Magnetic Fields lab

Introduction
The purpose of this lab is to explore magnetic fields produced by electric currents, and the force felt by a current-carrying wire in the presence of a magnetic field. You will measure the dependence of the field strength on the number of wraps in the loop or solenoid, and the current in the circuit. There are four parts to the lab, which can be done in any order.

You will be using an FW Bell Gaussmeter to measure the strength of the magnetic field. The axial probe (the round one) measures the field parallel to the probe. The field will be measured in Gauss. 10,000 Gauss equals 1 Tesla.

To use the meter:
1. Zero the meter
   a. Place the probe in the zero-gauss chamber
   b. Turn the meter on
   c. Turn knob to “Zero”
   d. Hit the “Auto” button
   e. The meter display will flash “Auto Zero” for a few seconds and then beep.

2. To make a measurement
   a. Turn the knob to “measure”
   b. Hit the “auto” button for auto ranging
   c. Place the probe tip at the location of your measurement. Make a test measurement of the Earth’s magnetic field. It should read about 0.5 Gauss.

I. Solenoids
A solenoid is a conducting wire wrapped in a tight helical coil. A current in the wire will produce a strong magnetic field within the coil. The field is strong and uniform inside the solenoid, but fairly weak outside. An ideal solenoid is one with very tightly wrapped coils and is infinitely long. The tightly wrapped coils can be approximated by N cylindrically stacked current loops.

Using Ampere’s Law on the path shown in figure 1, the magnetic field inside the solenoid is:

\[ \oint (\mathbf{B} \cdot d\mathbf{l}) = Bl = \mu_0 IN \]  

where \( B \) is the strength of the magnetic field in Tesla, \( l \) is the length of the path, \( \mu_0 = 4\pi \times 10^{-7} \) (Vs/Am), \( N \) is the number of wraps in the solenoid, and \( I \) is the current in Amperes in the wire coils.

When Ampere’s Law is applied to a path shown in figure 1, the horizontal side external to the solenoid contributes nothing to the integral since \( \hat{B} \) is zero outside of the solenoid. The vertical sides of the path do not contribute to the integral since \( \hat{B} \) is perpendicular to the path on those
sides. Therefore, the only contribution occurs inside the solenoid. The field inside the solenoid is

\[ B = \frac{\mu_0 IN}{l} \]  \hspace{1cm} (2)

1. Record the number of wraps (N) for the solenoid. Record the length (l) of the solenoid (just the section that includes the wire wraps). Set up the following circuit:

![Figure 2](image)

Zero the meter. Next, vary the current through the circuit from 0 to 2 Amps. *Note: be careful, the resistor will get very hot!* Record the current (I) through the solenoid and the strength of the magnetic field in the center of the solenoid for each measurement. Plot B vs. I. Perform a line fit to your data. What should the value of the slope be theoretically? How close is your slope value to the theoretical value?

2. Replace the solenoid in the circuit with a solenoid that has the wraps concealed by a paper sleeve. Repeat the measurement in part 1. Find the average number of wraps per length: \( n = \frac{N}{l} \) for this solenoid by looking at the slope of your B vs. I graph. Remove the paper sleeve and measure n. Compare your two numbers.

### II. Wire swing

1. At this lab station, you will find a Genecon generator, and a U-shaped wire hanging between the poles of a magnet. What do you predict will happen if you put a voltage from your generator across the ends of the U shaped wire? Use the right hand rule, along with the direction of the magnetic field to predict directions.

2. Connect your Genecon to the bare loops of wire (not through the resistor, if one is attached) around the horizontal bar on the ring stand. Turn the handle clockwise and note what happens. Turn it counterclockwise. Turn it fast, turn it slow. Alternate CW and CCW. Explain the results.

3. Use the protractor attached to the ring stand to measure the largest angle you can get the wire to swing to by only rotating in one direction. Now, put a resistor in series with the U shaped wire and measure how high you can get the wire to swing by only rotating in one direction. Why is there a difference?
III. Magnetic fields produced by a wire carrying an electric current

Magnetic fields are created whenever an electric current moves through a wire. This experiment will explore this phenomenon. You will be measuring the direction of the field using a compass. The compass is composed of a lightweight permanent bar magnet suspended on a pivot point. When the compass is placed in a magnetic field, the external field creates a torque on the compass needle, causing it to rotate until it is aligned with the external field.

1. Begin by building the following circuit out of a power supply, a switch, and some wires. With the power supply off, align the straight wire so that it lines up with the compass needle when the current is off. Place a compass on top of the wire as shown.

   ![Diagram of a simple circuit with a power supply and a compass](image)

   Figure 3

   Turn on the power supply. Increase the voltage gradually. Do not exceed 2 Amps of current. Observe the compass needle. Turn the power supply off, place the wire on top of the compass. Turn the power supply on again and observe the behavior of the compass needle. Turn the power supply off.

   2. Switch the wires attached to the power supply (red to black, black to red) so that the current runs the other direction. Repeat part 1.

   3. Deduce the direction of the magnetic field created by the current in the wire based on your results from parts 1 and 2.

IV. Torque on a current loop.

Go to the station that has a Genecon generator, a horse-shoe magnet, and a suspended wire that contains a small wire coil. When a current is run through the coil, a magnetic field is created perpendicular to the coil. Place the horseshoe magnet so that the coil rests between the magnet poles. Turn the Genecon handle clockwise to start the current through the coil. Observe what happens. Can you deduce the direction of the magnetic field created by the current in the wire coil by watching the coil’s reaction? Does the direction of this magnetic field created by the current in the coil agree with the right hand rule? Repeat by turning the Genecon handle counter-clockwise.