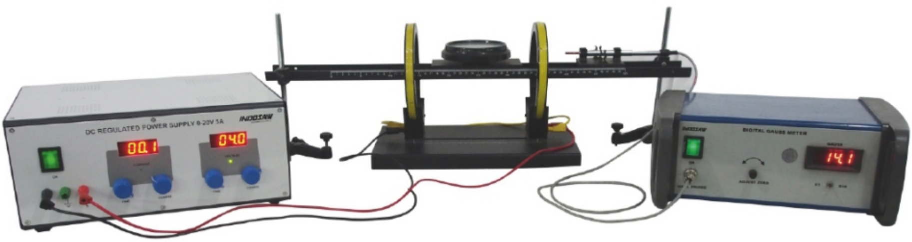
INDOSAW
COMMITTED TO EXCELLENCE

MAGNETIC FIELD OF TWO COILS IN HELMHOLTZ ARRANGEMENT

Instruction Manual



Manufacturer :

OSAW INDUSTRIAL PRODUCTS PVT. LTD.

P.O. Box No. 42, OSAW Complex, Jagadhri Road
Ambala Cantt - 133001 (Haryana) INDIA
E-mail : deducation@indosaw.com
E-mail : qc1@indosaw.com

Phone : +91-171-2699347, 2699267
Fax : +91-171-2699102, 2699222
Website : www.indosawedu.com
New Delhi, Phone : 011-46525029

TÜV SÜD South Asia
NABCB QMO11

An ISO 9001 :2008 Certified Company

OBJECTIVE:

To study the magnetic field along the axis of Helmholtz Coil

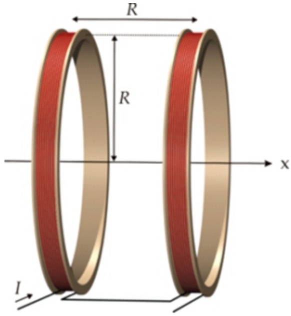
1. To measure the magnetic flux density along the x-axis of the circular coils when the distance between them $a = R$ (R = radius of the coils) and when it is greater and less than this.

2. To measure the spatial distribution of the magnetic flux density when the distance between coils $a = R$, using the rotational symmetry of the set-up

a. Measurement of the axial component Bx

b. Measurement of radial component Br.

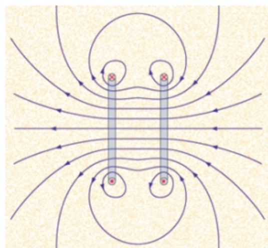
To measure the radial components Br1 and Br2 of the two individual coils in the plane midway between them and to demonstrate the overlapping of the two fields at Br = 0



S.No	Item Name	Qty
1	Power Supply DC 0-20V, 5 Amp	1
2	Digital Gauss Meter with Axial Probe	1
3	Coil N=390, Dia=140mm	2
4	Support Base	2
5	Support Rod	2
6	U Channel Big	1
7	U Channel Small	1
8	Deflection Compass with Base	1
9	Axial probe holder	1
10	Multimeter	1
11	Connecting Leads	4

PRINCIPLE

A useful experiment for getting a fairly uniform magnetic field is to use a pair of circular coils on a common axis with equal currents flowing in the same logic. For a given coil radius, you can calculate the separation needed to give the most uniform central field. This separation is equal to the radius of the coils. The magnetic field lines for this geometry are illustrated in figure at right side.



Magnetic field lines for Helmholtz coils.

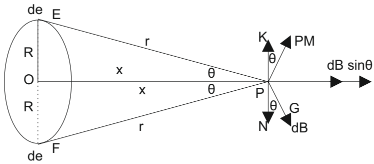
The spatial distribution of the field strength between a pair of coils in the Helmholtz arrangement is measured. The spacing at which a uniform magnetic field is produced is investigated and the superposition of the two individual fields to form the combined field of the pair of coils is demonstrated.

THEORY:

Field at any point on the axis of current carrying coil.

