PH170 LAB 5

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Aim:

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

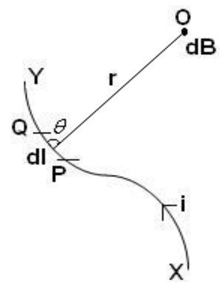
Apparatus:

Circular coil, compass box, ammeter, rheostat, commutator, cell, key, connection wires, etc. The purpose of the commutator is to allow the current to be reversed only in the coil, while flowing in the same direction in the rest of the circuit.

Theory:

A current carrying wire generates a magnetic field. According to Biot-Savart's law, the magnetic field at a point due to an element of a conductor carrying current is,

1. Directly proportional to the strength of the current, i
2. Directly proportional to the length of the element, dl
3. Directly proportional to the Sine of the angle θ between the element and the line joining the element to the point and
4. Inversely proportional to the square of the distance r between the element and the point.



Thus, the magnetic field at O is dB, such that,

$$dB \propto \frac{i\, dl\, Sin\,\theta}{r^2}$$

Then,

$$dB = k\frac{i\, dl\, Sin\,\theta}{r^2}$$

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where,

$k = \frac{\mu_0}{4\pi}$ is the proportionality constant and

$$\mu_0 = 4\pi \times 10^{-7}\, NA^{-2}$$

$\mu_0 = 4\pi \times 10^{-7}\, NA^{-2}$ is called the permeability of free space.

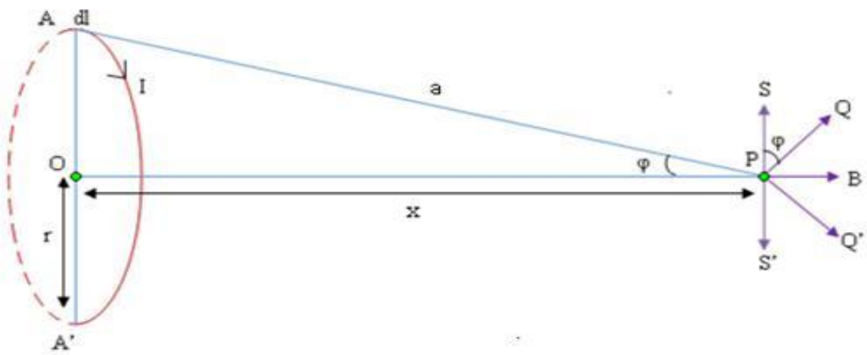
Then,

$$dB = \frac{\mu_0}{4\pi}\frac{i\, dl\, Sin\,\theta}{r^2}$$

In vector form,

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\, d\vec{l} \times \vec{r}}{r^3}$$

Consider a circular coil of radius r, carrying a current I. Consider a point P, which is at a distance x from the centre of the coil. We can consider that the loop is made up of a large number of short elements, generating small magnetic fields. So the total field at P will be the sum of the contributions from all these elements. At the centre of the coil, the field will be uniform. As the location of the point increases from the centre of the coil, the field decreases.



By Biot- Savart's law, the field dB due to a small element dl of the circle, centered at A is given by,

$$dB = \frac{\mu_0}{4\pi} I \frac{dl}{(x^2 + r^2)} \qquad (1)$$

This can be resolved into two components, one along the axis OP, and other PS, which is perpendicular to OP. PS is exactly cancelled by the perpendicular component PS' of the field due to a current and centered at A'. So, the total magnetic field at a point which is at a distance x away from the axis of a circular coil of radius r is given by,

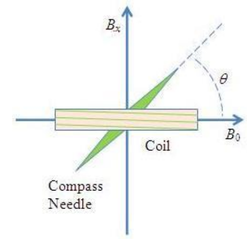
$$B_x = \frac{\mu_0 I}{2} \frac{r^2}{(x^2 + r^2)^{3/2}}$$

If there are *n* turns in the coil, then

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

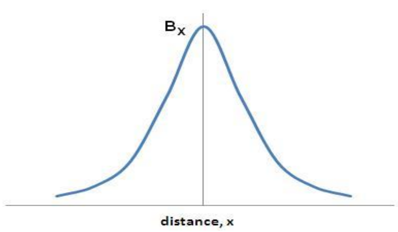
where μ_0 is the absolute permeability of free space.

