7. Earth's Magnetic Field

Driving Questions

How can models be used to visualize the magnetic field lines surrounding Earth?

- How does the magnetic field strength vary with different locations on Earth?
- What creates Earth's magnetic field?
- How does Earth's magnetic field help navigators stay on course during their travels?

Background

All magnetic objects produce invisible lines of force that connect the poles of the object. Although the Earth's magnetic field makes it appear that a powerful bar magnet exists near the Earth's center, such a bar magnet does not exist. The Earth's magnetic field is produced by a complex interaction between the convection currents in the molten outer core and the solid inner core, both of which contain large quantities of ferromagnetic metals, such as iron, nickel, and cobalt.

The north magnetic pole and the geographic North Pole are different. The north magnetic pole is the point at which the geomagnetic field in the north points vertically, that is, the magnetic dip is 90°. Compass needles generally point towards the north and south magnetic poles of the Earth. The north magnetic pole and the north geographic pole are not in the same place. In 2005, the north magnetic pole was at 82.7°N and 114.4°W and the geographic North Pole is by definition 90°N and 0°W. The Earth's magnetic north pole is not a fixed point but is constantly moving. In the past 100 years, the Earth's magnetic north pole has wandered approximately 600 miles to the north to its present location in the Canadian Arctic.

What are magnetic reversals? Considering that ships, planes and scouting groups navigate by it, the Earth's magnetic field is less reliable than you would think. Rocks in an ancient lava flow in Oregon suggest that for a brief time about 16 million years ago magnetic north shifted as much as 6 degrees per day. After little more than a week, a compass needle in the United States would have pointed toward Mexico City. According to this same data, the lava caught the Earth's magnetic field in the act of reversing itself, showing that the magnetic north headed south, and—over about 1,000 years—the magnetic field completely reversed. Geologic evidence, in the form of the "paleomagnetic" record, confirms such reversals have happened many dozens of times in Earth's history. Today, seafloor spreading can be measured by mapping the magnetic reversals in crustal rock in both directions from the diverging boundary in the Mid-Atlantic Ridge. Knowing the width of a band of rock with a similar polarity, and the amount of time it took to be created, the rate at which the plate moved can be determined.

Materials and Equipment

For each student or group:

- Magnetic field sensor
- Bar magnet
- Small cork
- Sewing needle
- Pin
- Water, 500 mL
- Clear plastic cup
- Magnetic field demonstrator plate (4), 2D
- Degree wheel template
- Map of Earth template

Safety

Add this important safety precaution to your normal laboratory procedures:

- Keep magnets away from electronic equipment.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Part 1 – Constructing a simple compass

You will build a compass using a needle, a cork, and a magnet. Remember, the needle of a compass always points towards magnetic north.

1. ☐ Magnetize the needle:
   a. Hold the needle by the needle's eye.
   b. Hold the bar magnet at its north end with the magnet horizontal.
   c. Stroke the needle off the south end of the magnet, from the needle's eye to the needle's point and repeat this motion 40 to 50 times.
2. ☐ Test the magnetic ability of the needle by placing the magnetized needle next to a pin.
3. ☐ How do you know whether or not the needle has become magnetized?

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4. ☐ In general, explain how two magnetized objects respond to each other.

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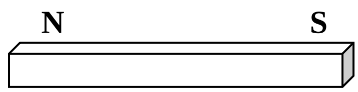
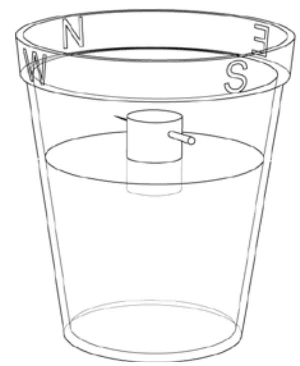
5. ☐ Determine which end of the needle is north and which end of the needle is south by placing the needle next to the bar magnet.

6. ☐ Draw a diagram of your needle next to the south end of the bar magnet you see pictured below. Label which end of the needle is north (N) and which side of the needle is south (S).



7. ☐ Cut off a small piece of cork and push the magnetized needle through it.

8. ☐ Label a clear plastic cup with the coordinates N, E, S, W.



