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Denver CO

Investigating Invisible Forces: Mapping Magnetic Fields

Experiments

Sea Flood Spreading

- Go Direct 3-Axis Magnetic Field Sensor

Electromagnets: Winding Things Up

- Go Direct 3-Axis Magnetic Field Sensor

Magnetic Field Explorations

- Go Direct 3-Axis Magnetic Field Sensor

Workshop Presenters

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Sea Floor Spreading

According to the theory of plate tectonics, the Earth's crust is broken into many slowly moving plates. *Sea floor spreading* occurs at the mid-ocean ridge where two plates are moving away from each other. Here, magma rises up from below as the sea floor spreads out to either side as shown in Figure 1. This spreading occurs at about the same rate as your fingernails grow.

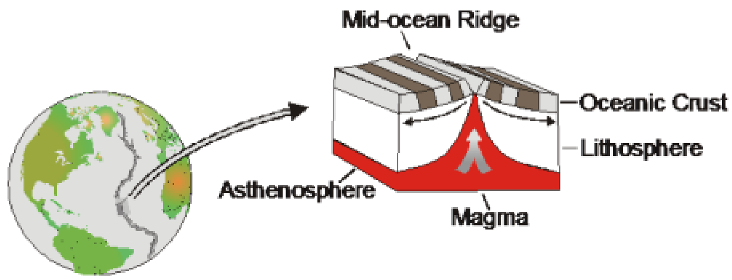

Figure 1

The pattern of sea floor spreading can be observed by studying the magnetic field of the rock on the sea floor. At the mid-ocean ridge, magma rises up from the mantle below and cools. As it continues to cool, iron in the rock aligns itself with the magnetic field of the Earth, much like the needle in a compass. When the rock solidifies, this magnetic "signature" is locked in place.

Throughout history, the orientation of the Earth's magnetic field has varied greatly. At times, the magnetic pole in the north has reversed completely and was located near the south geographic pole. Because new ocean floor is constantly moving away from the mid-ocean ridge, these reversals appear as bands of alternating magnetic fields as shown in Figure 1. On average, the Earth's magnetic field reverses every several hundred thousand years with the most recent reversal occurring about 780,000 years ago.

In this experiment, you will use a model of a sea floor spreading zone. The mid-ocean ridge is running north to south down the center of the model. You will use a magnetic field sensor to map the magnetic field of your model and use it to explain how this is evidence of sea floor spreading.

OBJECTIVES

- Use a magnetic field sensor to measure a magnetic field.
- Map sea floor spreading.
- Interpret your results.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct 3-Axis Magnetic Field
model sea floor spreading zone
ruler

PROCEDURE

1. Launch Graphical Analysis. Connect the 3-Axis Magnetic Field Sensor to your Chromebook, computer, or mobile device.
2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   b. Enter **Distance** as the Event Name and **cm** as the Units. Click or tap Done.
3. Change the graph appearance.
   a. Click or tap Graph Tools, , and choose Edit Graph Options.
   b. Under Appearance, select Lines.
   c. Dismiss the Graph Options box.
4. Zero the magnetic field sensor.
   a. Remove anything magnetic from the area where data collection will take place, including the model sea floor spreading zone.
   b. Hold the sensor vertically over the area where you will be collecting data as it will be during data collection (see Figure 2).
   c. Holding the sensor still, click or tap the Magnetic Field meter and choose Zero. The readings for the sensor should now be close to zero.

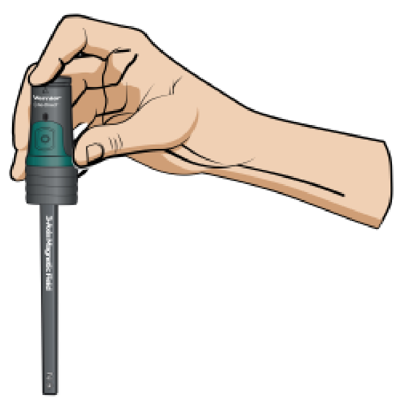

Figure 2

5. Prepare the model sea floor spreading zone for data collection.
   a. Place the model sea floor spreading zone on your table with the side marked North farthest away from you. The mid-ocean ridge is running north-south down the center of the model.
   b. Position the ruler so that it is lined up with the East and West marks on the sides of the pan. Align the 0 cm mark with the left edge of the pan as shown in Figure 3.