Since this field B_x from the coil is acting perpendicular to the horizontal intensity of earth's magnetic field, B_0, and the compass needle align at an angle θ with the vector sum of these two fields, we have from the figure



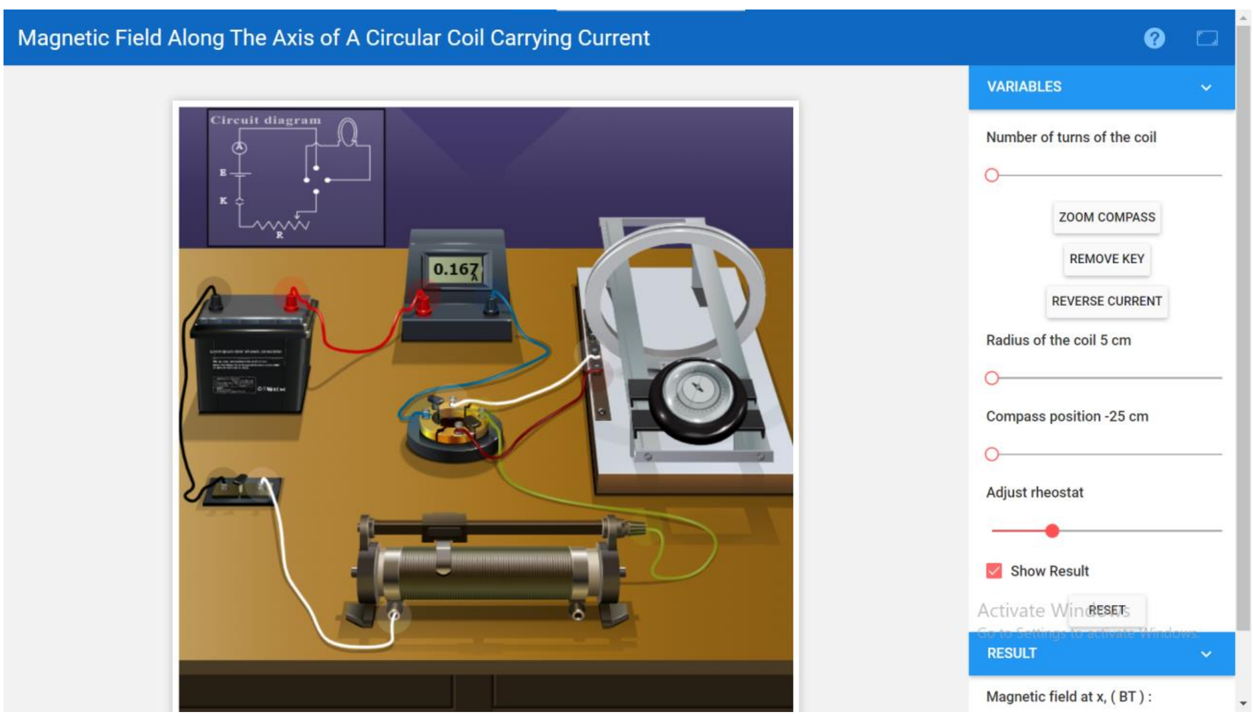
$$B_x = B_0 \tan\theta \qquad (3)$$

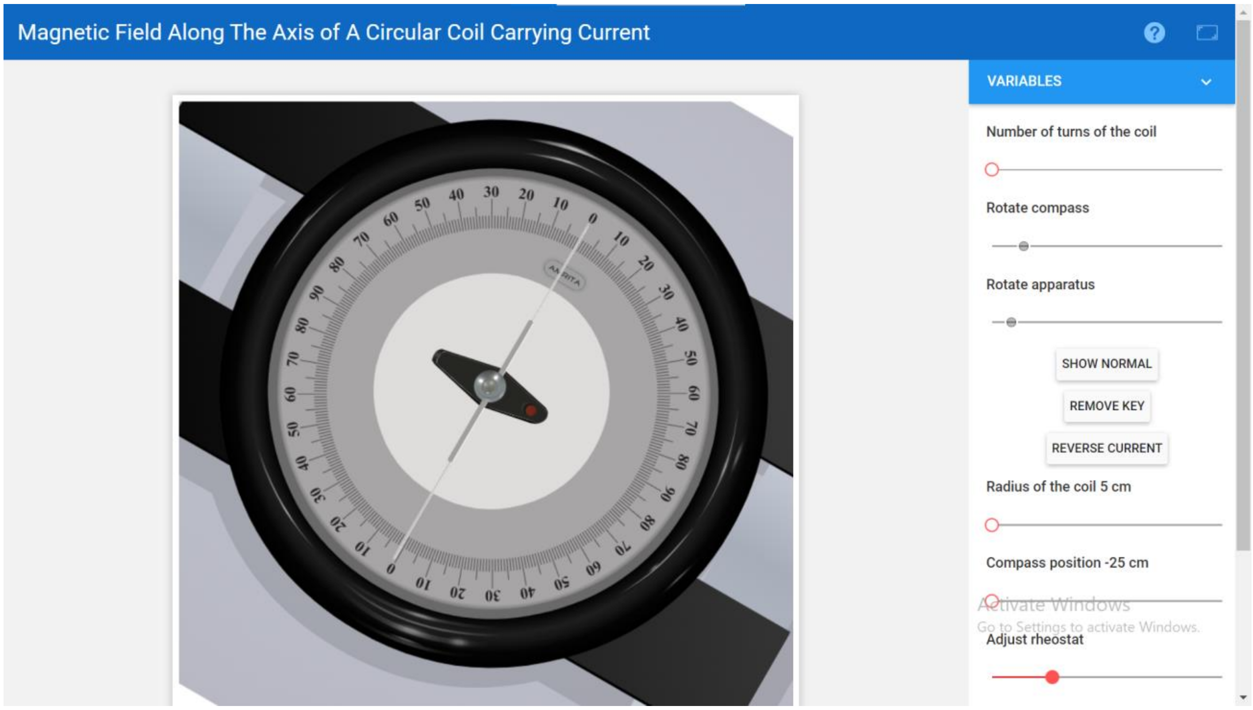