9. ☐ Fill the cup with water.

10. ☐ Float the cork with the needle in the water.

11. ☐ Rotate the cup so the needle points to the N to complete your simple compass.

12. ☐ Which end of the needle compass is pointing toward the north magnetic pole?

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13. ☐ What does this tell you about the polarity of Earth's north magnetic pole?

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14. ☐ Who uses compasses and why are they used?

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15. ☐ Is the north magnetic pole the same as the geographic North Pole?

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16. ☐ How do navigators account for any difference?

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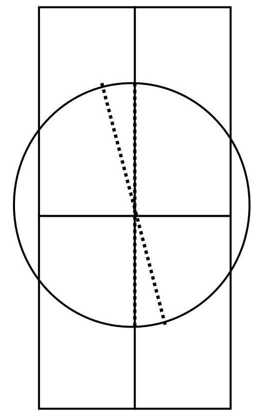
Part 2 – Visualizing the Earth's magnetic field



17. ☐ Lay all four 2D magnetic field demonstrator plates on top of the Map of Earth template to make a large rectangle as shown.

18. ☐ Place the bar magnet on top of the magnetic field demonstrator plates, lining it up with the magnet diagram on the template.

19. ☐ Ensure that the south pole of the magnet is in the North as shown on the template.

20. ☐ Why is the south pole of the magnet near the North Pole?

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21. ☐ Allow the iron pieces within the magnetic field demonstrator plates to orient themselves with the magnetic field of the bar magnet.

22. ☐ Describe the pattern the iron pieces make around the Earth (on the template).

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23. ☐ Make a sketch showing the alignment of the iron pieces over the template. You might want to use short arrows to indicate how the iron filings pointed relative to the magnet

Part 3 – Measuring the magnetic field of a bar magnet

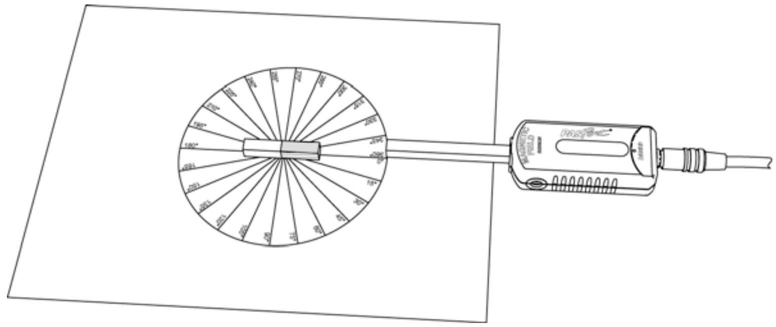
Set Up

24. ☐ Start a new experiment on the data collection system.

25. ☐ Connect a magnetic field sensor to the data collection system.

26. ☐ Put the data collection system into manual sampling mode with manually entered data. Name the manually entered data for the table "Degrees" and add a column to display "Magnetic field strength."

27. ☐ Place the bar magnet on the degree wheel template so that the north pole on the magnet points to the 0 degree line on the template.



28. ☐ Position the magnetic field sensor's tip at the 0 degree line on the template as shown in the diagram. The closer you place it, the stronger the field will be; keep the sensor the same distance from the magnet and in line with the circle.

Collect Data

29. ☐ Start a manually sampled data set.

30. ☐ Record the magnetic field strength every 15 degrees starting at the 0 degree mark on the template.

31. ☐ When you have recorded all of your data, stop the data set.

Analyze Data

32. ☐ Display Magnetic field strength on the y-axis of a graph with Degrees on the x-axis.

33. ☐ Find and label the coordinates of the data point with the highest magnetic strength value and the lowest magnetic strength value.

34. ☐ What was the highest and lowest magnetic strength value recorded?

