Induced Magnetic Fields – ID: 12596

Time required
45 minutes

Topic: Electricity and Magnetism

- *Determine the magnitude and direction of an induced magnetic field.*

Activity Overview

In this activity, students will use a strong permanent magnet to induce a magnetic field in a metal object. They will measure the magnitude and direction of the magnetic field around the permanent magnet and around the induced magnet. They will also compare how magnetic field strength changes with distance from a permanent magnet and with distance from a permanent magnet attached to a metal object.

Materials

To complete this activity, each student will require the following:

- *TI-Nspire™ technology*
- *strong permanent magnet*
- *metric ruler or meter stick*
- *Vernier Magnetic Field Sensor*

- *Vernier EasyLink™ or Go!® Link interface*
- *copy of student worksheet*
- *pen or pencil*
- *two magnetically susceptible objects*

TI-Nspire Applications

Graphs & Geometry, Notes

Teacher Preparation

Students will probably be familiar with the effects of magnets but may not have investigated them quantitatively. Before students carry out this activity, review with them the concepts of vectors and magnetic field strength.

- *You should experiment with the magnets students will be using, to determine which units—gauss (G) or millitesla (mT)—students should use. You should also experiment with appropriate distances for students to use.*

- *The TI-Nspire document (.tns file) for this activity is quite simple. If you wish, instead of distributing the files to the students, you may have students use a blank .tns file for the activity.*

- *This activity is designed to be qualitative; it is meant as an introduction to the effects of distance on magnetic field strength.*

- *The screenshots on pages 2–6 demonstrate expected student results. Refer to the screenshots on page 7 for a preview of the student TI-Nspire document (.tns file). Pages 8–10 show the student worksheet.*

- ***To download the .tns file, go to education.ti.com/exchange and enter "12596" in the search box.***

Classroom Management

- *This activity is designed to be **student-centered**, with the teacher acting as a facilitator while students work cooperatively. The student worksheet guides students through the main ideas of the activity and provides questions to guide their exploration. Students may answer the questions on blank paper or in the .tns file using the Notes application.*

- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

The following questions will guide student exploration in this activity:

- How does the magnitude of an induced magnetic field compare with the magnitude of the field around the magnet used to induce the field?
- How does a magnetically susceptible object affect the magnitude of the magnetic field around a magnet?

Students will first measure how the magnetic field around a strong magnet changes with distance. They will then use the magnet to induce a magnetic field in a susceptible object. They will measure how the magnetic field around that object changes with distance. Finally, they will "attach" the magnetically susceptible object to the magnet and collect data to determine whether its presence affects the magnitude of the magnet's magnetic field.

## Problem 1 – Measurement of an induced magnetic field

Step 1: Students should open the file **PhysWeek32_Induced_Magnetism.tns** and read the first two pages. 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).

Step 2: Students should connect the EasyLink or Go!Link to their handheld or computer. A dialog box should appear and ask students to select where to display the data. Students should choose to display the data in a new *Graphs & Geometry* application. (Before students conduct the investigation, you should experiment with the magnets they will be using, to determine the appropriate sensitivity and unit settings for them to use. Tell students which units (G or mT) to use in the data collection box, and which switch position (0.3 mT or 6.4 mT) to use on the Magnetic Field Sensor. Students can change the units on the data collection box from the **Sensors** menu (**Menu > Sensors > Units**).

Step 3: Students should hold the sensor as far from any magnets as possible, wait for the reading to stabilize, and then zero the sensor (**Menu > Sensors > Zero**).

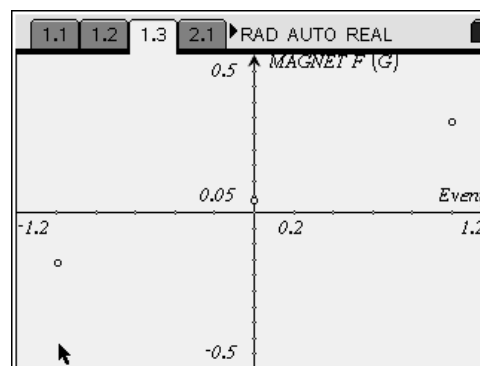**Step 4:** Next, students should set up the data collection software to **Events with Entry** mode.

