

PHYSICS 1040L

LAB 5: MAGNETIC FIELD

Objectives:

1. Determine the relationship between magnetic field and the current in a solenoid.
2. Determine the relationship between magnetic field and the number of turns per meter in a solenoid.
3. Study how the field varies inside and outside a solenoid.
4. Determine the value of μ_0 , the permeability constant.

Apparatus: Computer with Windows 7, Vernier LabPro computer interface, DC power supply, *Logger Pro 3.8.* software*, connecting wires, Vernier Magnetic Field Sensor, tape, Slinky, Single Pole Single Throw knife Switch.

Theory:

A solenoid is made by taking a tube and wrapping it with many turns of wire. A metal Slinky® is the same shape and will serve as our solenoid. When a current passes through the wire, a magnetic field is present inside the solenoid. Solenoids are used in electronic circuits or as electromagnets.

From Ampere's law, it can be shown that the magnetic field B inside a long solenoid is:

$$B = \mu_0 n I \quad (1)$$

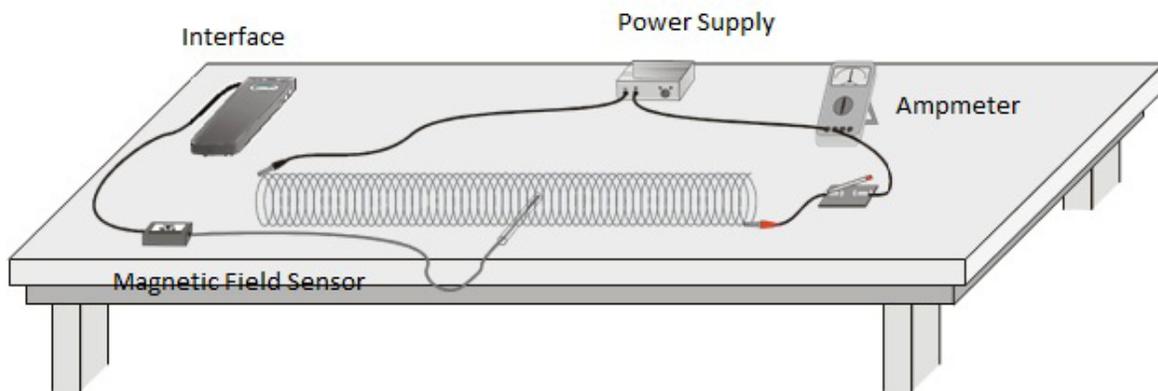
where μ_0 is the permeability constant, n is the density of turns, and I is the current through the solenoid.

In this lab we will explore factors that affect the magnetic field inside the solenoid and study how the field varies in different parts of the solenoid. By inserting a Magnetic Field Sensor between the coils of the Slinky, you can measure the magnetic field inside the coil. You will also measure μ_0 , the permeability constant. The permeability constant is a fundamental constant of physics.

Initial set up

1. Connect the Vernier Magnetic Field Sensor to Channel 1 of the interface.
2. Set the switch on the sensor to 0.3 mT (high amplification).
3. Turn on the computer.
4. Open the program LoggerPro 3.8.*.
5. Stretch the Slinky until it is 1 m long. The distance between the coils should be about 1 cm. Use a non-conducting material (tape, cardboard, etc.) to hold the Slinky at this length.

Figure 1: Experiment Setup



6. Turn on the power supply and adjust it so that the ammeter reads 2.0 then close the switch if one is used. You must also adjust the voltage to about 5 V. Note: This lab requires fairly large currents to flow through the wires and Slinky. Only turn on the power supply and close the switch so the current flows when you are taking a measurement. The Slinky, wires, and possibly the power supply may get hot if left on continuously.

7. Open the file “26 Mag Field Slinky” in the *Physics with Vernier* folder. A graph will appear on the screen. The meter displays magnetic field in millitesla, mT. The meter is a live display of the magnetic field intensity.

