KLINGER SCIENTIFIC
Bringing You Science Since 1955

BIOT-SAVART LAW - KSCIBSL

1. Key Concepts.. 2
2. Introduction.. 2
3. Objective.. 2
4. Theory.. 2-3
5. Equipment.. 4
6. Safety Instructions.. 5
7. Experimental Setup.. 5-6
8. Experiment.. 6-7

   8.1 Magnetic field due to straight conductor.................... 7

   8.2 Magnetic field due to a solenoid

9. Sample Measurements.. 7-10

   9.1 Magnetic field due to a straight conductor 9.2

   Magnetic field (B) at the center of solenoid 9.3

   Magnetic field (B) along the axis of solenoid

BIOT-SAVART LAW

1. Key Concepts

- Electromagnetism
- Magnetic Field
- Biot-Savart Law

2. Introduction

Hans Christian Oersted discovered that electric current generates magnetic field when he observed a deflection in the needle of a compass that was placed close to a current carrying conductor. This discovery gave birth to the field of electromagnetism. The mathematical formulations that describe the nature of the magnetic fields produced due to electric current was put forth by two French physicists Jean-Baptiste Biot and Felix Savart and hence it is called **Biot-Savart law**. The ability to precisely model the magnetic fields around the current carrying conductors of different geometry is crucial in designing devices in the field of electromagnetism.

3. Objective

Measure the magnetic field produced by current carrying conductors of the following geometry straight conductor and solenoid.

4. Theory

Magnetic fields exist in the region in the vicinity of the moving charges or current carrying conductors. The strength of the magnetic field at a distance from moving current carrying conductor is given by Biot-Savart law. A conductor carrying a constant current generates a uniform magnetic field around it. The direction of the produced magnetic field is given by the right hand thumb rule.

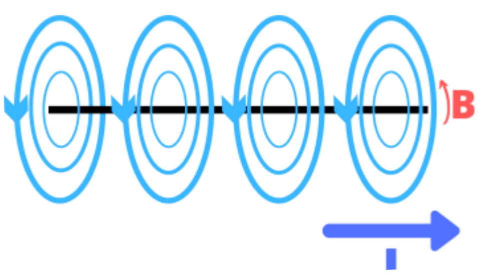


Image 1- Shows a section of a wire carrying a current I and the magnetic field around it.

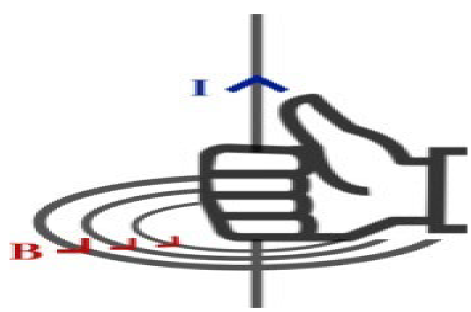


Image 2- Shows a section of a wire carrying a current I and the magnetic field around it.

BIOT-SAVART LAW

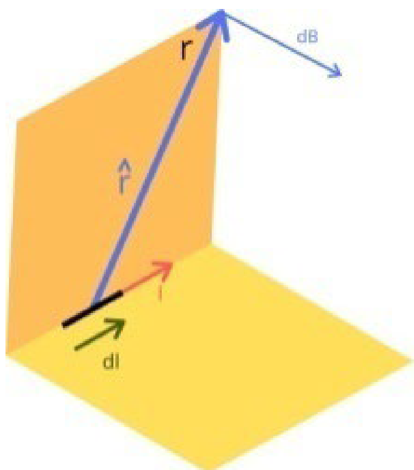


Image 3. Element dl

The magnetic field produced at a distance r due to an infinitesimally small element of the current carrying conductor under consideration, is given by the Biot-Savart law.

$$d\vec{B} = \frac{\mu_0}{4\pi} \cdot \frac{\overrightarrow{Id\ell} \times \vec{r}}{r^3} = \frac{\mu_0}{4\pi} \cdot \frac{Id\vec{\ell} \times \hat{\vec{r}}}{r^2}$$

where, dB is the magnitude of magnetic field, μ_o is the permeability of free space

$\mu_o = 4\pi \times 10{-}7 \ \frac{T \, . \, m}{A}$

I is the magnitude of current flowing through the conductor.

