Experiment No. 1

Magnetic Field (Helmholtz Coils)

Aim

1. To study the variation of magnetic field with position of paired coils in Helmholtz arrangement along the axis of the coils carrying current.
2. To study the principle of super imposition of magnetic field.
3. To calculate the radius of the coil.

Apparatus required:

IC regulated constant current source, digital gauss meter, two coils, movable magnetic field sensor.

Formula Used:

Radius of coil

$$a = \frac{2\pi n I * 10^{-3}}{B} \text{ m}$$

Where, n= number of turn(500)

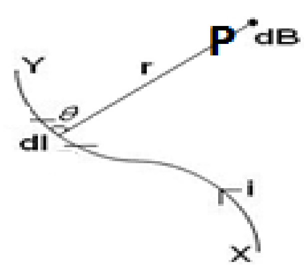
I= Current flowing through coil (500 mA)

B= Magnetic field produced (in Gauss). (Max. mag. Field due to a single coil).

Putting the values of n, I, & B radius of coil 'a' can be found.

Theory:

According to Bio Savart's law a current carrying conductor produces a magnetic field around it. Magnetic field at a point (P) fig.(1) from the current element is given by:



$$\vec{B} = \frac{\mu_0}{4\pi} \cdot \frac{\overrightarrow{Idl} * \vec{r}}{r^3} \ldots\ldots\ldots (1)$$

Fig. 1

This law when applied to the case of a circular current carrying coil gives the intensity of magnetic field (B) at a point 'P' lying on the axis of coil as follows:

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi n I a^2}{(a^2+r^2)^{3/2}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where,

n= number of turns in the coil, a= radius of coil

I= current flowing in the coil , μ_0= permeability of free space= 4 π*10^{-7} NA^{-2}

r = distance of point P from centre of coil

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

The direction of the magnetic intensity at *P* is along *OP (O* being center of the coil) 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.*

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

$$B= \frac{\mu_0 nI}{2a} \text{ Tesla}$$

as 1 Tesla= 10^4 Gauss

$$B=\frac{4\pi * 10^{-7} nI * 10^4}{2a} = \frac{4\pi * 10^{-3} nI}{2a} \text{ Gauss} \quad \dots\dots\dots\dots\dots\dots\dots(3)$$

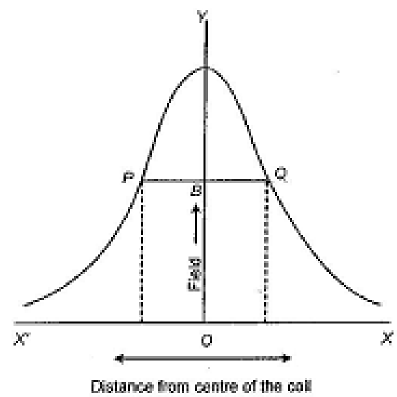


Fig. 2

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 *'r'* is given in Fig. 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.

If two such identical coils are placed coaxially, then depending on the relative sense of current flow in them, the two fields add or subtract (vector sum of two fields) to give the resultant magnetic field at any point on the axis (principle of superposition).

Helmholtz coils consists of a pair of identical coils (same no. of turns, radius) placed coaxially and separated by a distance equal to the radius of either coil. Such a pair produces an almost uniform magnetic field between the coils if the current through them is same and in the same sense such that two fields add. The resultant magnetic field at an axial point 'S' at a distance (x) from coil 1 is given by

$$B_{res} = \frac{\mu_0 n I a^2}{2}\left[\frac{1}{(a^2+x^2)^{\frac{3}{2}}} + \frac{1}{\{a^2+(a-x)^2\}^{\frac{3}{2}}}\right] \quad \text{.................................(4)}$$

Fig. (3) shows the resultant field for Helmholtz coils when current through them is same and wing in the same sense such that two fields add and create uniform magnetic field over a range.