Let E and F are two diametrically opposite element of coil through which current i is flowing. Field at P at distance x (=op) from the centre and at distance r from the element E is

$$dB = \frac{\mu 0}{4\pi} \frac{I(\vec{de} \times \vec{r})}{r^3} \quad \text{----------(1)}$$



or $$dB = \frac{\mu 0}{4\pi} \frac{I\,dl \sin 90 r}{r^3}$$ (angle between dl and r is 90°)

$$dB = \frac{\mu 0}{4\pi} \frac{I\,dl}{r^2} \quad \text{----------(2)}$$ along PM perpendicular to EP

The same field due to element F diametrically opposite to E acting along PG ⊥ to FP. The components dB cosθ get cancelled of all diametrically opposite elements.
The elements dB sinθ get added for all elements.
So field due to whole coil.

$$B = \int_0^{2\pi R} dB \sin\theta$$

$$= \frac{\mu_0}{4\pi} \int_0^{2\pi r} \frac{I\,dl}{r^3} \sin\theta$$

$$= \frac{\mu_0}{4\pi} \frac{I}{r^2} \times \frac{R}{r} \qquad \int_0^{2\pi R} dl$$

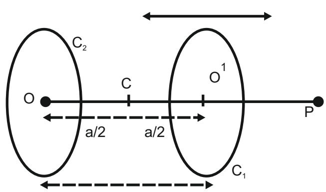
$$= \frac{\mu_0}{4\pi} \frac{IR}{r^3} (dl)_0^{2\pi R} \qquad = \frac{\mu_0}{4\pi} \frac{IR \times 2\pi R}{r^3}$$

$$= \frac{\mu_0 I}{2} \frac{R^2}{(R^2+X^2)^{3/2}} \qquad = \frac{\mu_0 I\, R^2}{2R^3 \{1+\frac{x^2}{R^2}\}^{3/2}}$$

$$B = \frac{\mu I}{2R \{1+\frac{x^2}{R^2}\}^{3/2}}$$

For N turns coil

$$B = \frac{\mu_0 NI}{2R \{1+\frac{x^2}{R^2}\}^{3/2}}$$



For two coils separated by distance 'a' then

$$O.P = X_1 = (X_0 - a/2) \quad \text{for coil - c}$$

and OP = x_2 =(X0+a/2) for coil c2
x_0 = distance of point P from the centre point C of two

when CP = X_0 then, $O^1P = x_0 - a/2$, and op = $x_0 + a/2 = x2$

$$\text{At } (x, r=o) = \frac{\mu_0 NI}{2R}\left(\frac{1}{(1+A_1^2)^{3/2}} + \frac{1}{(1+A_2^2)^{3/2}}\right)$$

$$A_1 = \frac{x_2}{R} = \frac{(x_0 + a/2)}{R}$$

$$A_2 = \frac{x_1}{R} = \frac{(x_0 - a/2)}{R}$$

When $x_0 = 0$, flux density has a maximum value when $a<R$ and a minimum value when $a>R$. The curve plotted for these are as shown.

When

a = R the field is

Virtually same when

$$\frac{-R}{2} < X > \frac{R}{2}$$

when a=R ($x_0 = 0$)

$$B = 0.716\ \mu_0 N\ \frac{I}{R}$$

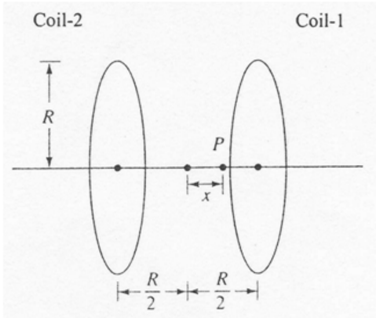
When N = 390 I_0 =0.5A R = 0.070^m

$$B = \frac{0.716 \times 4\pi \times 10^{-7} \times 390 \times 0.5}{0.070}$$

= 2.51 MT

HELMHOLTZ COILS

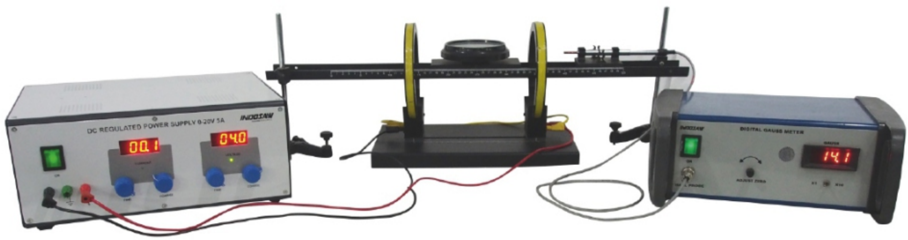
Helmholtz coils are constructed from two circular coils of wire, each perpendicular to the same axis, and each carrying the same current in the same direction. As shown in Figure right, the coils are separated by a distance R which is also the radius of each coil