Step 5: Students should place the ruler or meter stick on the floor or another flat, level surface. They should place one paper clip next to the ruler so that one of its curved ends is aligned with the 1 cm mark. They should place the Magnetic Field Sensor so that its tip is aligned with the 0 cm mark. (Note: The paper clips should be kept separate from the magnets prior to the investigation, to prevent the magnets from inducing magnetic fields in the paper clips.)

Paper clip

Magnetic Field Sensor
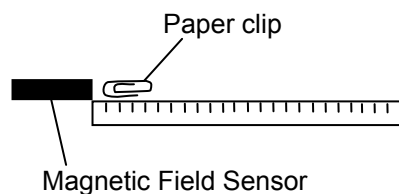
Step 6: Students should wait for the reading to stabilize and then record a data point (they should use 0 as the data value).

Step 7: Next, students should touch the magnet's north pole to one of the curved ends of the paper clip. They should then remove the magnet and replace the paper clip next to the ruler, as they did in step 5. They should record another data point (using 1 as the data value).

Step 8: Next, students should touch the magnet's south pole to the curved end of the paper clip (the same end they touched to the north pole in step 7). They should again remove the magnet and re-record the magnetic field strength (using –1 as the data value). Students should then stop the data collection, but they should not close the data collection box.

Step 9: Next, students should remove the paper clip from the ruler. They should place the magnet so that its north pole is at the 1 cm mark on the ruler. They should then restart the data collection, wait for the reading to stabilize, and then record a new data point (using 1 as the data value). (Students will be prompted to store or discard their previous data run. They should store that run.)

Step 10: Students should move the magnet so its south pole is at the 1 cm mark, wait for the reading to stabilize, and then record a second data point (using –1 as the data value). Students should stop the data collection, close the data collection box, and disconnect the interface. Students should then answer questions 1 and 2.
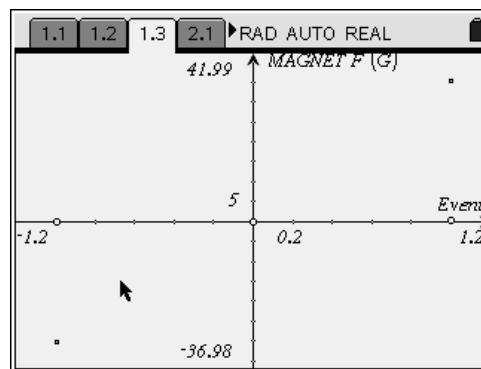
Q1. Compare the strength (magnitude) of the magnetic field around the permanent magnet with the strength of the magnetic field around the induced magnet.

   A. *The permanent magnet should have a much stronger magnetic field than the induced magnet (the paper clip). For the sample data shown, the difference in strength was two orders of magnitude.*

Q2. Compare the magnetic field readings for the north and south poles of both the permanent magnet and the induced magnet. Explain this result.

   A. *The magnitudes of the readings for the two poles of each magnet should be similar, but they should have opposite signs. (Because of the way some permanent magnets are constructed, the magnetic field strength at the two poles may not be identical. However, they should be similar.) The opposite signs indicate that the magnetic field has an opposite orientation at the north pole than at the south pole. This effect is expected in a permanent magnet; when the permanent magnet touches the paper clip, the magnetic domains in the paper clip align with the magnetic field of the permanent magnet. When the magnet is removed, the paper clip generates its own magnetic field. Unlike the magnetic field around the permanent magnet, the paper clip's magnetic field can be realigned upon exposure to a differently oriented magnetic field—such as the one produced when the opposite pole of the permanent magnet touches the paper clip.*

Problem 2 – The effects of a magnetically susceptible object on a permanent magnet

Step 1: Students should read the text on page 2.1 and then reattach the interface. When prompted, they should choose to display the data in a new *Graphs & Geometry* application.