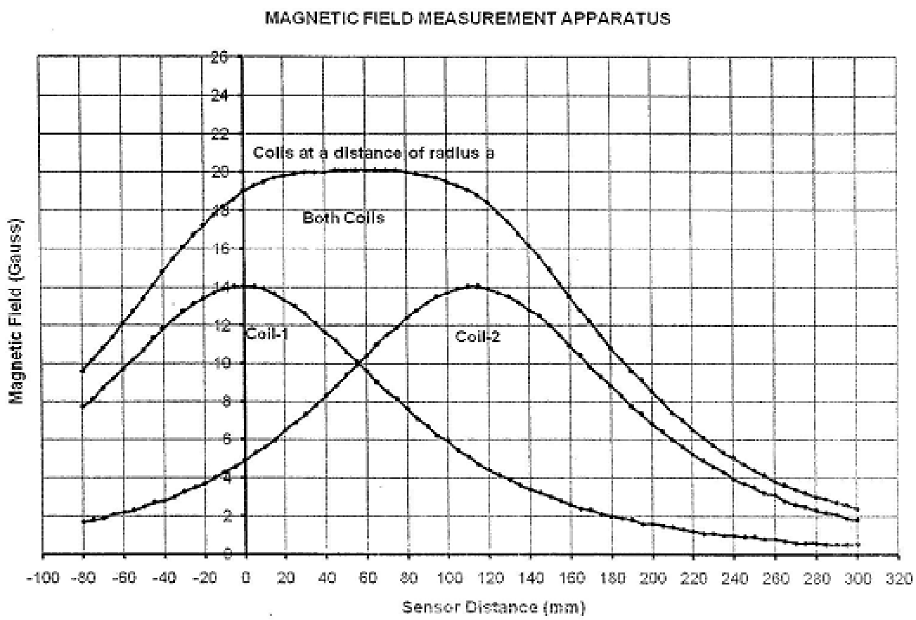


Figure 3

Procedure

(i) Connect the Sensor Cable (3-pin) to the sensor socket and Coil Cable (4-pin) to the coils socket.

(ii) Switch 'ON' the main's power.

(iii) Turn the current adjusting knob anti-clockwise to the minimum position; so that the current is reduced to zero.

(iv) Fix the position of COIL 2 at a distance of 112 mm from the COIL 1 i.e. equal to the radius of the coils.

(v) Keep the sensor pointer at -70mm and adjust the zero of Gaussmeter with 'ZERO ADJ.' knob.

(vi) Put the 'COIL' knob to Position 1 so that the COIL 1 is connected to the current source. Adjust the current to say 500 mA.

(vii) Note down the magnetic field at -70 mm along the axis of the Coil 1. Now put the coil knob to Position 2, so that COIL 2 is connected to current source and note down the magnetic field.

(viii) Put the coil knob to Position 3, i.e. 'BOTH', COIL 1 & COIL 2 will be connected to the source. Now again note down the readings.

(ix) Keep the current same and note down the magnetic field from -70 to +250 mm at an interval of 5 mm for all the positions i.e. COIL 1 , COIL 2 & 'BOTH', Draw the graphs between distance and magnetic field due to COIL 1, COIL 2 and BOTH along the axis of coils as shown in Fig. 3.

Observations :

No of Turns = 500

Position of 1st coil ……………

Position of 2nd coil …………..

S.No.	**Sensor position (mm)**	**Magnetic Field (Gauss)**			
		COIL 1 (B1)	**COIL 2 (B2)**	**BOTH COILS (B)**	**Mag. Field B'=(B1+B2)**
1					
2					
..					
..					
11					
12	-15.0	13.6	4.0	17.6	
13	-10.0	13.8	4.3	18.2	
14	-5.0	13.9	4.6	18.5	
15	0.0	14.0	4.9	18.9	
16	5.0	13.9	5.2	19.2	
17	10.0	13.9	5.6	19.5	
18					
19					
..					
..					
..					

Calculations & Results

1. The profile of magnetic field with distance along the axis of a circular coils carrying current is as shown fig 3.
2. Principal of super-imposition of magnetic field
   (i) It can be seen from the profile of magnetic field that when the current is flowing through both the coil, magnetic field at any point is the sum of the magnetic field due to coils 1 and coil 2 i.e. when the current was flowing individually.

   (ii) Another important conclusion is that the magnetic field is very uniform over a large space when the distance between the two current carrying coils is equal to the radius of the coils. This property is widely used in scientific and industrial applications.

3. Calculation of radius of coil

$$B = \frac{4\pi * 10^{-3} * nI}{2a}$$

Therefore,

$$a = \frac{2\pi nI * 10^{-3}}{B} \text{ m}$$

putting the values of n, I, & B radius of coil 'a' can be found.