We can use Equation 4 to find an expression for the B field at any point P on the axis of the coils. If the magnetic field strength due to coil 1 is B1 and that due to coil 2 is B2, then by superposition

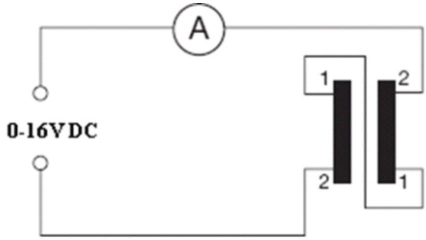
B = B1 + B2…………………..(5)

In this configuration, it is convenient to specify xo not at the center of a single coil, but rather at the midpoint between the two coils. Therefore, in the equation for B1, xo must be replaced by xo – R/2, and for B2, xo must be replaced by xo + R/2. Also note that Bo as defined above does not correspond to the field at this new position xo



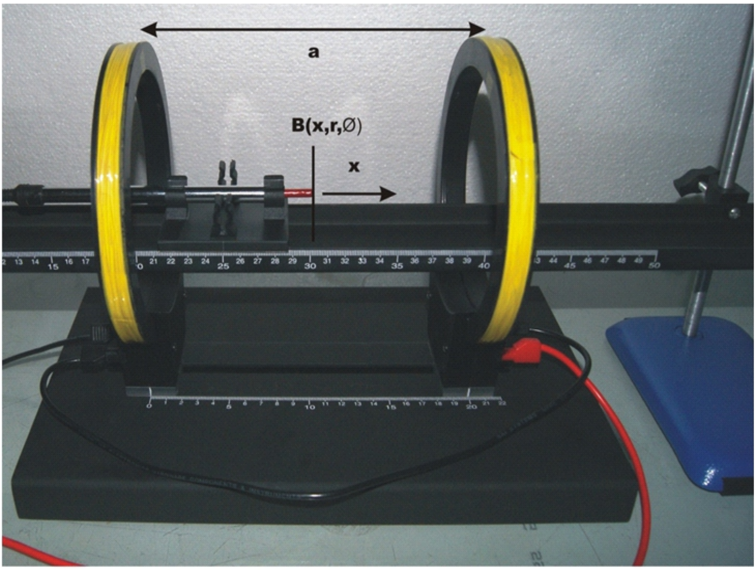
EXPERIMENTAL SETUP PROCEDURE

Connect the coils in series and in the same direction, see Fig. right the current 0.5 A (operate the power supply as a constant current source). Measure the Magnetic field with the axial Hall probe. The magnetic field of the coil arrangement is rotationally symmetrical about the axis of the coils, which is chosen as the x-axis of a system of cylindrical coordinates (x, r, Φ). The origin is at the centre of the system. The magnetic filed does not depend on the angle Φ, so only the components Bx(x, r) and Br (x, r) are measured. Clamp the axial probe on to a support base, level with the axis of the coils.



Wiring Diagram for Helmholtz Coil

HELMHOLTZ COILS ARRANGEMENT-I



Magnetic Field B along x-axis & Center x=0

1. Along the x-axis, for reasons of symmetry, the magnetic flux density has only the axial component *B*x. Figure right shows how to set up the coils, probe and rules. Measure the relationship *B* (x, *r* = 0) when the distance between the coils *a* = *R* and, for example, for *a* = *R*/2 *and a* = 2*R*

Distance	x (Cm)	B at a=R/2 (Gauss)	B at a=R (Gauss)	B at a=2R (Gauss)
0	-20	1.1	0.9	1.9
2	-18	2	1.5	3.5
4	-16	2.4	2.1	4.8
6	-14	3.9	3.1	7.9
8	-12	5.9	4.5	11.4
10	-10	8.5	6.5	16.1
12	-8	12.4	9.7	18.5
14	-6	18.7	14.7	18.3
16	-4	24.9	24.1	15.7
18	-2	30.9	25.3	13.1
20	0	32.6	25.7	12
22	2	30.5	25.3	13.1
24	4	24.8	24.1	15.8
26	6	17.8	20.2	18.1
28	8	12.1	15.4	19
30	10	8.3	10	15.8
32	12	5.6	6.9	11.9
34	14	3.8	4.5	8.6
36	16	3	2.9	5.3
38	18	2.1	1.9	3.1
40	20	1.2	1	2.3

