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Educator Material

Animal Navigation Using Magnetic Fields

Animal Navigation Using Magnetic Fields

Purpose

The purpose of this lesson is to introduce students to the concept of magnetic fields and magnetic field lines. Students will also learn about how one species of worm, *C. elegans*, detects and uses magnetic fields to navigate in their environments.

Audience

This lesson was designed to be used in an introductory high school physics class.

Lesson Objectives

Upon completion of this lesson, students will be able to:

- define magnetic field and describe common examples of magnetic fields.
- explain how magnetic field lines are draw and how to use them to determine the relative strength of a magnetic field at different places around a magnet.
- define polarity and explain how the polarity of Earth's magnetic field impacts how animals navigate.
- describe how animals use Earth's magnetic field to navigate.

Key Words

field line, magnetic field, polarity, vector field

Big Question

This lesson plan addresses the Big Question *"What does it mean to observe?"*

Standard Alignments

- **Science and Engineering Practices**

  SP 2. Developing and using models

- **MA Science and Technology/Engineering Standards (2016)**

  HS-PS3-5. Develop and use a model of magnetic or electric fields to illustrate the forces and changes in energy between two magnetically or electrically charged objects changing relative position in a magnetic or electric field, respectively.

- **NGSS Standards (2013)**

  HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

Misconceptions Addressed

This lesson addresses some common misconceptions about electromagnetism, including that

Earth's magnetic north and south poles are located at the geographical north and south poles (Question 2).

Primary Sources

- **Bite** "Magnetic Worms! Kind of..." based on:

  Vidal-Gadea, Andrés, Kristi Ward, Celia Beron, Navid Ghorashian, Sertan Gokce, Joshua Russell, Nicholas Truong, Adhishri Parikh, Otilia Gadea, Adela Ben-Yakar, and Jonathan Pierce-Shimomura. "Magnetosensitive Neurons Mediate Geomagnetic Orientation in Caenorhabditis Elegans." *ELife*4 (2015). doi:10.7554/elife.07493.

- This research was also reported by NPR:

  Chappell, Bill. "Worms Know What's Up - And Now Scientists Know Why." The Two-Way. June 17, 2015. Accessed June 10, 2018. https://www.npr.org/sections/thetwo-way/2015/06/17/415233214/worms-know-whats-up-and-now-scientists-know-why.

Materials

- Copies of the student handout and Science Bite for each student.

Materials for optional introductory activity:

- Compasses (1 for each group of 2 students)
- Bar magnets (1 for each group of 2 students)

Time

This activity should take approximately one 50-minute class period.

Student Prior Knowledge

This lesson can serve as an introduction to magnetic fields. Students should already understand that forces can act at a distance.

Instructions and Teacher Tips

- **General Procedure**
  - Have students read the introduction on the student document and answer Questions 1 and 2. Review the answers as a class.
  - Have students read the Science Bite on their own or in pairs or groups.
  - Have students answer Questions 3–6 and review the answers as a class.
- **Tips, Variations, and Extensions**
  - If students are already familiar with magnetic fields and magnetic field lines, the introductory reading can be skipped or can be assigned as homework for review.
  - It might be helpful to remind students of other forces that act at a distance like

magnetism, such as gravitational force and electric force.

- Optional introductory activity:
    - Provide each pair of students with a compass and a bar magnet.
    - Have students make observations of what the compass does when it is not near the bar magnet.
    - Then have students observe what happens to the compass when a bar magnet is placed near it.
    - You can have students examine this relationship quantitatively by measuring how much the compass is deflected when the magnet is different distances away from the compass.
- *Science* has a short video about animal navigation using magnetic fields that might be of interest to your students.
- Microscopic organisms can be difficult to wrap your heads around. This is a good, short video introduction to *C. elegans.*

Background Information and Research Details

- Previous research has found that a wide variety of organisms such as wolves, birds, salamanders, butterflies, turtles, sea slugs, bees, ants, and bacteria can detect small differences in the magnetic field, an ability known as magnetoreception. Magnetoreception is used by different organisms in different ways: to detect or avoid other organisms, to help them navigate, and/or orient themselves in space.
- The magnetic field sensing abilities of bacteria have been well studied. Scientists have found small magnetic particles in bacteria, but how these particles are used to aid navigation is still unknown.
- In the study discussed in this lesson, over 61,000 *C. elegans* were raised and studied at the University of Texas at Austin. Worms were placed on a welled-plate that had a 3.5-cm diameter neodymium magnet underneath it to create a magnetic field. The plates were wrapped in three layers of heavy-duty aluminum foil to see if the worms could use the magnetic field for navigation in the dark.

