The Magnetic Field of a Solenoid

Contents

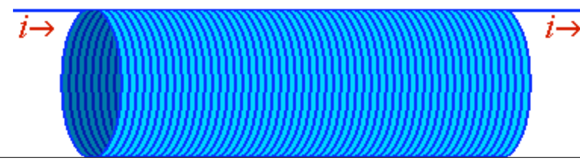
Introduction

In this lab we will explore the factors that affect the magnetic field inside a solenoid, and how the field varies in different regions of the solenoid.

A solenoid is composed of a number of turns of a conducting material, arranged in a cylindrical fashion. A Slinky is a good example of a solenoid.

Current passing through the Slinky creates a magnetic field inside the solenoid.

Solenoids are commonly used in electronic circuits, and electromagnets.



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Part I: Set-up

Connect the Vernier Magnetic Field Sensor to Channel 1 on the LabPro interface.

Set the switch on the sensor to **LOW**.

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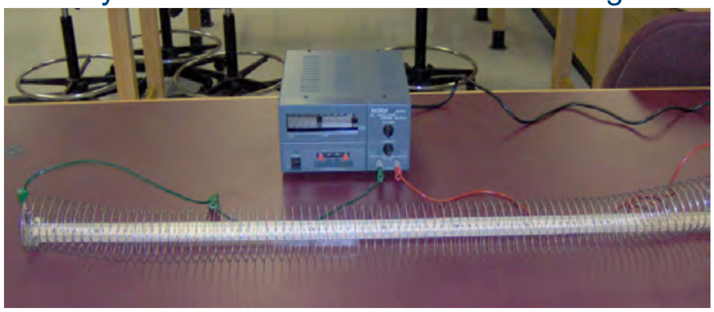
Set-up continued…

Use the metre stick and silver clamps provided stretch the Slinky so that it is about one metre in length.



Set up the circuit as shown in the figure above.

Use alligator clips to connect the Slinky to the power supply, and to help hold it to the metre stick clamps.

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Set-up continued…

Turn on the power supply and adjust the settings so that the current in the Slinky is 2.0 A when the switch is closed (**power on**).

This lab requires a fairly large current to flow through the Slinky. Only close the switch when taking measurements. If the switch is left closed for a period of time the apparatus may become extremely HOT!

Launch the ***LoggerPro*** program by clicking on the icon below.

Logger Pro

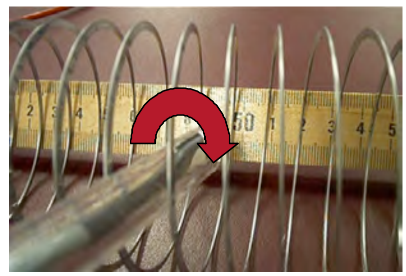
It should open with an empty graph of *Magnetic Field* versus *Time*. The time axis should have a maximum of 60 seconds.

If the data collection stops in less than 60 seconds, click **EXPERIMENT** then **DATA COLLECTION** and change the time to 60 seconds.

Part II:
Using the Magnetic Field Sensor

Open the switch (**power off**).
Place the Magnetic Field Sensor between the turns of the Slinky near its centre.
Click the **Zero** button (this removes contributions due to the Earth's magnetic field).
Close the switch (**power on**).
Click **Collect** in ***LoggerPro*** to begin taking some sample data.

Rotate the sensor to determine which direction gives the largest field measurement.



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Using the Magnetic Field Sensor

QUESTION 1: What direction is the white dot on the sensor pointing, relative to the axis of the solenoid, when the largest positive field measurement is registered? Specify if it is perpendicular or parallel to the axis and which terminal the white dot is facing.

Perpendicular to the axis means that the white dot is facing either the ceiling or the floor.

QUESTION 2: What happens when you rotate the sensor so that the white dot points the opposite way?

QUESTION 3: What happens when you orient the sensor so that the white dot is pointing *perpendicular* to the axis of the solenoid?

Part III: Current Dependence

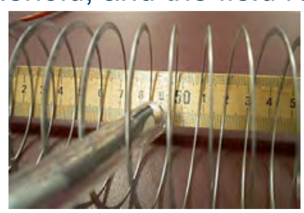
In this part of the experiment you will investigate how the magnetic field intensity at the centre of the solenoid varies with respect to the current flowing through the solenoid.

Remember to leave the switch **OPEN**, (i.e. power off) when you are not taking measurements.

Place the sensor between the turns of the Slinky near its centre.

Close the switch and rotate the sensor so that the white dot points directly along the long axis of the solenoid, and the field reading is positive.

This will be the position for **ALL** the measurements you will make in this section.



Continued...

Current Dependence

Relaunch ***LoggerPro*** by clicking on the icon below.
Click **Don't Save** in the window asking if you want to save your data.

Logger Pro

Adjust the power supply so that a current of 0.5 A is running through the circuit, then open the switch.

Insert the field sensor in its proper position. Click the **Zero** button.

Click **Collect** to start collecting data. Wait for five seconds, then close the switch to turn on the current.

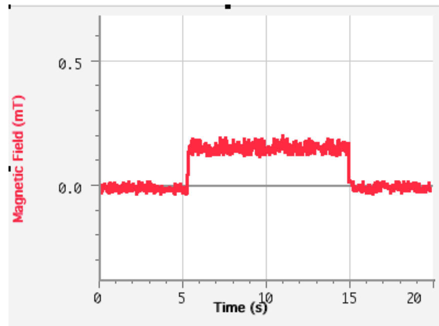
The field should **increase** to some relatively steady value when you close the switch.

