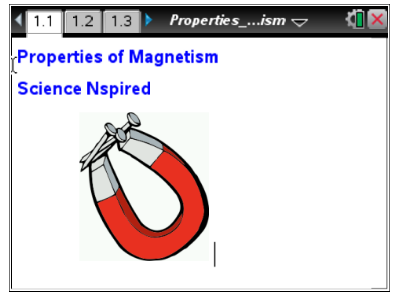


Science Objectives

- Students will describe the magnetic field around an electromagnet.
- Students will relate the strength of a solenoid-type electromagnet to the number of turns of a wire on the electromagnet.

Vocabulary

- magnet
- magnetic field
- electromagnet
- solenoid

About the Lesson

In this activity, students will create a solenoid-type electromagnet using two different methods of coiling the wire around the core. They will use a sensor to determine the relationship between the number of turns of wire and the magnetic field strength for each method.

TI-Nspire™ Navigator™

- Send out the *Properties_of_Magnetism.tns* file.
- Monitor student progress using Screen Capture.
- Use Live Presenter to spotlight student answers.
- Collect the student .tns file and evaluate student understanding.

Activity Materials

- *Properties_of_Magnetism.tns* document
- TI-Nspire™ Technology
- Student Activity Handout
- *Vernier Magnetic Field Sensor*
- *16-gauge electrical wire (at least 1.5 m)*
- *iron or steel nail or bolt, at least 8 cm long and 1 cm in diameter*
- *electrical tape*
- *blank sheet of paper*
- *pen or pencil*
- *two D-cell batteries*
- *wire strippers (if the wire is insulated)*
- *masking tape (optional)*

TI-Nspire™ Technology Skills:

- Download a TI-Nspire document
- Open a document
- Move between pages
- Data Collection with Probes

Tech Tip:

Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:

Student Activity

- Properties_of_Magnetism_Student.doc
- Properties_of_Magnetism_Student.pdf

TI-Nspire document

- Properties_of_Magnetism.tns

Discussion Points and Possible Answers

Allow students to read the background information on their student activity sheet.

Students may not have experimented with electromagnets before. You may wish to allow them to experiment with the materials to explore electromagnets qualitatively before carrying out the activity.

- Make sure the batteries students are using are fully charged. This investigation can be done with a single battery per student pair, but the resulting magnetic fields will be weaker.
  If the wire that students use is not insulated, they should wrap electrical tape around the parts of the wire they will touch. The wire may become warm as current flows through it, and the electrical tape will help prevent burns. If the wire is insulated, students should use the wire strippers to remove about 2 cm of the insulation from each end of the wire. Alternatively, you may strip the wire for the students.

The following questions will guide student exploration in this activity:

- How does the method of wrapping wire around a core affect the magnetic field around an electromagnet?
  How does the number of turns of wire around a core affect the intensity of the magnetic field around an electromagnet?

Students will first create an electromagnet by progressively wrapping wire around the full length of the core. They will collect data on how the number of turns of wire on the core affects the magnitude of the magnetic field around the electromagnet. They will then repeat the experiment, but they will "stack" the successive coils around the same part of the core.

Move to pages 1.2 – 1.3.

First students will explore progressive coils.

1. Students should read page 1.2, and then answer question 1 on either the handheld, on the activity sheet, or both.

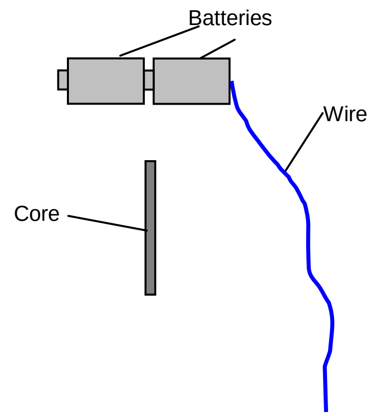
Q1. As the number of turns of wire in an electromagnet increases, the magnetic field around the electromagnet will increase. True or False?

Answer: There is no correct answer to this question; students are asked whether they think the statement is true or false and then asked to explain their answers. Encourage students to be as specific as possible in their explanations.

Move to page 1.4.

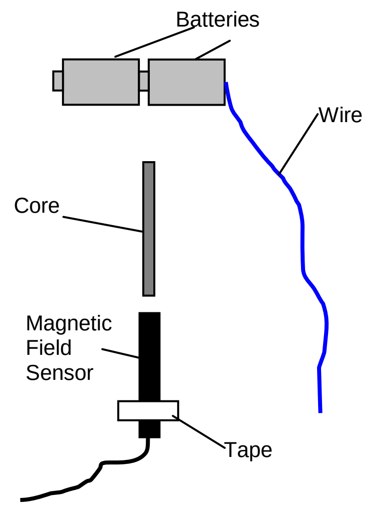
2. Next, students should read page 1.4. The directions for setting up and running the experiment are given in detail below.