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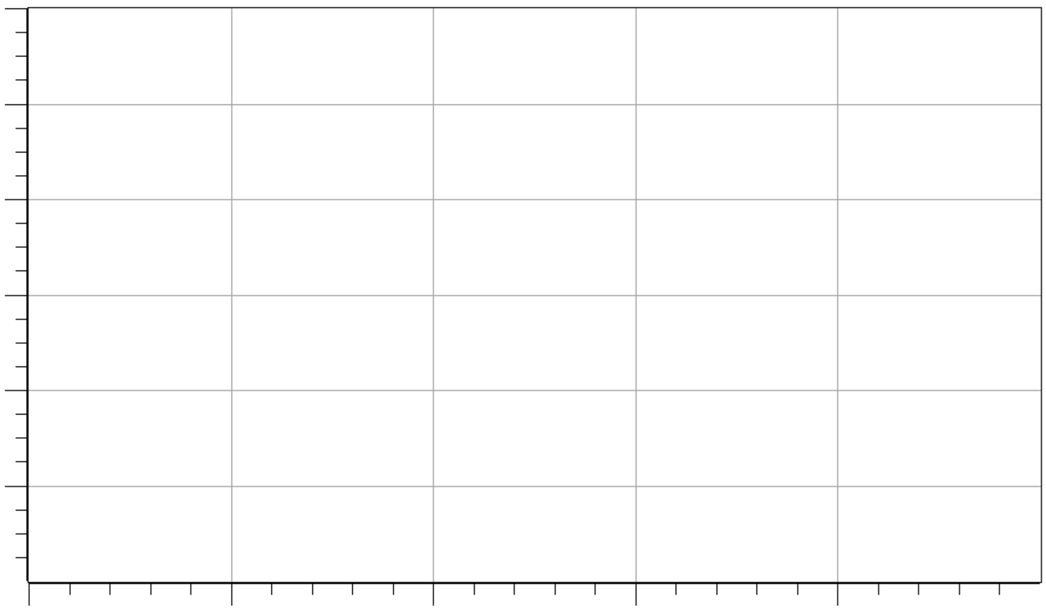
35. ☐ Sketch or print a Magnetic Field versus Degrees graph. Label the overall graph, the x-axis, and the y-axis. Include units and scales on the axes.



36. ☐ In the data, some of the values are positive and some are negative. What does that mean for the polarity?

37. ☐ At which locations on the magnet was the field strength the greatest? At which locations was it the least?

38. ☐ Save your file and clean up according to the teacher's instructions.

Data Analysis

1. ☐ If the north pole of the needle magnet pointed to the north magnetic pole, what is the polarity of the north magnetic pole? Explain your reasoning.

2. ☐ Describe how the magnetic field strength on Earth varies.

3. ☐ On the Map of Earth template, label the highest positive magnetic field strength readings and the lowest negative readings at their corresponding degree. What part of the bar magnet does each data point represent?

Analysis Questions

1. **Why did the needle on your compass point north? Explain.**

2. **Is the Earth's magnetic field a two or three dimensional magnetic field? Do you have any evidence for this?**

3. **What would the graph look like after a magnetic reversal? Explain.**

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4. **Do you think the model of the Earth's magnetic field you recorded in the lab would be different if you used a much stronger or much weaker magnet? Explain your answer.**

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Synthesis Questions

Use available resources to help you answer the following questions.

1. **Is the Earth's magnetic field a static, rigidly set magnetic field like a bar magnet? Explain.**

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2. **Humans use compasses to navigate the world. What other animals use Earth's magnetic field? Explain.**

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3. **How does the magnetic field of the Earth protect the planet in space?**

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4. **What would cause the magnetic field of Earth to disappear altogether? Explain.**

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Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. **The needle on a compass points north because the Earth's magnetic field resembles a**

   A. Horseshoe magnet
   B. Bar magnet
   C. Refrigerator magnet
   D. Single pole magnet
   E. None of the above

2. **Which statement best describes the pattern in which the magnetic field of a bar magnet varies with location from 0 or 360 degrees to 180 degrees?**

   A. Strong positive value at 0 or 360 degrees to strong negative at 180 degrees
   B. Strong negative value at 0, 180 and 360 degrees, strong positive at 90 and 270 degrees
   C. Strong negative value at 0 or 360 degrees to strong positive at 180 degrees
   D. Strong positive value at 0, 180 and 360 degrees, strong negative at 90 and 270 degrees
   E. None of the above

3. **Which statement best describes the orientation of magnetic field lines around a bar magnet?**

   A. The magnetic field lines resemble a series of straight lines from the north to the south pole in two dimensions.
   B. The magnetic field lines resemble a series of straight lines from the north to the south pole in three dimensions.
   C. The magnetic field lines resemble a two dimensional series of loops from one pole to the other.
   D. The magnetic field lines resemble a three dimensional series of loops from one pole to the other.
   E. The magnetic field lines run perpendicular to the surface of the magnet.