The magnetic field along the axis of two identical coils at a distance 'a' apart is explained as

$$B(x, r = 0) = \left(\frac{\mu_0\, N\, I}{2R}\right)\left(\frac{1}{(1 + Z_1^2)^{3/2}} + \frac{1}{(1 + Z_2^2)^{3/2}}\right)$$

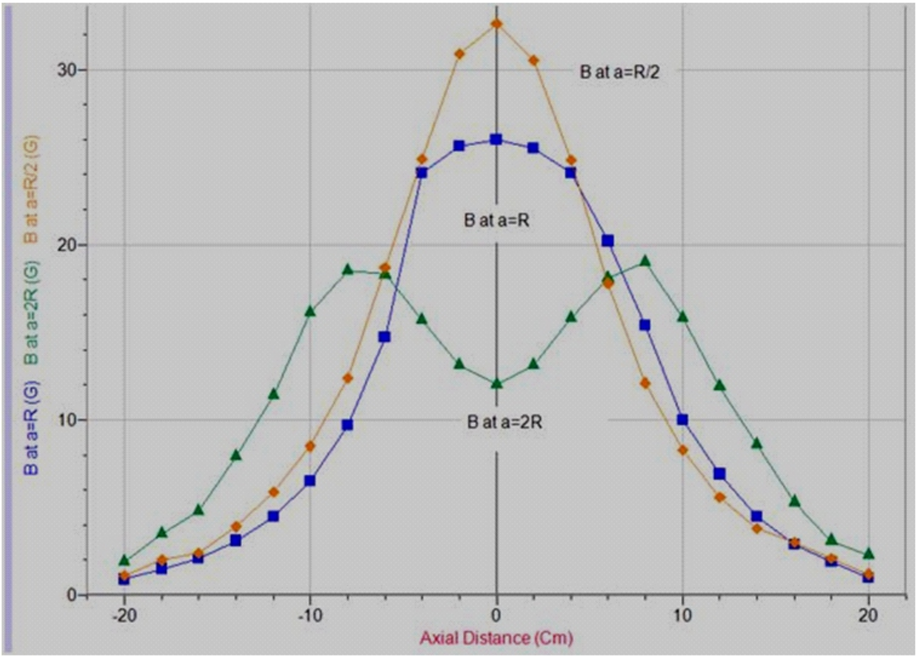
Where, $Z_1 = \frac{x+a/2}{R}$, $Z_2 = \frac{x+a/2}{R}$

When x = 0, Magnetic flux density has a maximum value when a < R and a minimum value when a > R. The curves plotted from our measurements also shown as below in figure; when a = R, the field is virtually uniform in the range $-R/2<x<+R/2$

Magnetic flux density at the mid-point when a = R is defined as

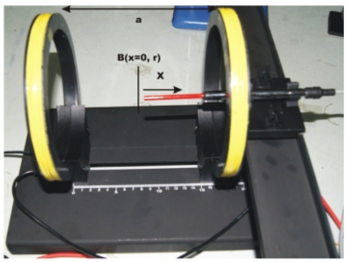
where $\mu_0 = 4\pi \times 10^{-7}$ web amp^{-1} m^{-1}

$B=0.716 \times 4 \times 3.14 \times 10^{-7} \times 390 \times 0.5/0.070$
=2.51x10^-3T=2.51mT=25.1Gauss



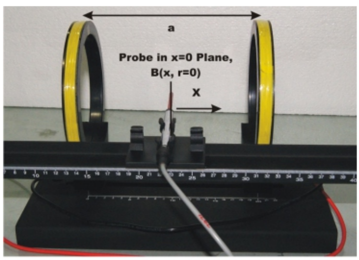
2.When distance a = R the coils can be joined together with the spacers.

a.Measure Bx (x, r) as shown in Figure above. Set the r-coordinate by moving the probe and the x-coordinate by moving the coils. Observed the magnetic flux density must have its maximum value at point (x = 0, r = 0).



Magnetic Field B(x=0,r)

b.Turn the pair of coils through 90° (Figure below). Check the probe: in the plane x = 0, Bx must = 0.



Magnetic Field B in Plane x=0