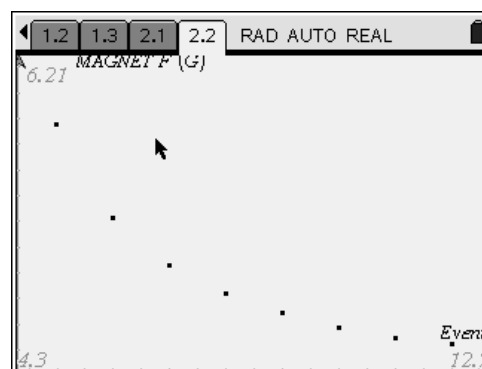**Step 2:** Students should repeat steps 3 and 4 from problem 1.

Step 3: Students should place the end of the sensor at the 0 cm mark.

Step 4: Tell students where to place the magnet for the initial measurement. The sample data here were collected with one pole of the magnet initially at the 5 cm mark. The distance between the tip of the sensor and the magnet should be at least 1–2 cm longer than the length of a paper clip.
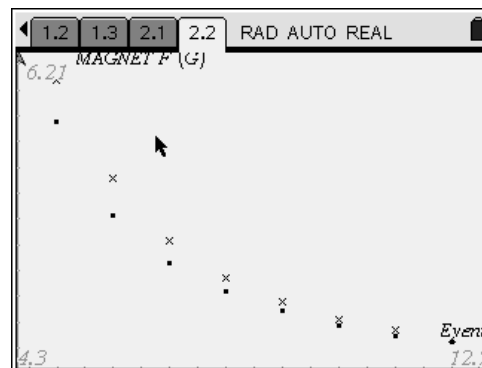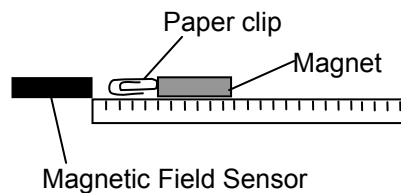
Step 5: Students should start the data collection, wait for the magnetic field reading to stabilize, and then collect a data point. They should use the distance reading as their data value (e.g., if the magnet is 5 cm from the sensor, the data value is 5).

Step 6: Students should repeat step 5 seven more times, moving the magnet 1 cm farther from the sensor each time. (You may adjust the increments if necessary, based on the particular magnets students are using.)

Step 7: Once students have collected eight data points, they should stop the data collection. They should not close the data collection box.

Step 8: Next, students should repeat steps 4–7. This time, however, they should place a paper clip next to the magnet so that the paper clip sticks to the magnet. The paper clip should point down the ruler toward the Magnetic Field Sensor, as shown to the right. When prompted, students should store (not discard) the previous run.

Step 9: Once students have collected the second set of data, they should end the data collection, close the data collection box, and disconnect the sensor. They should then answer questions 3–5.

Q3. Describe your collected data.

A. *Students' answers will vary. However, they should observe that the magnetic field decreases more slowly for the magnet with the paper clip attached than for the magnet by itself. The difference should be largest when the magnet is closest to the sensor; as the magnet moves farther away, the difference between the two data sets should decrease.*

Q4. Explain why the presence of the paper clip changed the magnetic field strength of the permanent magnet.

A. *The permanent magnet induces a magnetic field in the paper clip. The field in the paper clip is aligned with the field in the magnet. Therefore, the paper clip essentially acts as an "extension" of the magnet. Because the end of the paper clip is closer to the sensor than the end of the magnet is, the magnitude of the magnetic field is larger when the paper clip is present. If you wish, you may have students use the* **Power Regression** *tool to identify the best-fit equation for each data set and then compare the equations to determine the effects of the paper clip more quantitatively.*

Q5. Would you expect to see the same effect if you taped a wooden object to the magnet? Explain your answer.