4. **Which statement best describes the Earth's magnetic field?**

   A. The Earth's magnetic field is permanent.

   B. The Earth's magnetic field reverses every 1000 years.

   C. The Earth's magnetic field has varied in strength and orientation over time.

   D. The Earth's magnetic field is static.

   E. The Earth's magnetic field varies in strength and orientation with the lunar cycle.

5. **Magnetic declination:**

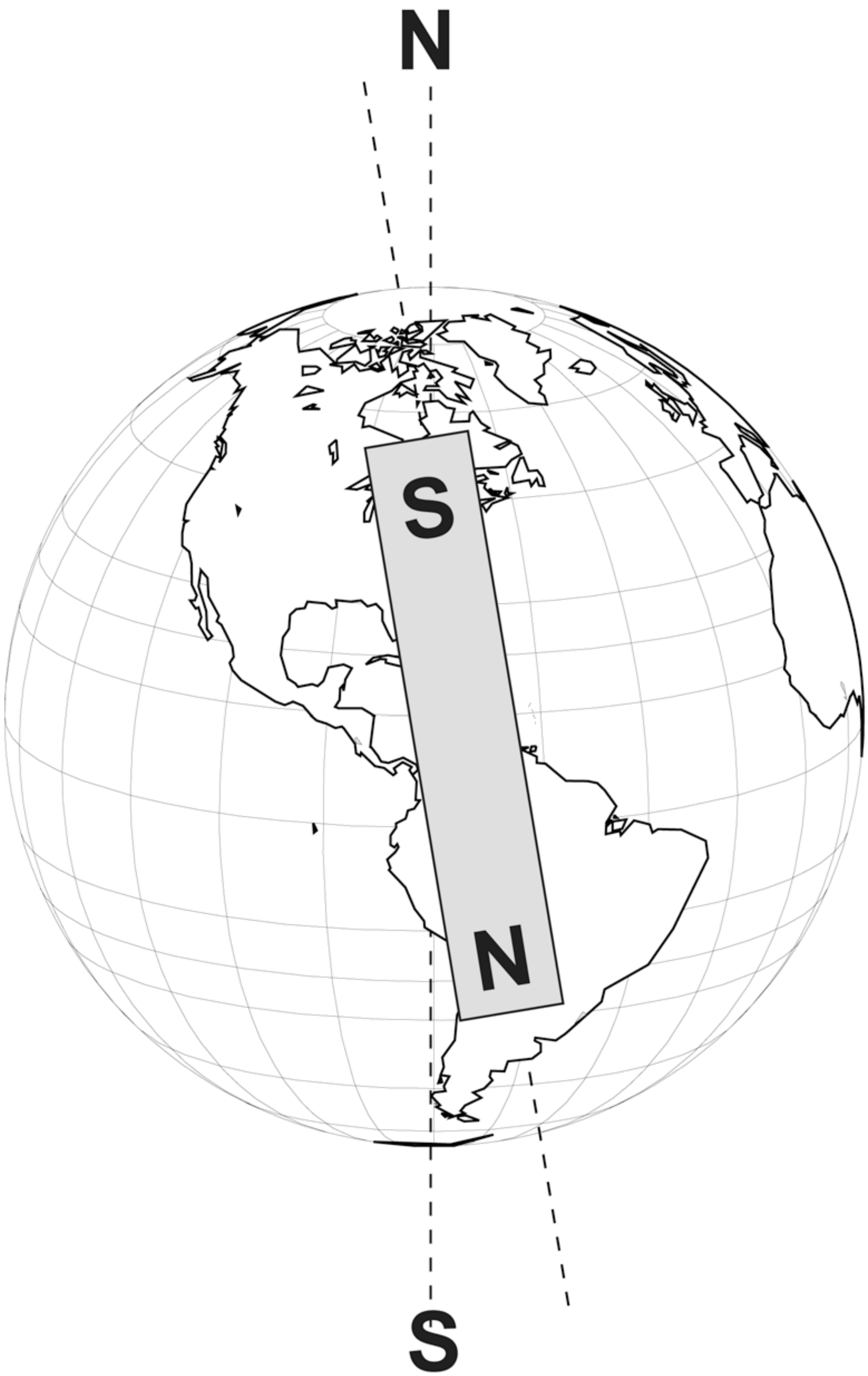
