Expt. # 12: Magnetic Field Mapping using two identical coils

The following studies will be performed with the set-up:

1. Study of magnetic field due to one coil and calculation of its diameter.
2. Study of Principal of superposition of magnetic fields due to two coils by keeping the distance between the coils at a, where a is the radius of the coil, i.e., at Helmholtz configuration.
3. Study the magnetic field in the Helmholtz configuration and at a distance of 5 cm on either side from the Helmholtz configuration.

A photograph of the entire apparatus is shown above. It consists of

(i) a pair of identical magnetic coils (having 500 number of turns at each coils), one of the coils is fixed and the other can move along its axis smoothly using a rail attached on it.

(ii) a Hall probe Gaussmeter head, mounted on another rail and can move along their common axis.

(iii) a constant current source and digital Gaussmeter are mounted on a common unit.

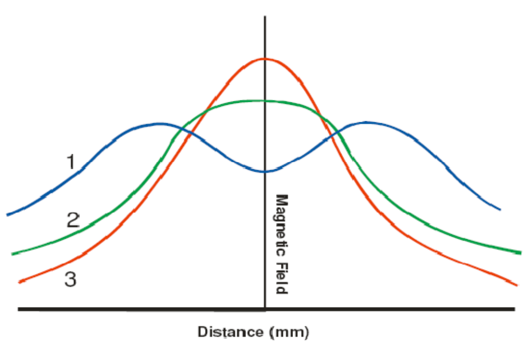

Figure 1: Demonstration of magnetic field profiles. Line1: when the distance between the coils is > a; Line 2: when the distance between the coils is = a; and Line 3: when the distance between the coils is < a.

Description of the apparatus:

1. **Constant current source for coils**

   It is an IC regulated constant current source

   Specification:

   Current Range : 0-500 mA
   Line Regulation : ± 0.2% for ± 10% mains variation
   Load Regulation : ± 0.2% for no load to full load
   Display : 3½ digit 7 segment LED display
   Power : 220 ± 10% Mains
   Protection : Protected against overload/short circuit
   The provision have been made to connect Coil 1 or Coil 2 separately or both the coils in Helmholtz Coil configuration.

2. **Digital Gaussmeter**

   A Hall Effect integrated circuits chip is used to increase the temperature stability and sensitivity. Laser trimmed thin film resistors on the chip provide high accuracy and temperature compensation to reduce null and gain shift over temperature

   Specification:

   Range : 0-200G
   Resolution : 0.1G
   Accuracy : ± 0.5%
   Display : 3½ digit 7 segment LED display
   Transducer : Hall Effect IC sensor

Current Carrying Coil Set-Up

It has two coils, one is fixed. The other coil and magnetic field sensor can be moved smoothly along the axis of the coils with the help of lead-screw system, independently.
The position of coil and magnetic sensor could be read on two separate scales.

Specification:

Radius of the coils: ~~112 mm (approx.)~~, you have to calculate.
Number of turn: 500

DESCRIPTION

We know, the intensity of magnetic field at a point 'P', lying on the axis of a circular coil 'AB' of radius 'a' having 'n' turns at a distance 'x' from the centre 'O' of the coil in S.I. units, is given by

$$B = \frac{\mu_0}{4\pi} . \frac{2\pi n I a^2}{(a^2 + x^2)^{3/2}}$$

I is the current flowing through the coil, μ_0 is the permeability of the free space, which is equal to $4\pi \times 10^{-7}\ H/m$.

The units of B are Tesla or Wb/m^2.

The direction of the magnetic intensity at P is along OP produced if the current flows through the coil in the anti-clock-wise direction as seen from P. If the direction of the current is clockwise the field at P is along PO *(Figure 1)*.

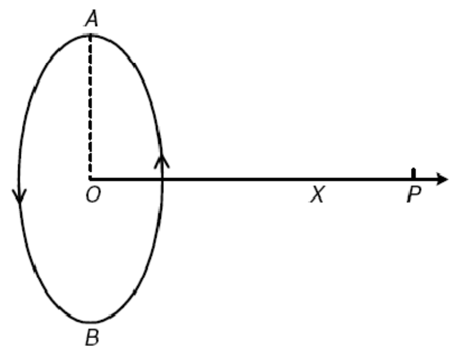

Figure 1

The value of the magnetic intensity is maximum at the centre O of the coil and is given by

$$B = \frac{\mu_0}{4\pi} . \frac{2\pi n I}{a} = \frac{\mu_0 n I}{2a}$$

Or,

$$\frac{4\pi \times 10^{-7} n I \times 10^4}{2a}\ Gauss \qquad (1)$$

If we move away from O towards the right or left, the intensity of the magnetic field decreases. A graph showing the relation between the intensity of the magnetic field B and the distance x is given in Figure 2. The curve is first concave towards O but the curvature becomes less and less, quickly changes sign at P and Q and afterwards becomes convex towards O. It can be shown that the points of inflexion P or Q where the curvature changes its sign lie at distances $\frac{a}{2}$ from the centre. Hence the distance between P and Q is equal to the radius of the coil.

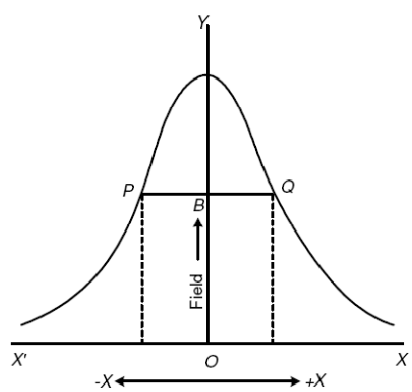

Figure 2

Procedure

(i) Switch ‘ON’ the main’s power.
(ii) Set the current zero. Adjust magnetic field to zero.
(iii) Set a constant current that can be applicable for all configurations and the value should be greater than 350 mA.
(iv) Calculate the radius of the coil from a measured value of magnetic field.
(v) Set the coils in Helmholtz configuration.
(vi) Study the superposition principle of magnetic field under Helmholtz configuration. Make an appropriate table. Graph required.
(vii) Study the magnetic field profile under Helmholtz configuration and at a distance of 5 cm on either side from the Helmholtz configuration. Make an appropriate table. Graph required.