EXPERIMENT 8
Magnetic Field of a Coil

Purpose:

- To measure the magnetic field of a long coil as a function of the current I.
- To measure the magnetic field of a long coil as a function of the L length and N number of turns of wire of the coil.

Experimental Instruments:

- Coils with a variable number of turns per unit length.
- High-current power supply
- Teslameter
- Hall probe
- Multicore cable
- Support rods for coil and tube

Theoretical Information:

An electric field is produced by an electric charge, we might reasonably expect that a magnetic field is produced by a magnetic charge. However, individual magnetic charges do not exit. Magnetic field is produced by moving electrically charged particles, such as current in a wire. Stationary charges produce electric fields that are constant in time; hence the term is named electrostatics. Steady currents produce magnetic fields that are constant in time; the theory of steady currents is called magnetostatics. By steady current it is meant that a continuous flow that has been going on forever, without change and without charge piling up anywhere.

<u>The Biot-Savart Law:</u>

According to the Biot-Savart law as shown in Figure 8.1, the magnetic field **B** that is generated at a point P by a conductor passing current at r distance away is,

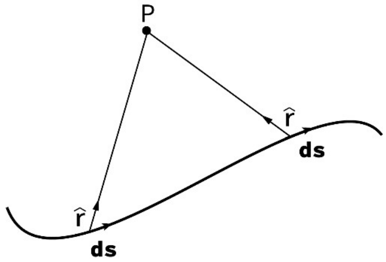

Figure 8.1 Biot-Savart Law

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$$\mathbf{B} = \frac{\mu_0 \, I}{4\pi} \int \frac{d\boldsymbol{s} \times \hat{\boldsymbol{r}}}{r^2} \tag{8.1}$$

Permeability of empty space : $\mu_0 = 4\pi \times 10^{-7} \frac{H}{m}$

In many cases, this integral calculation is quite complex and only analytical solutions can be obtained for conductors with certain symmetries (i.e. Cylindrical symmetry, spherical symmetry). It is easier to use **Ampere's law** when the magnetic field of a long coil is to be calculated.

Ampere's Law:

Ampere's Law states that for any closed loop path, the sum of the length elements times the magnetic field in the direction of the length element is equal to the permeability times the electric current enclosed in the loop (see Figure 8.2).

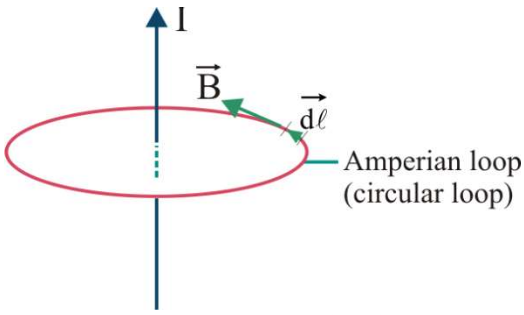

Figure 8.2 Amperian loop

$$\oint_S \boldsymbol{B}\, d\boldsymbol{\ell} = \mu_0 \int_A \boldsymbol{J}.d\boldsymbol{A} = \mu_0 \, \boldsymbol{I_A} \tag{8.2}$$

J = Current density (A/m^2),

I_A = Current passing through area A

In order to calculate the magnetic field of a long coil, A and S are chosen as in Figure 8.3. If the coil is long enough, the magnetic field inside the coil is parallel to the axis of the coil and is approximately zero outside the coil.

$$\oint_S \boldsymbol{B}.d\boldsymbol{s} = \boldsymbol{BL} = \mu_0 \boldsymbol{I_A} \tag{8.3}$$

$$I_A = N.I \tag{8.4}$$

N: Number of tuns in A

I: Current passing through the coil

L: Length of the coil

$$B = \mu_0 I \frac{N}{L} \tag{8.5}$$

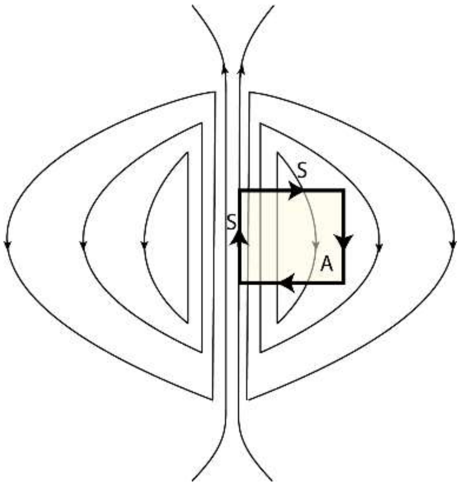

Figure 8.3 Magnetic field lines for a long coil

Experimental Procedure:

Connect the coil with a variable number of turns per unit length to the high-current power supply.

