**EXPERIMENT: THE MAGNETIC FIELD OF A COIL**

[Equipment list: Computer Laptop, Computer Interface, Magnetic Field Probe, DC Power Supply, 270-turn Coil, 122-cm Track, Ring Stand, Ring Stand Clamp, PVC Tubing, Ruler, Vernier Caliper, Wires]

**Overview:**

It has been shown that a current carrying wire generates a magnetic field about it. When this wire is wrapped into the shape of a coil the magnetic field becomes uniform within the coil and near zero outside of the coil. For this experiment, you, the experimenter, will measure the magnetic field of the coil with a magnetic field sensor hooked up to a computer interface as a function of distance and graph this data.

**Part 1: Magnetic Field within a Coil**

In this experiment you will measure the magnetic field along the axis of a long coil (solenoid) and compare the data with the following equation:

This equation represents the magnetic field (measured in Tesla) along the axis of the coil. The value µo is the permeability of free space, and is approximately equal to 4π x 10-7 H/m (=1.26 x 10-6 H/m). I is the current in amperes. N is the number of turns of the coil. The variable is the length of the coil in meters. The variables x1 and x2 are measurements along the coil as indicated in the following diagram in meters. Finally, r is the radius of the coil in meters.

x1

x2

B

r

figure 1: Cut-away view of coil

As you can see, x1 is the distance from one side of the coil to a point B along the axis, while x2 is another distance from the other end of the coil to the same point B.

The magnetic field sensor used in this experiment has a Hall probe centered in the rotatable tip (its position is marked as a white line near the end of the rotatable tip). This will be the “point” from which you will determine the position with respect to the coil. The magnetic field sensor is held stationary during the data taking so that no extraneous magnetic field values will be sensed during data taking. Instead, the coil is moved to change the position of the “point” of the magnetic field sensor within the coil.

The magnetic field sensor is inserted into a length of PVC tubing and the tubing is clamped to the ring stand so that PVC tubing and probe are horizontal. Set the solenoid coil on the track and adjust the height of the magnetic field probe so that it is centered to the solenoid coil.

B

Length of Solenoid Coil

Figure 2: Magnetic Field Probe

The copper wire of the solenoid coil is wrapped around another tube of PVC material and has two endcaps that act as a stand. The coil starts and stops on the inside edges of these two endcaps. To measure the length of the coil measure from the inside edge of one endcap to the inside edge of the other endcap. An approximate average diameter of the coil can be determined by measuring the outer diameter of the coil (it is covered by a clear plastic sleeve, measure this) and the inner diameter of the white PVC tubing that the coil is wrapped around. Average these two diameters.

With the ring stand at one end of the track (as shown in figure 2) such that the track scale starts at 0 centimeters at this end, determine the position of the Hall probe using the centimeter scale on the track and record this position.

Slide the solenoid coil such that the magnetic field probe passes through the center of the coil, all the way to very near the end of the track. The coil should now be very near the ring stand and the magnetic field probe should be sticking out of the other side of the solenoid coil.

Turn on and adjust the DC voltage source to 1.5 volts. Record the current below. Also, record the magnetic field at this first position in the table below. Determine the initial position for X1 using the track position of the Hall probe and the track position of the end of the coil. Record this initial X1 in Table 1. Move the coil one centimeter and record the field again. Continue this to the other end of the coil. When you reach the other end of the coil continue to move the coil in one-centimeter increments away from the coil, recording the magnetic field outside of the coil, but still along the axis of the coil, for 7 more data points. Plot this data on a graph of the magnetic field in Tesla (y-axis) versus the distance, X1, in meters (x-axis).

**Answer the questions A, B, C, and D in the Results section of your lab report.**

**Question A: How does the magnetic field vary as you move the magnetic field sensor towards the end of the coil, but while still near the middle of the length of the coil?**

**Question B: How does the magnetic field change as the sensor nears the end of the coil, but still inside the coil? How does the magnetic field change as the sensor leaves the end of the coil?**

When measuring the positions of x1 and x2, inside the coil x2 takes on negative values. When the magnetic field probe is outside of the coil (probe on the left side of the coil), both x1 and x2 are negative (keeping with the convention we started with). Plot on the same graph as your measured values of the magnetic field the magnetic field as determined with equation (1) for the same positions (x1) of the measured field values. **Generate graph on Excel worksheet**.

**Question C: How many data points passed the end of the coil did it take for the magnetic field to be essentially near zero as compared to the maximum value measured at the middle of the length of the coil?**

Use the magnetic field sensor to measure the magnetic field at various points along the length of the outside of the coil.

**Question D: What values of the magnetic field did you measure at various points along the length of the outside of the coil?**

**Part 2: Determination of the Inductance of the Coil**

**Inductance by Equation**

For a tightly packed coil the inductance of the coil is determined from the following equation:

In this equation the L stands for inductance of the coil, N is the number of turns of the coil, ΦB is the magnetic flux through each coil, and I is the current through the wire of the coil. The flux is the product of the magnetic field passing through an area perpendicular to the field. The cross-sectional area of the coil is that for a circle.

Equation (1) can be simplified to determine the magnetic field at the midpoint between the two ends inside the coil by assuming that >> r. This relationship becomes:

Substituting equations (3), (4), and (5) into equation (2) results in:

This equation determines the inductance of a solenoid using only the physical aspects of the coil. Determine the inductance of the coil using equation (5), **calculate and show work on the Excel worksheet**.

**Inductance by Experiment**

Another way to determine the inductance of the coil is to measure the magnetic field for various currents running through the coil. Plotting this data and determining the slope of the graph will lead you to determine the inductance.

Combining equations (2) and (3) results in:

Here it can be seen that the slope of the magnetic field versus current graph is equal to . To determine the magnetic field for different current values insert the magnetic field probe so that it resides at the midpoint of the length of the coil. Attach the DC voltage source to the coil and start with 0 volts and 0 current. Zero the magnetic field sensor. Adjust the voltage until a reading of 0.30 amps is displayed. Record the magnetic field for this initial current. Increase the voltage such that the current is increased as indicated in Table 2 on the Excel worksheet, recording the corresponding magnetic fields.

Plot the magnetic field versus the current on the Excel worksheet and determine the slope of the line.

Determine the inductance of the coil. **Show work on the worksheet**.

**Further Questions (Answer these in your report numbering your answers to reflect the question numbers.)**

1. How well does the graph of the equation for the magnetic field compare to the graph of the measured magnetic field? Are the magnitudes of each value reasonably the same? Is the inflection point of the field near the end of the coil occurring at the same position?

2. Compare the inductance of the coil found by equation to that of the inductance of the coil found by experiment. Use the percent difference formula to do this comparison.

A percent difference of less than 10% is considered acceptable.

3. The magnetic field outside of the coil is said to equal zero, or near zero Tesla. Why is this so? What physically is happening to cause this?

4. For each of the currents listed in table 2, and using the inductance of the coil found by experiment, determine the total stored energies in the coil.