Step 1: Student need to set up the batteries, wire, and core as shown to the right. (Make sure students mark the position of the core so that they can accurately reposition it for each trial. Students should use electrical tape to tape the batteries together.) They should use masking tape or electrical tape to hold the batteries in place on the table top. They should also use electrical tape to tape one end of the wire to the negative terminal of the battery. They should then connect a Vernier Magnetic Field Sensor to an EasyLink interface (if using a handheld) or a Go!Link interface (if using a computer). They should set the range switch on the Magnetic Field Sensor to the 6.4 mT setting.

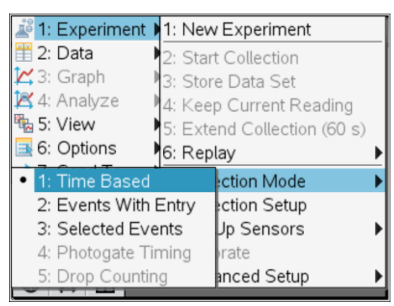


Step 2: Students should connect the interface to their handhelds or computers. When prompted, they should choose to display their data in a new *Data & Statistics* application.

Step 3: Students should tape the Magnetic Field Sensor down so that its tip is about 1 cm away from one of the ends of the core of the electromagnet, as shown to the right. They should wait for the magnetic field reading to stabilize and then zero the sensor (**Menu > Sensors > Zero**). Students will probably get better results if they change the units displayed from millitesla (mT) to gauss (G). Students can change the units from the **Sensors** menu (**Menu > Sensors > Units**).



Step 4: Next, students should set up the data collection software to **Events with Entry** mode (**Menu > Experiment > Set Up Collection > Events with Entry**).



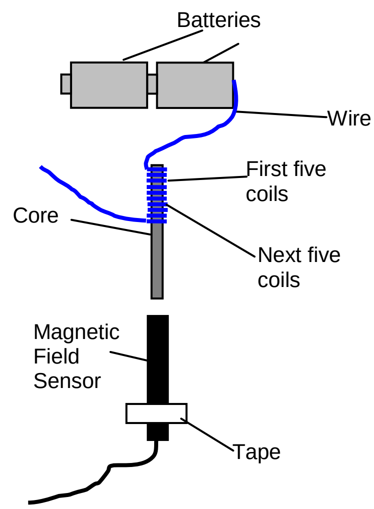
Step 5: Students should wrap the wire around the end of the core that is farther from the Magnetic Field Sensor. They should wrap the wire so that there are five coils of wire around the core. They should use electrical tape to hold the wire in place around the core. (Make sure students wrap the wire around the core such that the turns of wire are touching. Students will need to keep the

density of turns constant as they add more wire, so they should wrap the wire compactly enough that they can fit a large number of turns on the core.)

Step 6: Students should touch the free end of the wire to the free positive terminal of the battery pair. They should make sure the wire makes good contact with the terminal.

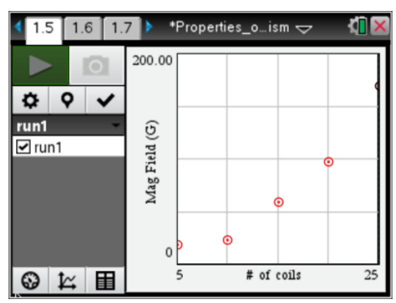
Step 7: Once the magnetic field reading has stabilized, students should collect a data point. They should use 5 for the data value (because there are five turns of wire around the core). Once they have collected the data point, they should move the free end of the wire away from the positive battery terminal.

Step 8: Next, students should wrap five more coils of wire around the core, immediately next to the previous coils, as shown to the right. They should again use electrical tape to hold the wire in place. They should then replace the electromagnet in its original position. (They may need to use masking or electrical tape to hold the electromagnet in position.)



Step 9: Students should repeat steps 6–8 until they have wrapped the wire along the entire length of the core. For each data point, students should use the number of turns, or coils, on the core as the data value.

3. Once they have collected all their data, students should end the data collection, close the data collection box, and disconnect the interface.



Move to pages 1.6 – 1.8.

Have students answer questions 2 - 4 on either the handheld, on the activity sheet, or both.

Q2. Was your answer to question 1 correct? If not, explain the errors in your reasoning.

