EXPERIMENT – 4
VARIATION OF MAGNETIC FIELD WITH DISTANCE ALONG THE AXIS OF A CIRCULAR COIL

AIM: To study the variation of magnetic field with distance along the axis of a current carrying circular coil and hence estimate the radius of the coil.

APPARATUS: Tangent galvanometer of the Stewart and Gee type, Battery eliminator, Rheostat, Commutator, Plug key and connecting wires.

FORMULA

The magnetic field on the axis of a circular coil is given by:

$$B = \frac{2\pi n I a^2}{10(a^2 + x^2)^{3/2}}$$

Where n = number of turns in the coil

$\boldsymbol{a}$ = radius of the coil in cm

I = current in the coil in amperes

$\boldsymbol{x}$ = distance of the point from the centre of the coil in cm

THEORY

If we pass a current of I ampere in the coil keeping it vertical in magnetic N-S direction and place the needle at a distance x from the centre on any side of the arm, the magnetic field B acting on the needle due to the current in the coil is given by

$$B_1 = \frac{2\pi n I a^2}{10(a^2 + x^2)^{3/2}}$$

This acts East-West in horizontal plane. The horizontal component of earth magnetic field B_H acts on the needle in N-S direction horizontally. Thus two mutually perpendicular coplanar magnetic fields act on the needle deflecting it. According to tangent law:

$$B_2 = B_H \tan\theta$$

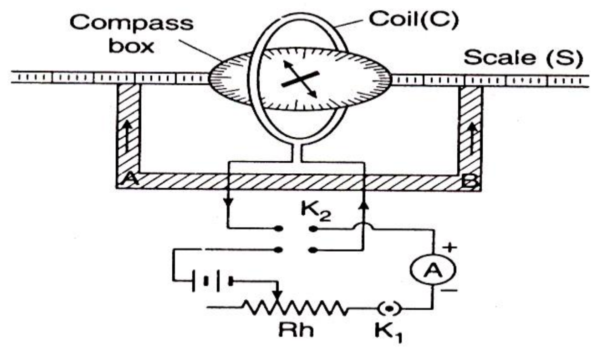
or,

$$\frac{2\pi n I a^2}{10(a^2 + x^2)^{3/2}} = B_H \tan\theta$$

Hence, the variation of θ with x is studied which gives the variation of magnetic field along the axis of the circular coil.

PROCEDURE

1. The apparatus called Stewart and Gee tangent galvanometer is used to study the variation of magnetic field along the axis of current carrying circular coil and is shown in the figure.



2. Rotate the whole apparatus in the horizontal plane such that the coil lies in the magnetic meridian roughly. In this case the coil, needle and its image all lie in the same vertical plane. Rotate the compass box till the pointer ends read $0^{\circ} - 0^{\circ}$ on the circular scale.
3. To set the coil exactly in the magnetic meridian, send the electric current in one direction with the help of commutator and note down the deflection of the needle. Now reverse the direction of the current and again note down the deflection. If the deflections are equal then the coil is in magnetic meridian.
4. With the help of rheostat, adjust the current such that the deflection in the compass box should be $65^{\circ} to\ 70^{\circ}$ when it is placed at the center of the coil.
5. Displace the compass box on the bench through $2\ cm$. each time along the axis of the coil and for each position note down the mean deflection.
6. Repeat the measurements exactly in the same manner on the other side of the coil.

OBSERVATION TABLE

Current , $I = ..\ Amp$

S. No.	Distance $x\ cm$	Deflection on Eastern Arm						Deflection on Western Arm						Mean tan θ	$B_2 = B_H tan\ \theta$
		Current in one direction (Direct)		Current in other direction (Reverse)		Mean	$tan\ \theta$	Current in one direction (Direct)		Current in other direction (Reverse)		Mean	$tan\ \theta$		
		θ_1	θ_2	θ_3	θ_4	θ		θ_1	θ_2	θ_3	θ_4	θ			
1.	0														
2.	2														
3	4														

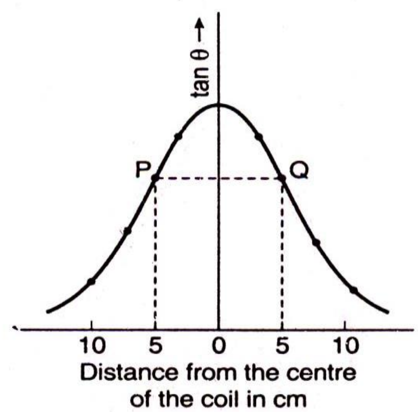
Graph

Plot a graph taking distance along X-axis and tan θ along Y-axis. Mark the pointsof inflection P and Q and hence the radius of the coil.

Result

(i) The graph shows the variation of Magnetic field along the axis of a Current carrying circular coil.

(ii) The radius of the coil $(R_m) =..cm$



Standard result

The radius of the coil as estimated by measuring its circumference $(R_s) = 10\ cm$

Percentage error

$$\frac{(\boldsymbol{R_m - R_s})}{\boldsymbol{R_s}} \times \mathbf{100} = ..\%$$

where R_m and R_s are the measured and the standard values of the radius.

PRECAUTIONS

1. The coil should be adjusted carefully in the magnetic meridian.
2. All the magnetic materials and current carrying conductors should be at a considerable distance from the apparatus.
3. The current passed in the coil should be of such a value so as to produce a deflection of nearly 65°.
4. Before reading the two ends of the pointer parallax between the pointer and its image in the plane mirror should be removed so as to record the correct value of the deflection.
5. The curve should be drawn smoothly.

VIVA-VOCE

Q. 1 : What do you mean by a uniform magnetic field?

Q. 2 : What is magnetic effect of a current?

Q. 3 : What is the Tangent law?

Q. 4 : What is magnetic meridian?

Q. 5 : How the coil is set in the magnetic meridian? How can you test this setting?

Q. 6 : What is the direction of the magnetic field produced by the coil?

Q. 7 : Why is it necessary to set the coil ion the magnetic meridian?

Q. 8 : Why both the ends of the pointer in the compass box be read?

Q. 9 : Why the readings must be repeated after reversing the current?

Q. 10 : How does the field vary along the axis of the coil?

Q. 11 : What is the magnitude of the field at the centre of the coil?

Q. 12 : Is the field uniform at the centre?

Q. 13 : Will the presence of any current carrying conductor close by, will affect the results?

Q. 14 : How do you find out the radius of the coil from x x Vs $\tan\theta$ from graph?

APPLICATIONS

Motors, transformers, microphones, compasses, telephone bell ringers, television focusing controls, advertising displays, magnetically levitated high-speed vehicles, memory stores, magnetic separators etc.