   A. Varies according to location

   B. Is stronger near the South Pole

   C. Is constant within a hemisphere

   D. Is stronger near the North Pole

   E. Is zero when you are standing at the Equator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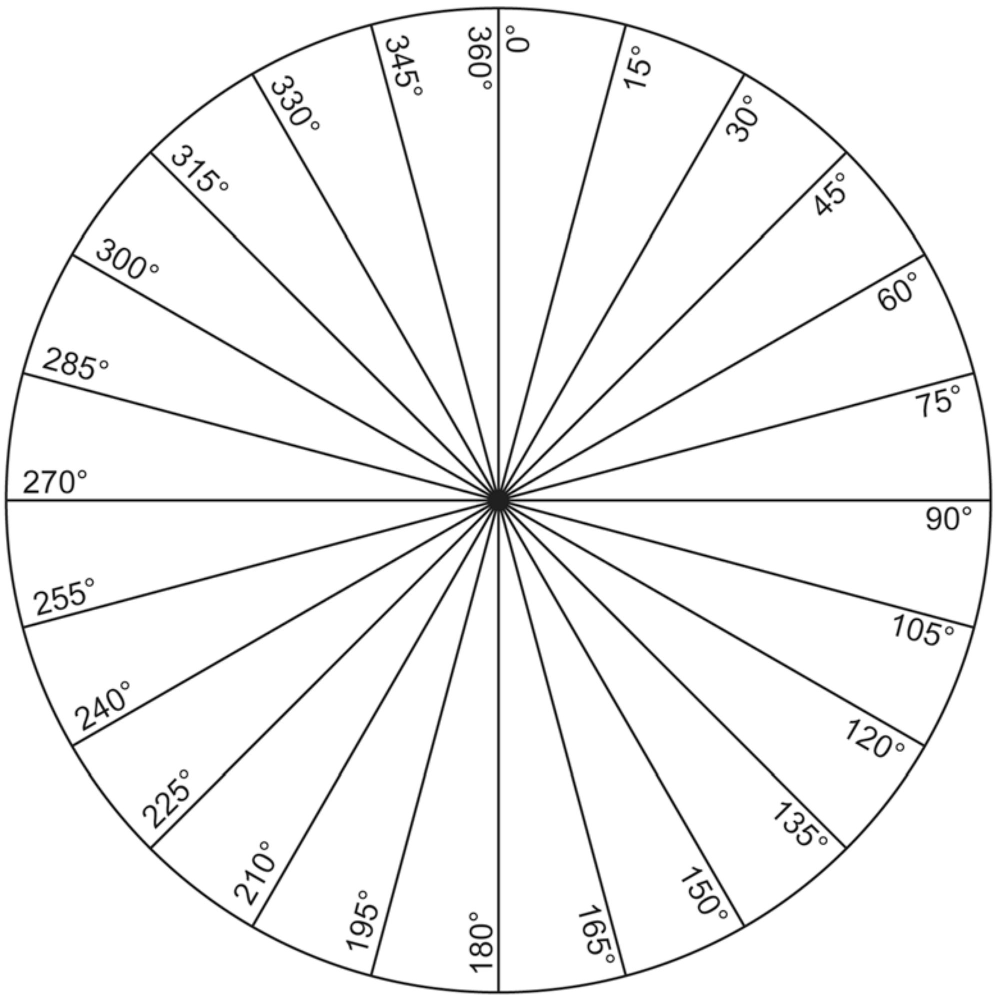
0°
360°
15°
30°
45°
60°
75°
90°
105°
120°
135°
150°
165°
180°
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210°
225°
240°
255°
270°
285°
300°
315°
330°
345°