Big Question Discussion

This lesson addresses the Big Question *“What does it mean to observe?”* Specifically, students discuss the importance of comparing observations. If you choose to delve into the Big Question further, consider the following idea:

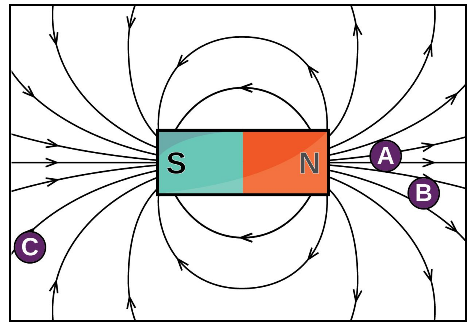
After students answer the last question on the Student Handout, you can have them discuss the Big Question using the following prompt:

- When have we made comparisons in class in order to come to conclusions. Describe an experiment where we have made comparisons. What did those comparisons allow you to conclude? Why was that important? Why do you think this type of comparison is important for scientists?

Answers

1. Examine the bar magnet with field lines.

At which location (A, B, or C) is the magnitude of the magnetic field the strongest? Explain your answer and refer to the diagram in your response.



The magnetic field is strongest at A. The field lines are closer together. A is also closer to the magnet.

2. A compass is a small device used to determine the direction you are going. It contains a very small magnet that rotates easily. The north pole of the magnet inside the compass points towards Earth's magnetic north pole.

   a. Based on this information, in which direction is Earth's magnetic field oriented? Explain your answer and include a drawing in your response.

The magnetic south pole is near the geographic north pole of the Earth. If the north pole of a magnetic points to the Earth's geographic north pole then it is attracted to that pole. Since opposite poles of magnets attract, the Earth's magnetic south pole must be geographically north.

   b. How does **Figure 2** support your answer to part a?

Figure 2 shows the field lines pointing towards the Earth's geographic north pole. Magnetic field lines always point towards the south pole of a magnet, this implies that the Earth's geographic north pole is its magnetic south pole.

STOP & read Science Bite:
Magnetic Worms! Kind of...

3. In what ways is the AFD sensory neuron pair in *C. elegans* similar to a compass? In what ways is it different? Justify your response.

The AFD sensory neuron pair helps animals sense differences in a magnetic field, similar to how a compass reacts to the Earth's magnetic field and magnetic fields of magnets in its vicinity. Both are tools used by living things to help them navigate. It is different than a compass in that it is a biologically developed neuron pair while a compass is a manmade tool.

4. Using **Figure 2** above, explain why it makes sense that Australian and English worms went in opposite directions when placed in the same magnetic field.

Figure 2 shows that the Earth's magnetic field points in the opposite direction in the southern hemisphere than in the northern hemisphere. Therefore Australian worms experience a magnetic field oriented in the opposite in direction from that experienced by English worms. It makes sense that when Australian and English worms were exposed to the same magnetic field that they would go in opposite directions, because in their native habitats they are accustomed to magnetic fields that were opposite each other.

5. Use **Figure 2** and information from the Bite to explain why it makes sense that worms from countries near the Earth's equator were influenced less by magnetic fields than worms from countries near Earth's poles.

Magnetic fields are stronger near a magnet's poles. In **Figure 2** this is shown as the field lines being closer together near the north and south pole. By contrast, the magnetic field lines are less dense near the equator. This indicates that the Earth's magnetic field is weaker there. It makes sense that worms from the equator were less affected by magnetic fields, because they are exposed to weaker magnetic fields and therefore less likely to depend on them for navigation.

6. **Connect to the Big Question**. In this work, scientists were observing the effects of something invisible (magnetic field) on worms. They first observed the worms without any added magnetic field and then with an added magnetic field. Why was it important to observe them without the magnetic field first? Scientists often make comparisons between their observations in order to come to conclusions. Why is comparing observations such a powerful tool?

Sample answer: It was important to first get baseline data about how the worms move, so that scientists could see if the added magnetic field changed their behavior at all. You can't measure a change if you don't know what the original behavior was like. Comparing observations in a powerful tool, because it allows to see if the variable we have changed has an impact on the system we are studying. With careful comparisons, we can find correlations