8. Explore: Place the Magnetic Field Sensor between the turns of the Slinky near its center. Rotate the sensor and determine which direction gives the largest magnetic field reading.

What direction is the white dot on the sensor pointing relative to the field? _____

9. What happens if you rotate the white dot to point the opposite way? _____

10. What happens if you rotate the white dot so it points perpendicular to the axis of the solenoid? _____

Procedure

Part I How Is the Magnetic Field in a Solenoid Related To the Current?

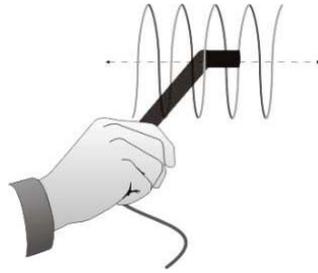
For the first part of the experiment you will determine the relationship between the magnetic field at the center of a solenoid and the current flowing through the solenoid. As before, leave the current off except when making a measurement.

1. Count the number of turns of the Slinky and measure its length. If you have any unstretched part of the Slinky at the ends, do not count it for either the turns or the length. Calculate the number of turns per meter of the stretched portion. Record the length, turns, and the number of turns per meter in the data table. Place the Magnetic Field Sensor between the turns of the Slinky near its center. See Figure No. 2.

2. Turn on the power supply and rotate the sensor so that the white dot points directly down the long axis of the solenoid. This will be the position for all of the magnetic field measurements for the rest of this lab. Turn the power supply off.

3. Click to begin data collection. Wait a few seconds and close the switch to turn on the current.

Figure 2: Magnetic Sensor inside Slinky



4. If the magnetic field increases when the switch is closed, you are ready to take data. If the field decreases when you close the switch, rotate the Magnetic Field Sensor so that it points the other direction down the solenoid.
5. With the Magnetic Field Sensor in position and the power supply off, click the Zero button , zero the sensor and remove readings due to the Earth's magnetic field, any magnetism in the metal of the Slinky, or the table.
6. Adjust the power supply so that 0.5 A will flow through the coil.
7. Click to begin data collection. Read the magnetic field for at least 10 seconds during the data collection.

8. View the field vs. time graph and determine the region of the curve where the current was flowing in the wire. Select this region on the graph by dragging over it. Determine the average field strength while the current was on by clicking the Statistics button, . Record the average field in the data table.

9. Increase the current by 0.5 A and repeat Steps 7 and 8.

10. Repeat Step 9 up to a maximum of 2.0 A.

Part II How is the Magnetic Field in a Solenoid Related to the Spacing of the Turns?

For the second part of the experiment, you will determine the relationship between the magnetic field in the center of a coil and the number of turns of wire per meter of the solenoid. You will keep the current constant. Leave the Slinky set up as shown in Figure 1. The sensor will be oriented as it was before, so that it measures the field down the middle of the solenoid. You will be changing the length of the Slinky from 0.5 to 1.0 m to change the number of turns per meter.

11. Adjust the power supply so that the current will be 1.5 A.

12. With the Magnetic Field Sensor in position, but no current flowing, click to zero the sensor and remove readings due to the Earth's magnetic field and any magnetism in the metal of the Slinky. Since the Slinky is made of an iron alloy, it can be magnetized itself. Moving the Slinky around can cause a change in the field, even if no current is flowing. This means you will need to zero the reading each time you move or adjust the Slinky.

13. Click to begin data collection. Close and hold the switch for about 10 seconds during the data collection. As before, leave the switch closed only during actual data collection.