A. *Wooden objects are not magnetically susceptible. Therefore, a wooden object would not "extend" the magnet's magnetic field, and no increase in magnetic field would be observed. (If you wish, you may have students carry out an investigation to test their predictions.)*

Induced Magnetic Fields – ID: 12596

(Student)TI-Nspire File: *PhysWeek32_Induced_Magnetism.tns*

`1.1` `1.2` `2.1` RAD AUTO REAL	`1.1` `1.2` `2.1` RAD AUTO REAL	`1.1` `1.2` `2.1` RAD AUTO REAL
INDUCED MAGNETIC FIELDS **Physics** Magnetic Fields	A permanent magnet produces a magnetic field. Magnetically susceptible objects can be made to produce a magnetic field through contact with a permanent magnet. In this activity, you will explore the effects of permanent magnets on magnetically susceptible objects.	Next, you will explore the effects of a magnetically susceptible object on a magnet's magnetic field.

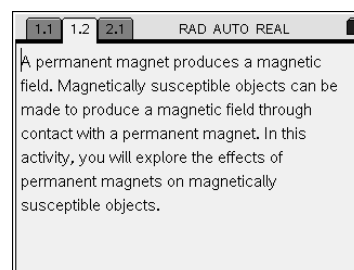# Induced Magnetic Fields

ID: 12596

Name _____

Class _____

In this activity, you will explore the following:

- *the effects of a permanent magnet on a magnetically susceptible object*
- *the effects of a magnetically susceptible object on the magnetic field of a permanent magnet*

Open the file **PhysWeek32_Induced_Magnetism.tns** on your handheld or computer and follow along with your teacher for the first two pages. Move to page 1.2 and wait for further instructions from your teacher.

A permanent magnet generates a magnetic field. This field can affect any magnetically susceptible objects that enter it. (For example, iron is magnetically susceptible, so it will be attracted to a permanent magnet.) In this investigation, you will explore the interactions between a permanent magnet and a magnetically susceptible object, such as a metal paper clip.
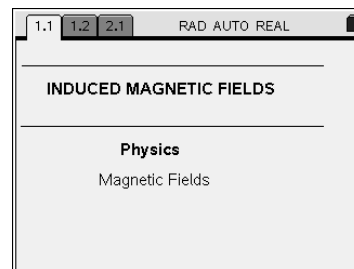
## Problem 1 – Measurement of an induced magnetic field

Step 1: Connect a Vernier Magnetic Field Sensor to an EasyLink interface (if using a handheld) or a Go!Link interface (if using a computer).

Step 2: Connect the EasyLink or Go!Link interface to your handheld or computer. A dialog box should appear asking you where you want to display your data. Use the arrow keys to highlight *Graphs & Geometry*, and then select OK. (Press (tab) to highlight the OK button, and click (press (🔆)) to select it.) A data collection box should appear, and data should appear in the data collection box. Your teacher will tell you which units to use, whether gauss (G) or millitesla (mT), and which setting (0.3 mT or 6.4 mT) to set the switch on the Magnetic Field Sensor to.
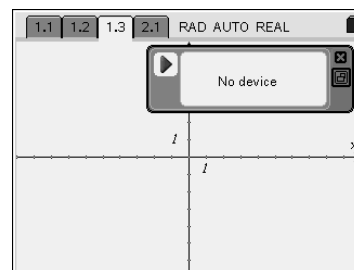
Step 3: Hold the Magnetic Field Sensor as far from any magnet as possible. Wait for the magnetic field strength reading to stabilize, and then zero the sensor (**Menu > Sensors > Zero**).