$\overrightarrow{dl}$ is the length of the conductor under consideration, r is the distance between the segment of the conductor under consideration and $\vec{r}$ is the unit vector along r.
In particular, for an infinite long straight conductor, the induction of the magnetic field at a point of space at a distance r therefrom is determined by

$$B = \frac{\mu_0}{2\pi} \cdot \frac{I}{r}$$

Induction of the magnetic field generated by a solenoid element of length dz located at a distance z from the observation point

$$dB = \frac{\mu_0 I}{2} \cdot ndz \cdot \frac{R^2}{(R^2 + z^2)^{3/2}}$$

where n is the number of turns per unit length. Then $N = ndz$ is the number of turns on the dz segment. For the field along the solenoid axis, we can write

$$B(z) = \frac{\mu_0 I}{2} \frac{NR^2}{(R^2 + z^2)^{3/2}}$$

where z is the point on the solenoid axis, calculated from its center, B (z) is the magnetic field at the z point, N is the number of turns at the z segment, R is the radius

The induction of the magnetic field at the center of the circular current (one turn) is given by

$$\vec{B} = \frac{\mu_0}{2} \cdot \frac{I}{R} \vec{k}$$

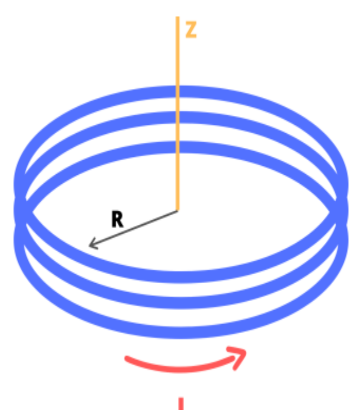
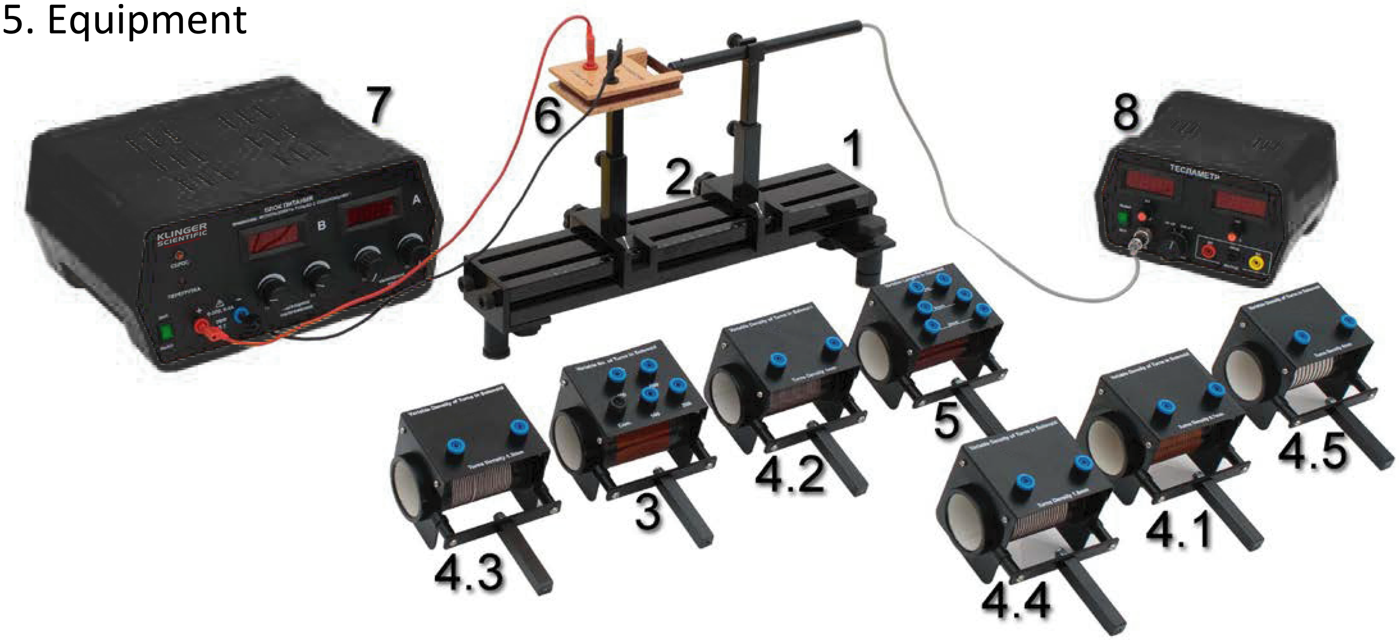