Answer: Students' answers will vary. Encourage metacognitive thinking to help students identify errors in their reasoning.

Q3. Describe the relationship between the number of turns in the electromagnet and the strength of the magnetic field around the electromagnet.

Answer: As the number of coils of wire around the core increases, the magnetic field around the electromagnet increases.

Q4. Explain the shape of the graph.

Answer: The graphs should be nonlinear. The nonlinearity is a result of the progressive lengthening of the electromagnet as the number of coils increases. (The electromagnet is properly defined to be the coils of wire and the portion of the core enclosed by those coils. Therefore, the part of the core that extends past the coils is not included in the length of the electromagnet.) As more coils are added, the length of the electromagnet increases. In addition, the "end" of the electromagnet moves closer to the Magnetic Field Sensor. These two effects combine to yield the nonlinear relationship seen in the graph.

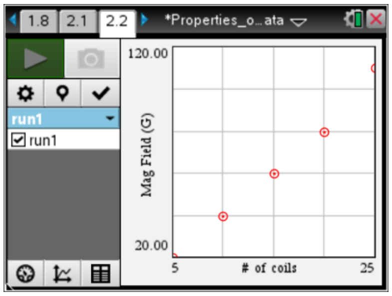
If you wish, you may have students experiment with different patterns of wrapping—for example, have them start wrapping the coils at the end of the core that is closer to the Magnetic Field Sensor and wrap successive coils farther and farther from the sensor. Students can explore how the pattern of wrapping affects the magnetic field. If you wish, you may also have students use the Regression tool to identify the best-fit curve for the data. (A quadratic curve will most likely provide the best fit.) If you wish, you may have students extend this activity by asking them to predict what will happen if they remove the nail from the electromagnet to leave only a solenoid. Have them remove the nail and measure the magnetic field produced by the coil (the solenoid). Encourage them to discuss their predictions and results.

Move to page 2.1.
Now students will investigate stacked coils.

4. Students should read the text on page 2.1. They should then repeat steps 3–10 from problem 1, with the following exceptions: Instead of wrapping the first five coils of wire around the end of the core, students should wrap them around the middle of the core, and instead of wrapping successive coils along the length of the core, students should wrap successive coils on top of one another (making the coil of wire around the core quite thick).

Students should collect data for the same number of coils that they collected data for in problem 1.

For example, if they were able to fit 25 coils of wire on the core in problem 1, they should collect data for up to 25 coils of wire for this data set, as well.



Move to pages 2.3 – 2.4.

Have students answer questions 5 and 6 on either the handheld, on the activity sheet, or both.

Q5. Compare the graph for the stacked wire showing field strength vs. number of turns to the graph for progressive wrapping (from problem 1). Explain any differences.

Answer: In both cases, the magnetic field strength around the electromagnet increases as the number of turns increases. However, when the coils are stacked, the increase is approximately linear, instead of having the nonlinear relationship apparent in the progressively wrapped electromagnet. Stacking the coils removes the effects of varying length and distance from the Magnetic Field Sensor that caused the nonlinearities in the progressively wrapped electromagnet. Therefore, the stacked coils more accurately represent an idealized electromagnet, in which magnetic field strength is linearly proportional to the number of coils per unit length of the electromagnet. If you wish, you may have students use the Regression tool to identify the best-fit equation for the data. If you wish, you may have students carry out another extension activity to test the effects of current on magnetic field strength. Students should design and carry out an experiment to test the effects of increasing the number of batteries (i.e., the current) in the circuit. Encourage them to discuss their results. They could also try connecting the batteries in parallel, as well as in series, to explore the effect.

Q6. For the solenoid-type electromagnets listed below, the current is the same and the coiled wire goes the whole length. Which electromagnet would most likely have the strongest magnetic field?

Answer: B. The relevant parameter in determining magnetic field strength (assuming current is constant) is the number of coils per unit length of the electromagnet. The electromagnet in the second option has the highest coil density: 3 turns (or coils) per cm.

TI-Nspire Navigator Opportunities

Make a student a Live Presenter to display the graphs of the data gathered from the experiment. Throughout the lab, discuss the activity with students using Slide Show. At the end of the lab, collect the .tns files and save to Portfolio.

Wrap Up

When students are finished with the activity, retrieve the .tns file using TI-Nspire Navigator. Save grades to Portfolio. Discuss activity questions using Slide Show.

Assessment

- Formative assessment will consist of questions embedded in the .tns file. The questions will be graded when the .tns file is retrieved. The Slide Show will be utilized to give students immediate feedback on their assessment.
- Summative assessment will consist of questions/problems on the chapter test.