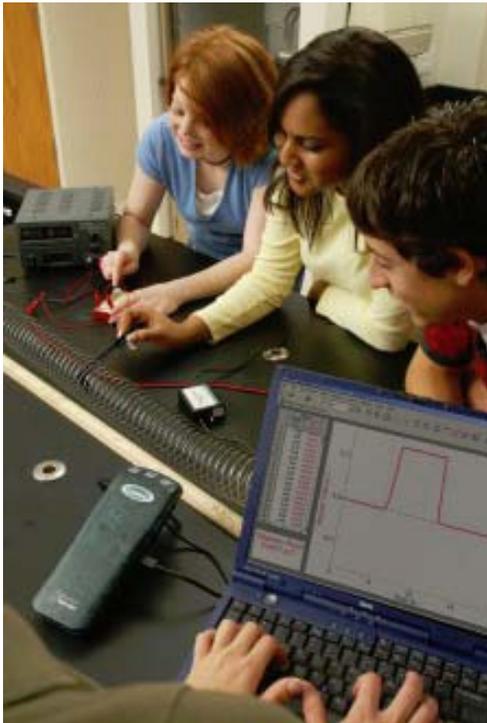
14. View the field vs. time graph and determine where the current was flowing in the wire. Select this region on the graph by dragging over it. Find the average field while the current was on by clicking on the Statistics button, . Count the number of turns of the Slinky and measure its length. If you have any unstretched part of the Slinky at the ends, do not count it for either the turns or the length. Record the length of the Slinky and the average field in the data table.

15. Repeat Steps 13–15 after changing the length of the Slinky by 10 cm at a time to 0.9 m, 0.8 m, 0.7 m, 0.6 m, and 0.5 m. Each time, when power supply is off readjust the slinky to a new length, make sure that the sensor is in the center of the slinky; zero the Magnetic Field Sensor with the current off.

16. Make sure that the current remains at 1.5 A each time you turn it on.

Data analysis

1. Transfer your data from the data page to an EXCEL file or you may use Vernier's Graphical Analysis or LoggerPro.
2. Plot a graph of magnetic field B vs. the current I through the solenoid for the Part 1 data. How is the magnetic field related to the current through the solenoid?
3. Determine the equation of the best-fit line, including the y-intercept. Note the constants and their units.
4. Calculate μ_0 , the permeability constant, using equation (1).
5. For each of the measurements of Part II, calculate the number of turns per meter. Enter these values in the data table.
6. Plot a graph of magnetic field B vs. the turns per meter of the solenoid (n) from Part 2 of your data.
7. Determine the equation of the best-fit line to your graph. Note the constants and their units
8. Calculate the value of μ_0 using your graph of B vs. n and equation (1).
9. Look up the value of μ_0 , the permeability constant.
10. Compare it to your experimental values in Part 1 and Part 2.