Section 1: **Measurement of the magnetic field as a function of current I**

1. Connect the Hall sensor to the teslameter using a multi-core cable, clamp on the retaining rod and adjust so that it remains in the center of the coil.
2. Turn on the teslameter to set zero and move the hall sensor to the center of the coil.
3. Push the connection slots (**b, c**) symmetrically to adjust the length of the coil to 15 cm (**b: 12.5 cm, c: 27.5 cm**). Make sure that the intervals of the turns are proper.
4. Turn on the power supply. Increase the I current in 2-A intervals (it may also be necessary to apply some voltage when adjusting the current) and in each case after recording the value of the magnetic field; set the high-current power supply to zero and do the teslametre zero setting before each new measurement.
5. Record to the **Table 8.1** the current and the magnetic field that you have measured.

Section 2: Measuring the magnetic field as a function of the length of the coil

1. Apply current I = 20A.
2. Pull the connection slots (**b, c**) symmetrically to adjust the length of the coil to different L values and determine the value of the magnetic field in each case; set the current zero value to zero before each new measurement.
3. Record the magnetic field values that you have measured for different values of the length of the coil L in **Table 8.2**.

Section 3: Measuring the magnetic field at different points on the axis of the coil

1. Apply current I = 15A.
2. Adjust the coil length to L = 30 cm.
3. Record the magnetic fields at different points at 3 cm intervals on the coil axis and record in **Table 8.3.**

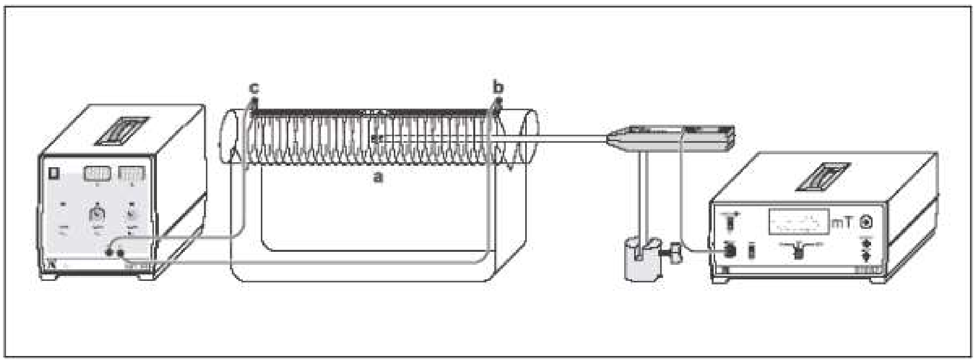

Figure 8.4 Experimental scheme

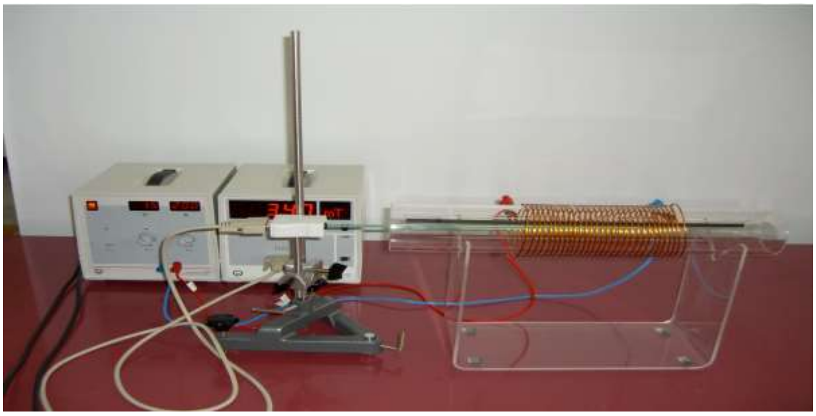

Figure 8.5 Magnetic field of a coil experiment setup

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EXPERIMENT 8

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DATE :

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Student ID	Name Surname	Signature

Experiment Expectation	

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CALCULATIONS AND RESULTS:

Section 1

Table 8.1 Magnetic field measurements at different values of current I

I **(A)**	B **(mT)**
0	
2	
4	
6	
8	
10	
12	
14	
16	
18	
20	

- Plot the B-I graph using the data from Table 8.1. Using this graph you have drawn, find the value of the permeability μ_0 of empty space. Compare this value with the actual value of μ_0.

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Section 2

Table 8.2 Magnetic field measurements at different values of L

L (**cm**)	1/L **(1/cm)**	n **(1/cm)**	B **(mT)**
8			
10			
15			
20			
25			
30			
35			
40			

- Plot the B - n (**n = N/L**: Number of turns per unit length) and $B - \frac{1}{L}$ graph using the data from Table 8.2. Check the accuracy of Eq. 8.5 using this graph you have drawn.

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Section 3

Table 8.3 Magnetic field measurements at different points on the coil axis

x (**cm**)	B (**mT**)
3	
6	
9	
12	
15	
18	
21	
24	
27	
30	

- Plot the B-x graph using the data of Table 8.3. Using this graph you have drawn, explain how the magnetic field changes on the coil axis.

DISCUSSION AND COMMENTS:

1) Discuss how magnetic fields are changed according to all the parameters (i.e. current I, lenght L, turns per unit length n, different points on the coil axis x).