.5×10^{-9}	3.5×10^{-9}

Calculations :

Mean θ at $x = 5$ => $69°$

$\boxed{\text{Avg } B_0 = 3.48 \times 10^{-9}\ T}$

$B_0 = \frac{B_x}{\tan\theta}$

Similarly Calculate at other values of x

B_0 at $x = 5 \rightarrow B_0 = 3.45 \times 10^{-9}$ T