Step 4: For this experiment, you will need to collect data on field strength and distance at specific points. To set up the TI-Nspire to collect data in this way, select **Events with Entry** from the **Experiment** menu (**Menu > Experiment > Set Up Collection > Events with Entry**). Click the Play button (►) to begin the experiment.
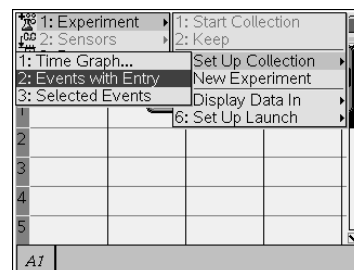
Step 5: Place the ruler or meter stick on the floor or another flat, level surface. Place one paper clip next to the ruler so that one of its curved ends is aligned with the 1 cm mark. Place the Magnetic Field Sensor so its tip is aligned with the 0 cm mark, as shown to the right.

Paper clip

Magnetic Field Sensor
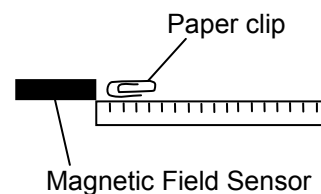
Step 6: Wait until the field strength reading has stabilized, and then click the button in the lower right corner of the data collection box. A dialog box should appear. Enter the number 0 for the data value, and then click OK.

Step 7: Touch the permanent magnet's north pole to one of the curved ends of the paper clip. Then, remove the magnet and replace the paper clip next to the ruler, as you did in step 5. (Make sure the paper clip is in the same orientation as it was in step 5.) Wait for the magnetic field reading to stabilize, and then record another data point (use 1 as the data value). Make sure the permanent magnet is far away from the Magnetic Field Sensor when you record your measurement.

Step 8: Next, touch the permanent magnet's south pole to the curved end of the paper clip (touch the same end of the paper clip that you did in step 7). Again, remove the magnet, replace the paper clip, and record another data point. This time, use –1 as your data value. Once you have recorded the data point, stop the data collection, but do not close the data collection box.

Step 9: Remove the paper clip from the ruler. Place the magnet so that its north pole is at the 1 cm mark on the ruler. Restart the data collection, wait for the reading to stabilize, and then record a new data point using 1 as the data value. (You will be asked whether you want to store or discard the previous run. You should store that run so that you can compare it with the data on just the magnet by itself.)

Step 10: Move the magnet so its south pole is at the 1 cm mark, wait for the reading to stabilize, and collect another data point (use –1 as the data value). Then, stop the data collection, close the data collection box, and disconnect the interface.

 Q1. Compare the strength (magnitude) of the magnetic field around the permanent magnet with the strength of the magnetic field around the induced magnet.

 Q2. Compare the magnetic field readings for the north and south poles of both the permanent magnet and the induced magnet. Explain this result.

Problem 2 – The effects of a magnetically susceptible object on a permanent magnet

Step 1: Read the text on page 2.1, and then reattach the interface to your handheld or computer. When prompted, choose to display the data in a new *Graphs & Geometry* application.

Step 2: Repeat steps 3 and 4 from problem 1.

Step 3: Place the end of the sensor at the 0 cm mark on the ruler.

Step 4: Your teacher will tell you where to place the magnet for the first measurement. Place the magnet where your teacher indicates.

Step 5: Start the data collection, wait for the magnetic field reading to stabilize, and then collect a data point. Use the distance (in centimeters) between the magnet and the sensor as your data value. For example, if the magnet is at the 5 cm mark, use 5 as your data value.

Step 6: Repeat step 5 seven more times, moving the magnet 1 cm farther from the sensor each time.

Step 7: Once you have collected 8 data points, stop the data collection. Do not close the data collection box.

Step 8: Repeat steps 4–7. However, before beginning the data collection again, place a paper clip next to the magnet so that the paper clip sticks to the magnet. The paper clip should point down the ruler toward the Magnetic Field Sensor, as shown to the right. (When you are prompted, you should choose to store, not discard, the previous data run.)

Step 9: Once you have collected the second set of data, end the data collection, close the data collection box, and disconnect the sensor.

Q3. Describe your collected data.

Q4. Explain why the presence of the paper clip changed the magnetic field strength of the permanent magnet.

Q5. Would you expect to see the same effect if you taped a wooden object to the magnet? Explain your answer.