  Graphical Analysis 25

The Magnetic Field in a Coil

When an electric current flows through a wire, a magnetic field is produced around the wire. The magnitude and direction of the field depends on the shape of the wire and the direction and magnitude of the current through the wire.

In this activity, you will examine how the magnetic field is related to both the current through a coil and the number of turns in a coil. A Magnetic Field Sensor will be used to detect the field at the center of the coil. The sensor will also detect the Earth’s field and any local fields due to electric currents or some metals in the vicinity of the sensor, so you will need to account for these fields.

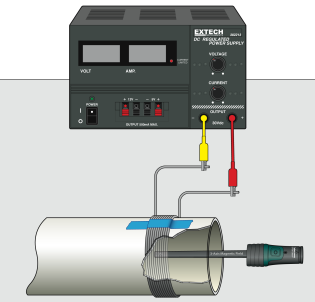


Figure 1

Objectives

* Measure the field at the center of a coil.
* Determine the relationship between magnetic field and the number of turns in a coil.
* Determine the relationship between magnetic field and the current in a coil.
* Explore Earth’s magnetic field in your classroom.

Materials

Chromebook, computer, or mobile device

Graphical Analysis 4 app

Go Direct 3-Axis Magnetic Field

Extech Digital DC Power Supply

mailing or poster tube, 4–10 cm diameter

magnetic compass

insulated wire (at least 1 m)

Initial setup

1. Loop the wire 10 times around end of the tube, creating a coil of 10 turns.
2. Connect the coil and power supply, as shown in Figure 1.
3. Launch Graphical Analysis. Connect the 3-Axis Magnetic Field Sensor to your Chromebook, computer, or mobile device. Only the x-axis sensor, oriented along the length of the wand, is active.
4. Set up the data-collection mode.
   1. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   2. Enter Current as the Event Name and A as the Units.
   3. Click or tap Done.

preliminary questions and additional setup

1. Move the magnetic field sensor far away from the coil of wire. Hold it so that the sensor wand is horizontal. Rotate the sensor around a vertical axis. Monitor the readings. What do you observe? What is causing the variation of field reading?
2. Determine the orientation of the sensor when the magnetic field is at a maximum, and compare the direction that the wand is pointing with the direction that the magnetic compass needle points. What did you discover? How much does the reading change in one rotation?
3. Insert the sensor into the end of the tube. The sensor tip should be at the center of the coil, with the tip of the sensor in the plane of the coil (see Figure 2). Turn the current dial on the power supply to its lowest setting. Turn the voltage dial to about half way (the dot on the dial will face upwards). Turn on the power supply and slowly increase current to 3 A. Monitor the magnetic field readings. What did you observe?

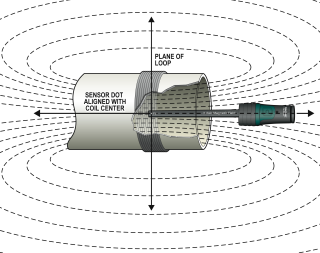


Figure 2

Procedure

Part I  How is the Magnetic Field in a Coil Related to Current?

In the first part of the experiment, determine the relationship between the magnetic field in the center of a coil and the current through the coil. Use the coil with all 10 turns for all of Part I.

1. Verify that the power supply is set to 3 A. Confirm that the sensor wand is still aligned coaxially with the tube, and keep it in this position throughout the experiment.
2. Turn off the power supply. To zero the sensor with no current flowing, click or tap the X Magnetic Field meter and choose Zero. By doing this, you remove the effect of Earth’s magnetic field and any local magnetism.
3. Collect data.
   1. Click or tap Collect to start data collection.
   2. Turn on the power supply.
   3. Click or tap Keep. When prompted, enter 3.0 as the current. Click or tap Keep Point to store the data pair.
   4. Decrease the current by 0.5 A. Click or tap Keep. Enter 2.5 as the current and click or tap Keep Point.
   5. Repeat this process until you collect data for 0.0 A, and then stop data collection.
   6. Turn off the power supply.
   7. Answer the Analysis questions for Part I before proceeding to Part II.

Part II  How is the Magnetic Field in a Coil Related to the Number of Turns?

In the second part of the experiment, determine the relationship between the magnetic field at the center of a coil and the number of turns in the coil. Orient the magnetic field sensor as before. Use a current of 3.0 A for all of Part II.

1. Set up the data-collection mode to collect data as a function of number of coils rather than current.
   1. Click or tap File, , and choose New Experiment.
   2. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   3. Enter Turns as the Event Name and leave the Units field blank.
   4. Click or tap Done.
2. To zero the sensor with no current flowing, click or tap the X Magnetic Field meter and choose Zero.
3. Now you are ready to collect magnetic field data as a function of the number of turns.
   1. Click or tap Collect to start data collection.
   2. Turn on the power supply and verify that it is set to 3 A.
   3. Click or tap Keep. When prompted, enter 10 as the number of coils. Click or tap Keep Point to store the data pair.
   4. Turn off the power supply. Remove one loop of wire from the tube to reduce the number of turns by one. If you moved the tube or the sensor, verify that you put it back to the same position as before.
   5. Turn on the power supply.
   6. Click or tap Keep and enter 9 as the number of turns. Click or tap Keep Point.
   7. Repeat this process until you have only one turn of wire on the tube.
   8. Click or tap Stop to stop data collection and turn off the power supply.
   9. Proceed to the Analysis questions for Part II.

Analysis

Part I  How is the Magnetic Field in a Coil Related to Current?

1. Inspect your graph of magnetic field vs. current. What is the relationship between the current in a coil and the resulting magnetic field at the center of the coil?
2. If the points on your graph of magnetic field vs. current through the coils follow a generally linear path, fit a straight line to the data.
   1. Click or tap Graph Tools, , and choose Apply Curve Fit.
   2. Select Linear as the curve fit, and click or tap Apply. The linear regression statistics are displayed.
   3. Record the slope and y-intercept of the regression line in the data table, along with their units.
   4. Export, print, or sketch your graph.
3. Inspect the equation of the best-fit line through the data points. Explain the significance of the constants in your equation. What are the units of the constants? Should the fitted line pass through the origin? Why or why not?

Part II  How is the Magnetic Field in a Coil Related to the Number of Turns?

1. Inspect your graph of magnetic field vs. the number of turns. What is the relationship between the number of turns and the resulting magnetic field at the center of the coil?
2. If the points on your graph of magnetic field vs. number of turns follow a generally linear path, fit a straight line to the data.
   1. Click or tap Graph Tools, , and choose Apply Curve Fit.
   2. Select Linear as the curve fit, and click or tap Apply. The linear regression statistics are displayed.
   3. Record the slope and y-intercept of the regression line in the data table.
   4. Export, print, or sketch your graph.
3. How is magnetic field related to the number of turns? Explain the significance of the constants in your equation. What are the units of the constants? Should the fitted line pass through the origin? Why or why not?

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| Data Table  Part I   |  |  | | --- | --- | | Magnetic field vs. current fit parameters | | | Slope |  | | Intercept |  |   Part II   |  |  | | --- | --- | | Magnetic field vs. turns fit parameters | | | Slope |  | | Intercept |  | |

Extensions

1. How does the diameter of the coil loop affect the magnetic field? Design and conduct an experiment to answer this question.
2. Remove the magnetic field sensor from the coil, and hold it vertically. Collect data while rotating it smoothly about a horizontal axis, so that it measures the field readings in a vertical circle. Explain where the maximum and minimum readings occur and where zero or near-zero readings occur. Compare your pattern to the data you collect while rotating about a vertical axis.