Image 4. Solenoid with turns of radius, along which current flows

5. Equipment



S.No	Equipment	Item Code	Qty
1	Optical Bench Set 0.4m	KSCIOB2	1
2	Solenoid with variable turns	KSCIHA015	1
3	Solenoid with variable length	KSCIHA016	1
4	Solenoid with different winding density (Set)	KSCIHA017	1
4.1	Winding pitch 0.714 mm		1
4.2	Winding pitch 1 mm		1
4.3	Winding pitch 1.285 mm		1
4.4	Winding pitch 1.875 mm		1
4.5	Winding pitch 4 mm		1
5	Straight conductor of specified length	KSCIHA018	1
6	Teslameter, with Axial and Tangential Hall Probe	KSCIPH93240	1
7	Power Supply 0-30V,5A	KSCIPS61035D/5	1

6. Safety instructions

- The horizontal bench and power supply are quite massive. Be careful when installing and using it.
- A significant direct current is applied to the coils. It is forbidden to use pipelines without insulation to connect them. Do not touch the electrical terminals of the unit run-in.
- Always turn off power to the coils before replacing them. To prevent burns, do not to the coils with your bare hands. Use heat-insulating gloves

7. Experimental Setup

Image 5.Experimental installation with conductors of various configurations and axial Hall sensor

- Place the bench on a stable and strong surface, achieve horizontal positioning of the bench.
- Carefully place the conductor under study in the holder on the bench.
- Connect the conductor according to the connection diagram.
- Place the Hall sensor in the sensor holder and connect it to the tesla meter.

List of experiments that can be performed

A.Magnetic Field due to straight conductor

I. Measurements of magnetic field (B) as a function of distance (z) at a constant current value.

II. Measurements of the magnetic field (B) as a function of the current (I) at a constant distance.

B.Magnetic Field due to Solenoid

I. Measurements of the magnetic field (B) as a function of the current (I) in the center of the solenoid under study.

II. Measurements of the magnetic field (B) as a function of the number of turns (N) in the center of the solenoid under study at a constant current value.

III. Measurements of the magnetic field (B) at different points on the solenoid axis (z) at a constant current value.

C.Magnetic Field due to different winding densities

I. Measurements of the magnetic field (B) as a function of the winding density at the center of the solenoids under study at a constant current value.

8. Procedure for conducting experiments

8.1. Direct conductor magnetic field

1. Securely secure the straight conductor in the holder and place it on the horizontal bench.
2. Secure the Hall sensor in the holder.
3. Connect the Hall sensor and direct conductor to the power supply.
4. Bring the Hall probe to the straight conductor. Take the corresponding reading of the Hall sensor as zero.
5. Measure distances relative to the zero reference point.

The variables in this experiment are: current through the conductor (I), the distance between the conductor and the Hall sensor (z).

Experiment 8.1.1. B vs Z (I constant)

At a constant current value (I), measure the magnetic field (B) as a function of the distance from the straight conductor (z) and record the results in the table. Plot the obtained data.

Experiment 8.1.2. B vs I (z constant)

At a constant distance to the straight conductor (z), measure the magnetic field (B) as a function of current (I) and record the results in the table.Plot the obtained data.

8.2. Solenoid magnetic field

The variables in this experiment are current (I), number of turns (N), winding density (wd), axial distance from the center of the solenoid (z).

Experiment 8.2.1. B vs I at the center of the coil (z=0) & N is constant.

For a solenoid with a given number of turns (N), measure the magnetic field (B) in the center of the solenoid as a function of current (I). Record the readings in the table and plot them.

Repeat the experiment for a solenoid with a different number of turns (N).

Experiment 8.2.2. B vs N at the center of the coil (z=0) & I is constant.

Measure the magnetic field (B) at the center of the given solenoid. For a constant current (I). Repeat the process for solenoids of different number of turns(N). Tabulate the readings and plot the obtained data.

Experiment 8.2.3. B vs z N constant & I is constant

Measure the magnetic field (B) at various positions along the axis of the given solenoid. For a constant current (I) and constant number of turns. Repeat the process for the solenoid of different number of turns(N). Tabulate the readings and plot the obtained data.