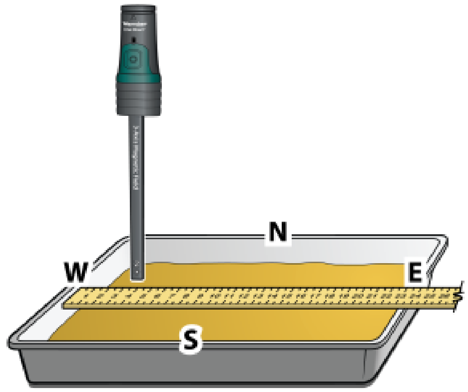

Figure 3

6. Click or tap Collect to start data collection and position the tip of the sensor at the 0 cm mark. **Important**: For each reading, make sure the tip of the probe is at the same height as the ruler.

7. Holding the sensor steady, click or tap Keep.

8. Enter **0** (indicating 0 cm). Click or tap Keep Point to save this data pair.

9. Move the tip of the sensor to the 1 cm mark. Holding the sensor steady, click or tap Keep. Enter **1**, and click or tap Keep Point.

10. Repeat the Step 9 procedure at 1 cm intervals until you reach the other side of the pan.

11. When data collection is complete, click or tap Stop to stop data collection.

12. Sketch or export an image of your graph according to your teacher's instructions.

PROCESSING THE DATA

1. Study your graph. The mid-ocean ridge runs north to south down the center of your model. Use a ruler or straight-edge to draw a line on your graph representing the mid-ocean ridge. Label the line "Mid-Ocean Ridge".

2. Draw the bands of magnetic reversal on your graph.

   a. Study your graph. A change between normal magnetic field ("normal" meaning the north magnetic pole is aligned with the north geographic pole) and reverse magnetic field ("reverse" meaning the north magnetic pole is aligned with the south geographic pole) occurred each time the line crosses zero. Using a straight-edge or ruler, draw a vertical line on your graph at each point where the line crosses zero.

   b. In locations where the magnetic field values are positive, the magnetic field of the Earth was normal. In locations where the magnetic field values are negative, the magnetic field of the Earth was reversed. Lightly shade the bands of ocean floor where the Earth's magnetic field was reversed with a colored pencil.

   c. Across the top of your graph, label each band either "Normal" or "Reverse".

3. Toward the bottom of your graph, draw two arrows indicating the direction of movement of the ocean floor. Remember from Figure 1 that the ocean floor is moving away from the mid-ocean ridge.

4. What is sea floor spreading?

5. Explain how the Earth's magnetic reversals provide evidence of sea floor spreading.

EXTENSIONS

1. Research the proposed causes of magnetic field reversals.

2. If the last magnetic reversal occurred about 780,000 years ago, approximately how long ago did it take for the ocean floor at the center of your model to reach the outside edge of your model?

Electromagnets: Winding Things Up

When electric current flows through a wire, it creates a magnetic field. Winding a wire around a piece of iron increases the strength of this magnetic field. A temporary magnet made in this way is called an electromagnet. In this experiment, you will use a Magnetic Field Sensor to study the relationship between number of wire winds and magnetic field strength of an electromagnet.

OBJECTIVES

- Build an electromagnet.
- Use a Magnetic Field Sensor to measure magnetic field strength.
- Graph the results.
- Make conclusions about the relationship between number of wire winds and magnetic field strength.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct 3-Axis Magnetic Field
large iron nail
80 cm piece of insulated wire
battery (size D)
tape