If the field decreases when you close the switch, you must reorient your field sensor so that the white dot points in the opposite direction.

Continued...

Current Dependence: Data Collection

Click **Collect** to take a set of data. After 5 seconds close the switch for 10 seconds. Your data should look similar to the example.



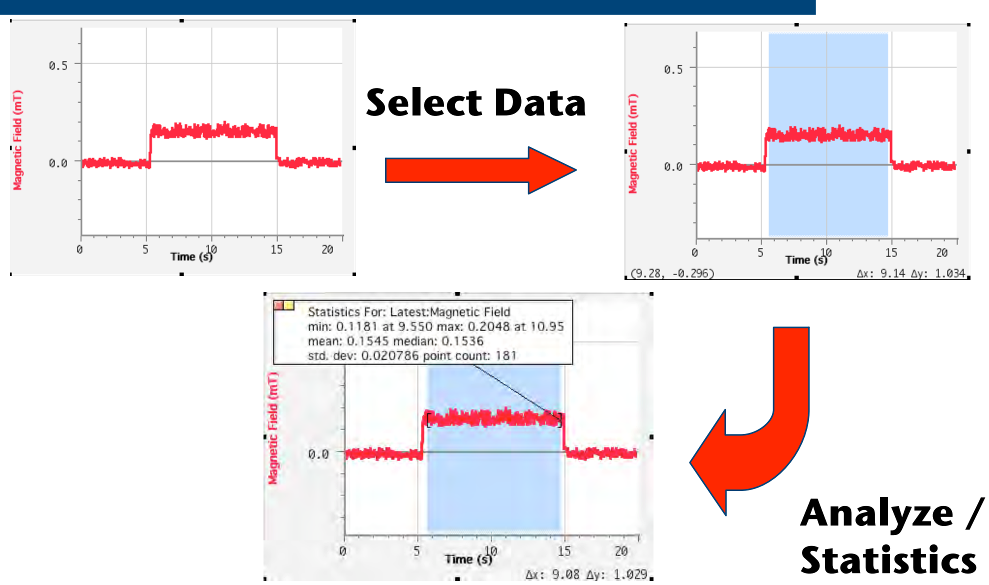
Inspect the *Field vs. Time* graph, and determine the region for which the current was flowing through the wire. Select this region of the graph by clicking and dragging the mouse over it. The highlighted region will be blue. (See the next slide for an example).

Determine the average field strength and the associated standard deviation by clicking on the **Analyze** menu, and selecting **Statistics**.

AL Enter these results in the first row of **Table 1** in your Activity Log.

Continued...

Example of Data Analysis



Current Dependence:
Data Collection

In ***LoggerPro*** select the **Experiment** menu and click **Store Latest Run** before collecting the next set of data.

Increase the current by 0.5 A, so the current in the circuit is around 1.0 A.

AL Repeat the steps outlined previously, including **zeroing the probe**, and **storing the run**, and enter the average field strength and the associated standard deviation for that particular current in **Table 1** of your Activity Log.

AL Repeat this part of the procedure for currents of around 1.5 A and 2.0 A, and enter the results in your Activity Log.

Your graph should have 4 lines - one for each current.

Continued....

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Current Dependence:
Data Collection

CP Before proceeding, have an instructor come check your graph and initial your lab report.

AL Measure the length of your Slinky.
Enter this value and associated uncertainty in **Table 2** of your Activity Log.
Do not include bunched up coils at the ends of the slinky.

P Print this graph and include it with your Activity Log.

Using Ampere's Law

QUESTION 4: Derive an expression for the slope of a graph of *Magnetic Field* versus *Current* in terms of the number of turns in the Slinky, using Ampere's law for a solenoid as given by Equation 1 in the introduction.

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Graphical Analysis

Launch **Graphical Analysis** by clicking on the icon below.

Graphical Analysis

Use **Graphical Analysis** to plot ***Magnetic Field*** versus ***Current*** for your Slinky solenoid.

Calculate and display the regression line for this data set.
To do so, pull down the **Analyze** menu and select **Linear Fit**.
Double click on the box that appears and in the **Standard Deviations** section check both the **Slope** and **Intercept**.
Enter the results in **Table 3** of your Activity Log.

Print this graph and include it with your Activity Log.

Analysis

The accepted value for the permeability constant is

$$\mu_o = 4\pi \times 10^{-7}\ T\ m / A$$

QUESTION 5: Calculate the number of turns in the Slinky using the slope of your *Magnetic Field* versus *Current* graph. Be sure to also calculate the associated uncertainty.

QUESTION 6: Count the number of turns in your Slinky (**not including the bunched up coils at the end**) and record the value. Is the result you calculated above consistent with this value? If not, explain why.

Summary

QUESTION 7: **Based on your experimental results**, which of the following best describes the relationship between magnetic field at the centre of the solenoid and current in the solenoid? Justify your answer.

A. $B \propto i$ **B.** $B \propto i^2$ **C.** $B \propto 1/i$ **D.** $B = constant$

QUESTION 8: List the sources of error in this experiment as classify each as random or systematic.Justify your answers.

Wrap it up!

- Check that you have completed all the **Tables** of your Activity Log.

- Make sure that you have answered all the **Questions** completely, including the **Summary Questions**.

- Attached to your Activity Log should be the following graphs:
  - ***Magnetic Field*** versus ***Current*** (***Graphical Analysis***)
  - ***Magnetic Field*** *versus* ***Time (four currents)*** (***LoggerPro***)