Experiment 8.2.4. B vs wd N constant & I is constant

Measure the magnetic field (B) at the center of a solenoid of a given winding density (Wd) for a constant current (I). Repeat the process for solenoids of different winding density. Tabulate the readings and plot the obtained data

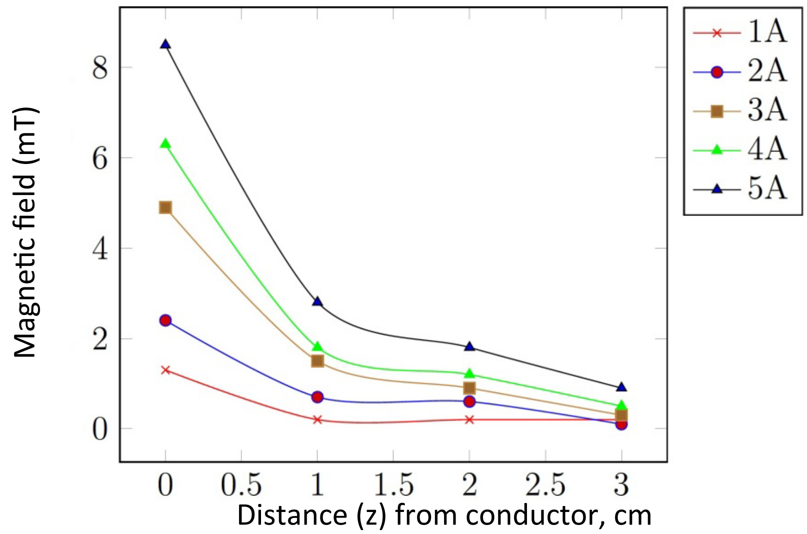
9.Measurement Example

9.1 Magnetic field due to a straight conductor

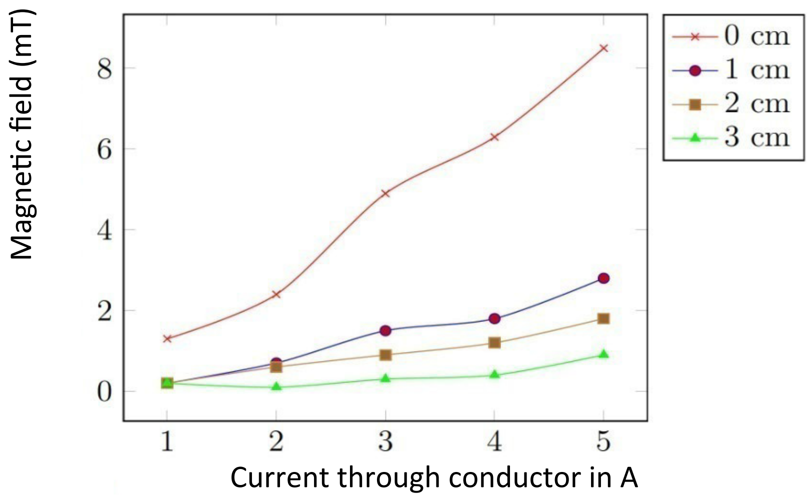
Table 1. Magnetic field (B) depending on the distance (z) from the conductor

Distance (z) from conductor, cm	Magnetic field (mT) for different current values				
	I = 1A	I = 2A	I = 3A	I = 4A	I = 5A
0	1.3	2.4	4.9	6.3	8.5
1	0.2	0.7	1.5	1.8	2.8
2	0.2	0.6	0.9	1.2	1.8
3	0.2	0.1	0.3	0.5	0.9