Precautions

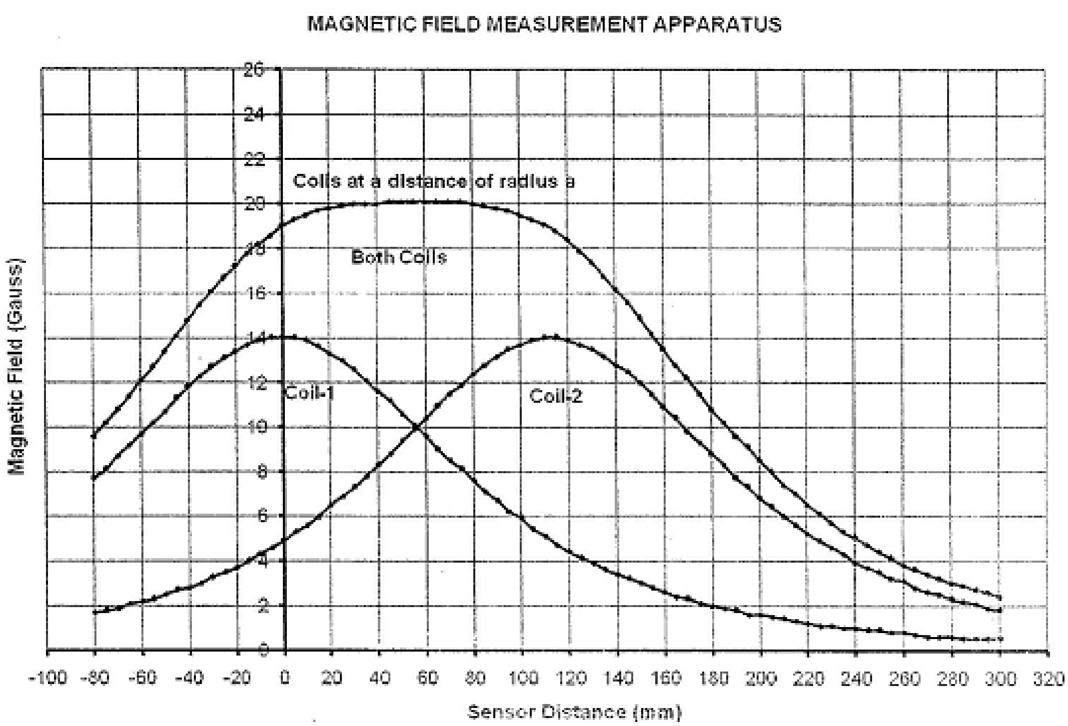
1) Care should be taken that is no stray magnetic field or ferromagnetic material, such as keys, screwdriver etc. near the set up , while performing the experiment

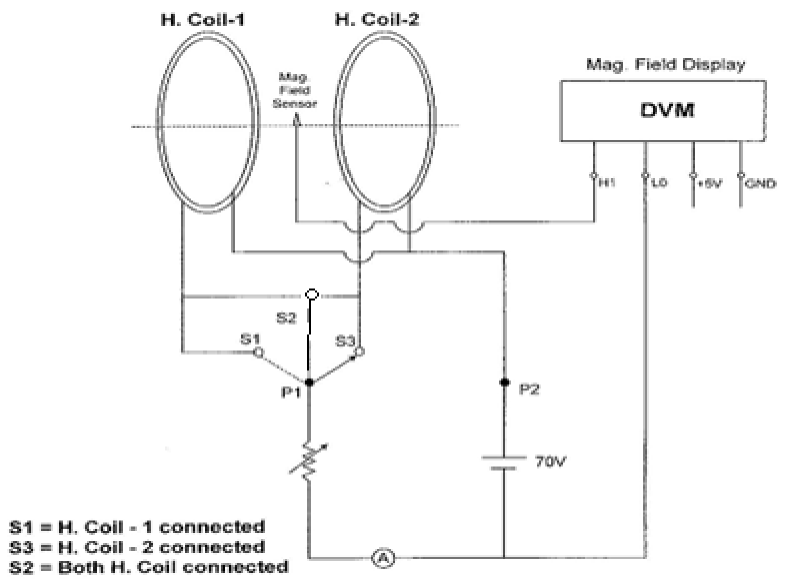
2) The radius of the coil is calculated from the centre of winding.

3) The Zero of the Gauss meter should be adjusted each time before beginning the experiment and verified after completion of experiment by reducing the current in both the COILS to zero.

4) In order to avoid the interference of each magnetic field the axis of coils should be East -West.

West ←————————————————→ East





Principal Diagram

MAGNETIC FIELD MEASUREMENT APPARATUS