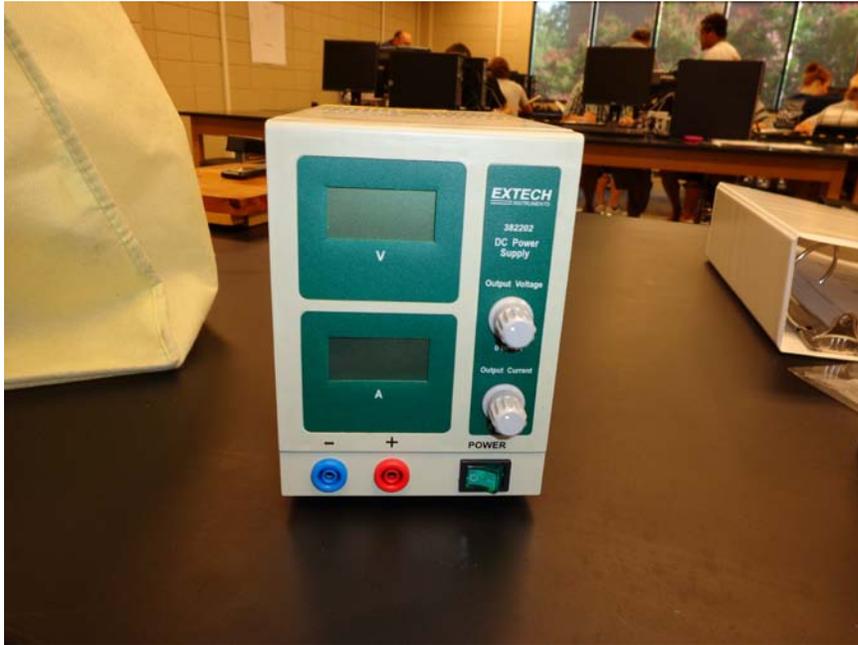


Figure 3: EXTECH Power Supply

Figure 4: Magnetic Field Sensor



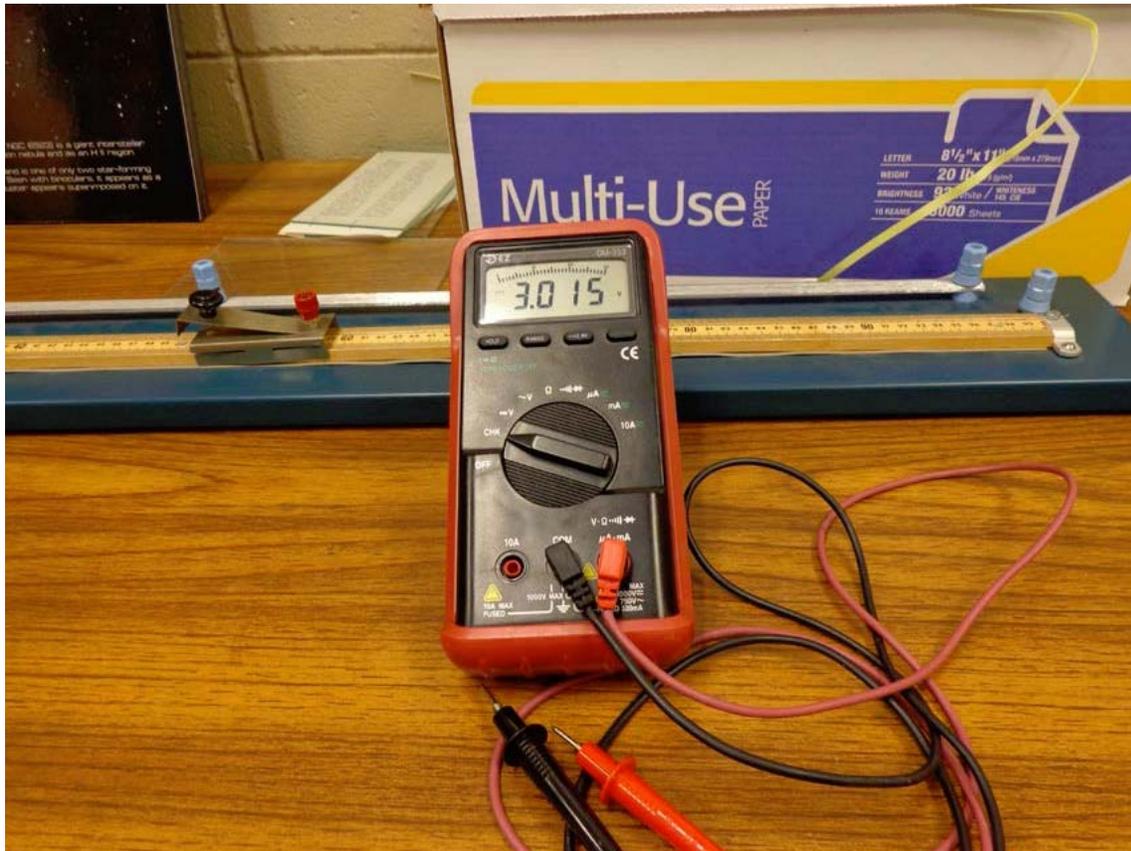


Figure 5: Multimeter. In previous labs we used this device to measure Voltages and Resistances. In this lab we will use it to measure currents



Figure 6: Single Pole Single Throw Switch