Magnetic field (B) depending on the distance (z) from the conductor



Magnetic field (B) vs current through straight conductor

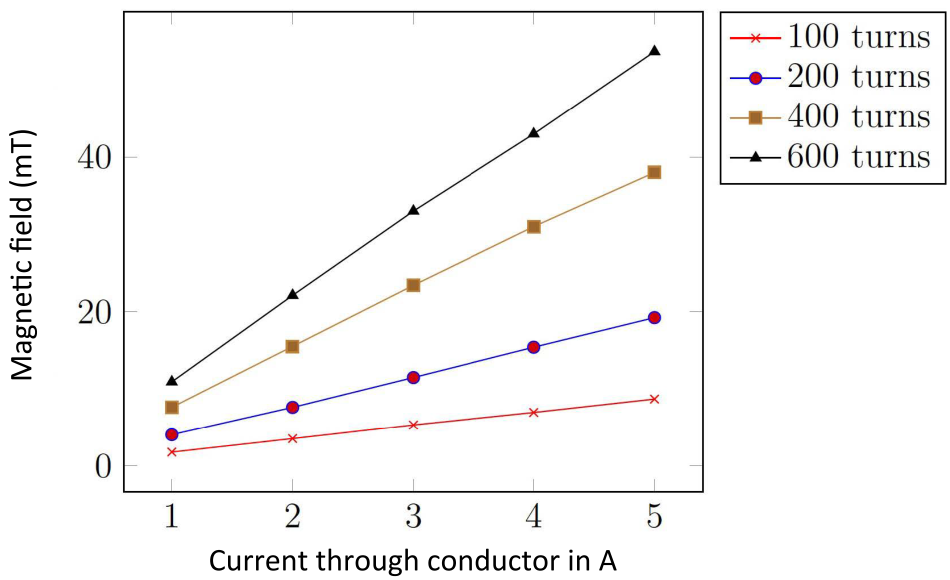


9.2 Magnetic field at the center of solenoid

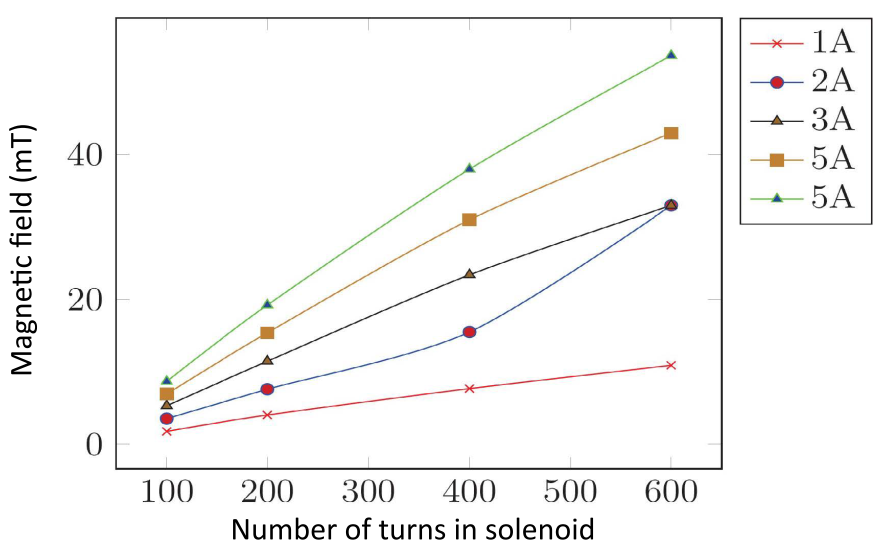
Table 2. Magnetic field (B) of solenoid depending on number of turns (N)

Current (I), A	Solenoid magnetic field (mT) for different number of turns (N)			
	N = 100	N = 200	N = 400	N = 600
1	1.77	4.03	7.68	10.9
2	3.52	7.59	15.5	22.1
3	5.3	11.46	23.4	33
4	6.93	15.39	31	43
5	8.67	19.22	38	53.7

Magnetic field (B) vs Current (I) through solenoid



Magnetic field (B) vs No. of turns (N)



9.3 Magnetic field along axis of solenoid

Table 3. Magnetic field (B) along solenoid axis as a function of current (I)

Distance (z) along the axis relative to the center, mm	Magnetic field (mT) for different current values = 100				
	I = 1A	I = 2A	I = 3A	I = 4A	I = 5A
0	0.3	0.8	1.1	1.4	1.8
5	0.4	0.9	1.4	1.8	2.3
10	0.5	1.2	1.7	2.2	2.7
15	0.7	1.4	2.3	3	3.2
20	0.7	1.5	2.5	3.3	3.6
25	0.8	1.7	2.6	3.5	4.1
30	0.9	1.8	2.7	3.6	4.3
35	0.9	1.8	2.7	3.6	4.4
40	0.9	1.8	2.6	3.4	4.4
45	0.9	1.8	2.4	3.2	4.2
50	0.8	1.7	2.1	2.9	3.8
55	0.8	1.5	1.9	2.5	3.5
60	0.7	1.3	1.6	2.2	3.1
65	0.6	1.1	1.3	1.8	2.6
70	0.5	0.9	1	1.4	2.1
75	0.4	0.7	0.8	1.1	1.7
80	0.3	0.6	0.7	0.9	1.3
85	0.2	0.5	0.5	0.7	1.1
90	0.2	0.4	0.4	0.6	0.9

Magnetic field along axis of solenoid