The horizontal component of the earth's magnetic field varies greatly over the surface of the earth. For the purpose of this simulation, we will assume its magnitude to be $B_0 = 3.5\text{x}10^{-5}$ T. The variation of magnetic field along the axis of a circular coil is shown here.



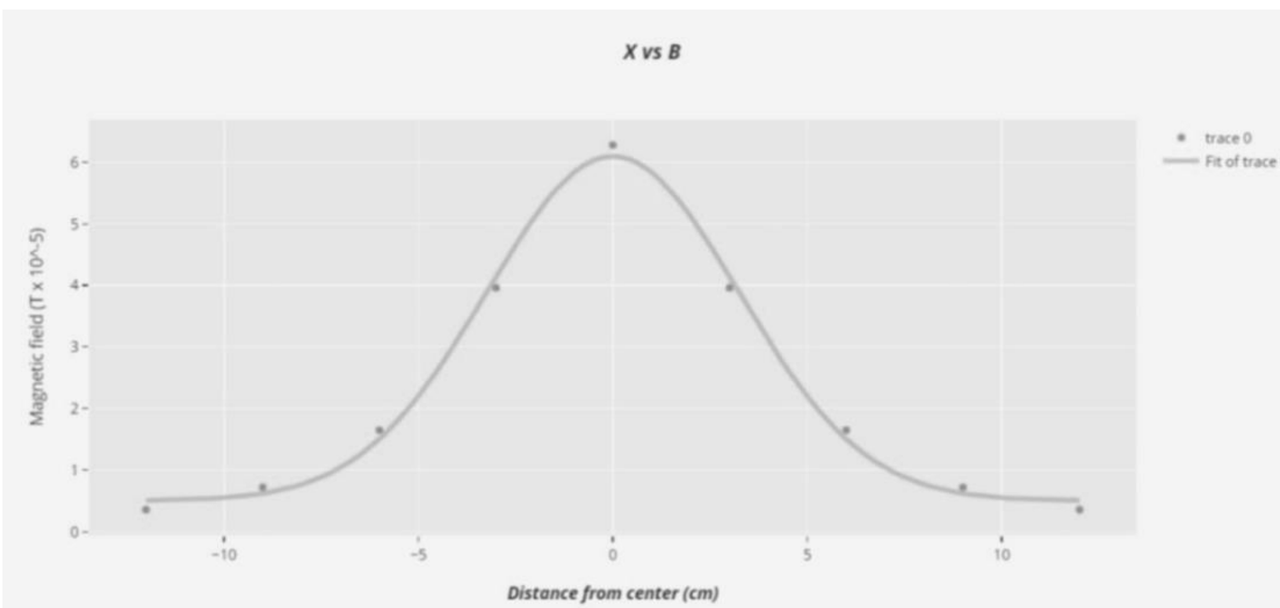
Observation:

Sr. No.	No. of turns (n)	Current (I)	Radius of coil (r)	Distance from centre (x)	Deflection from compass box on left side				Deflection from compass box on right side				Mean θ degrees	tanθ	Bx (T) (x10^(-5))	Bo (T) (x10^(-5))
					Direct		Reverse		Direct		Reverse					
					θ1	θ2	θ3	θ4	θ5	θ6	θ7	θ8				
1	45	0.083	8	20	2	3	3	2	2	3	3	2	2.5	0.04366	0.151	3.458543
2	45	0.083	8	10	12	11	11	12	12	11	11	12	11.5	0.20345	0.718	3.529123
3	45	0.083	9	10	12	13	13	12	12	13	13	12	12.5	0.2217	0.783	3.5318
4	45	0.1	9	10	14.5	15.5	15.5	14.5	14.5	15.5	15.5	14.5	15	0.2679	0.94	3.508772
5	25	0.1	9	10	8	9.5	9.5	8	8	9.5	9.5	8	8.75	0.1539	0.522	3.391813
6	20	0.25	10	20	4	5	5	4	4	5	5	4	4.5	0.0787	0.281	3.570521
7	20	0.143	10	25	1	2	2	1	1	2	2	1	1.5	0.02618	0.092	3.514133
8	30	0.125	6	15	3	4	4	3	3	4	4	3	3.5	0.06116	0.201	3.286462
9	35	0.125	5.5	10	8.5	9.5	9.5	8.5	8.5	9.5	9.5	8.5	9	0.15838	0.559	3.529486





Magnetic Field Along The Axis of A Circular Coil Carrying Current
VARIABLES
Number of turns of the coil
Rotate compass
Rotate apparatus
SHOW NORMAL
REMOVE KEY
REVERSE CURRENT
Radius of the coil 5 cm
Compass position -25 cm
Activate Windows
Go to Settings to activate Windows.
Adjust rheostat



X vs B
trace 0
Fit of trace 0
Magnetic field (T x 10^-5)
Distance from center (cm)

RESULTS AND CONCLUSION:

By performing this experiment and plotting the graph between variation of magnetic field along the axis and distance from the centre of the coil, we were able to conclude that plotted points satisfied the relation,

$$Btotal = \frac{\mu_0 n i R^2}{2(x^2+R^2)^{\frac{3}{2}}}$$

We were also able to understand that the component of the earth's magnetic field varies greatly over the surface of the earth.

Error Percentages were also within the acceptable range of errors and hence we can confirm say that we have got the correct practical results in respect with the theoretical theories!!

Moreover, we were able to improve the peer learning capabilities by working in groups and improve our analytical study of errors and methods of avoiding them while performing calculations.

Thank you