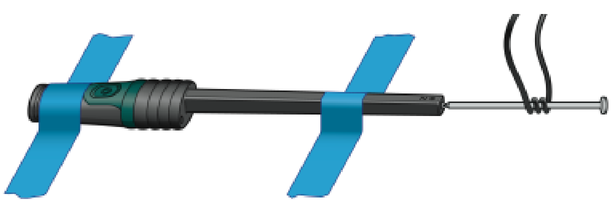

Figure 1

PROCEDURE

1. Tape the sensor to the tabletop as shown in Figure 1.

2. Launch Graphical Analysis. Connect the Magnetic Field Sensor to your Chromebook, computer, or mobile device.

3. Set up the mode.
   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   b. Enter **Winds** as the Event Name and leave the Units field blank. Click or tap Done.
4. Collect the data for zero winds.
   a. Click or tap Collect to start data collection.
   b. Get a large iron nail and place its pointed end next to the end of the Magnetic Field Sensor as shown in Figure 1. When the reading has stabilized, click or tap Keep.
   c. Enter **0** (for 0 winds).
   d. Click or tap Keep Point to store the data.
5. Tape one bare end of your insulated wire to the bottom end of a battery provided by your teacher.
6. Place the nail on the wire at a position 10–15 cm from the battery. Tightly wind the wire around the nail 3 times as shown in Figure 1.
7. Collect data for 3 winds.
   a. Firmly press the other bare end of the wire to the top of the battery.
   b. A partner should again touch the pointed end of the nail to the end of the sensor, as shown in Figure 1. **Important**: If the reading decreases, reverse the wire connections to the battery.
   c. When the reading has stabilized, click or tap Keep. **Caution**: The battery will become warm as it is used. To keep it from getting hot, and to use up the battery's energy more slowly, remove the wire from the top of the battery immediately after selecting Keep.
   d. Enter **3** (for 3 winds) and click or tap Keep Point.
8. Repeat Step 7 for 6, 9, 12, 15, 18, and 21 winds. **Important**: Wrap all winds at nearly the same distance from the nail end. As you wind more turns of wire, the wire should look more and more like a ball (see Figures 2 and 3).
9. Click or tap Stop to stop data collection.
10. Record the magnetic field strength values in your data table.
11. Export, download, sketch, or print the graph as directed by your teacher.
12. Before closing Graphical Analysis, continue to the Processing the Data section.

DATA

Winds	Magnetic field (mT)	Winds	Magnetic field (mT)
0		12	
3		15	
6		18	
9		21	

PROCESSING THE DATA

1. What is the relationship between number of winds and magnetic field strength?

2. According to your graph, what would the magnetic field strength reading be for 10 winds? For 30 winds? Explain.

3. Use the curve fit tool of Graphical Analysis to answer Question 2 by adding a best-fit line to your graph and then interpolating along this line.

   a. Click or tap Graph Tools, 📈, and choose Apply Curve Fit.
   b. Select Linear as the curve fit and dismiss click or tap Apply.
   c. Click or tap Graph Tools, 📈, and turn on Interpolate. Dismiss the Graph Tools menu.
   d. Tap the curve fit line at a position above 10 winds—the x-value should be about 10. The y-value is the magnetic field strength for 10 winds. Record the value.
   e. Tap the best-fit line at a position above 30 winds and record the y-value. **Note**: You will likely need to adjust the end points of the x-axis and the y-axis to view the bet-fit line at 30 winds.

EXTENSIONS

1. Determine the mass of paper clips or staples your electromagnet will pick up with the same numbers of winds used in the above experiment. Compare mass of paper clips or staples picked up to magnetic field strength.

2. Remove the nail from the wire and measure its magnetic field. Compare the magnetic field of the nail after the experiment with its magnetic field before it had been used in an electromagnet. Measure the magnetic field of the nail again after striking it on a hard surface. Explain these results using the idea of magnetic domains.

Magnetic Field Explorations

When playing with a magnet, you have probably found that objects were more strongly attracted or repelled when they were closer to the magnet. In this experiment, you will first use a Magnetic Field Sensor to study magnetic field strength at various distances from a bar magnet. In the second part of the experiment, you will measure and map the magnetic field at one-centimeter intervals along the length of the bar magnet.

OBJECTIVES

- Use a Magnetic Field Sensor to measure magnetic field strength.
- Graph and analyze data.
- Make conclusions about the relationship between magnetic field strength and distance.
- Measure and graph magnetic field strength at points along a bar magnet.
- Make conclusions about the magnetic field at various points on a bar magnet.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct 3-Axis Magnetic Field
meter stick
bar magnet
tape
ruler

Figure 1

PROCEDURE

Part I Magnetic field strength and distance

1. Launch Graphical Analysis. Connect the Magnetic Field Sensor to your Chromebook, computer, or mobile device.

2. Tape a meter stick to the table top with pieces of tape at 50 cm and 95 cm.

3. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   b. Enter **Distance** as the Event Name and **cm** as the Units. Click or tap Done.
4. Collect data at the 4 cm distance.
   a. Click or tap Collect to start data collection.
   b. Position the Magnetic Field Sensor so the Sensor Location dot is at the 0 cm mark (see Figure 1).
   c. Place the S pole of the bar magnet at the 4 cm line of the meter stick (see Figure 1). If the poles are not marked, orient the magnet so that you get positive magnetic field readings. Keep the magnet in this orientation throughout Part I.
   d. When the reading has stabilized, click or tap Keep.
   e. Enter **4** (for 4 cm). Click or tap Keep Point to save this data pair.
5. Move the magnet and repeat the Step 4 procedure at each 2 cm interval up to 14 cm.
   Note: You do not need to start data collection each time.
6. When you have finished, stop data collection and answer the Part I Processing the Data questions before moving on to Part II.
7. (optional) Print a copy of the graph.

Part II Mapping the magnetic field of a bar magnet

8. Position the bar magnet beside the ruler with the S-pole end of the magnet at the 3 cm mark (see Figure 2). Tape the magnet to the table top.

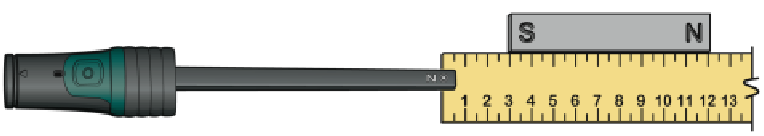

Figure 2

9. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change the Event Name to **Position**. Click or tap Done.
10. Collect data at the 0 cm position.
    a. Click or tap Collect to start data collection.
    b. Position the Magnetic Field Sensor so the Sensor Location dot is at the 0 cm mark (see Figure 2).
    c. When the reading has stabilized, click or tap Keep.
    d. Enter **0** (for 0 cm). Click or tap Keep Point.

11. Move the sensor and repeat the Step 10 procedure at 1 cm intervals until you have reached a point 3 cm beyond the N-pole end of the bar magnet. **Important**: Keep the Magnetic Field Sensor parallel to the bar magnet during data collection, as shown in Figure 3.

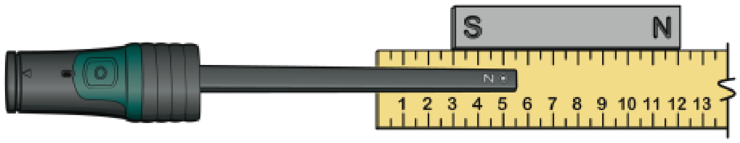

Figure 3

12. When you have finished, stop data collection and answer the Part II Processing the Data questions.

13. (optional) Export, download, or print a copy of the graph.

14. Before closing Graphical Analysis, continue to the Processing the Data section.

PROCESSING THE DATA

Part I Magnetic field strength and distance

1. What happens to magnetic field strength as distance increases?

2. What would the magnetic field strength be at 7 cm? What would it be at 16 cm?

Part II Mapping the magnetic field of a bar magnet

3. Where on the bar magnet was the largest positive magnetic field strength reading observed?

4. Where on the bar magnet was the most negative magnetic field strength reading observed?

5. At what centimeter position does your graph have a zero value magnetic field strength value? At what point is this on the bar magnet?

6. Why does the graph have both positive and negative magnetic field strength values?

7. Use what you learned in Part I to explain the shapes of the end portions of your Part II graph.

EXTENSIONS

1. Test the strengths of different magnet types at the same distance from the sensor. Which magnet types are strongest? Weakest?

2. Stack similar magnets, one at a time, and measure the combined field strength. Graph your data and describe the relationship you find.

3. Place two magnets 5 cm apart and facing each other. You may need tape to hold them in place. Use a Magnetic Field Sensor to explore the field strength between the magnets. Try N-N, N-S, and S-S pole combinations. What differences do you find?