

Earth's Magnetic Field from Space

High School Grades

Lesson Summary

Students use their experience with magnetic fields to understand and explain the Earth's magnetosphere

Prior Knowledge & Skills

Completed the lesson:

- *Mapping the field of Multiple Dipole Magnets*

AAAS Science Benchmarks

The Nature of Science

The Scientific World View

Scientific Inquiry ★

The Physical Setting

The Universe ★

The Structure of Matter

Motion

Forces of Nature ★

NSES Science Standards

Science as Inquiry

Abilities to do Scientific Inquiry ★

Understandings of Scientific Inquiry

Physical Science★

Motions and Forces

Science and Technology

Understandings about Science and Technology

History and Nature of Science

Science as a Human Endeavor

NCTM Mathematics Standards

Data Analysis & Probability

Problem Solving

Reasoning and Proof

Teaching Time: One 45-minute period

Materials for Students

- Pencils/pens
- Drawing paper
- Magnets
- Magnetometer

Advanced Planning

Preparation Time: 20 minutes

1. Review lesson plans
2. Gather materials
3. Arrange room for discussion and team work

Recommended Reading:

<http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magearth.html>

Live from the Aurora, pp. 59-61, NASA (2003)

http://sunearth.gsfc.nasa.gov/sunearthday/2003/educators_guide2003/pdf/lfa_educators_guide.pdf

Activity 4 Earth's Magnetic Field From Space

Teacher Instructions

Goal: Understand that the interaction between the solar wind and Earth's magnetic field is influential to shape of the Earth's magnetosphere.

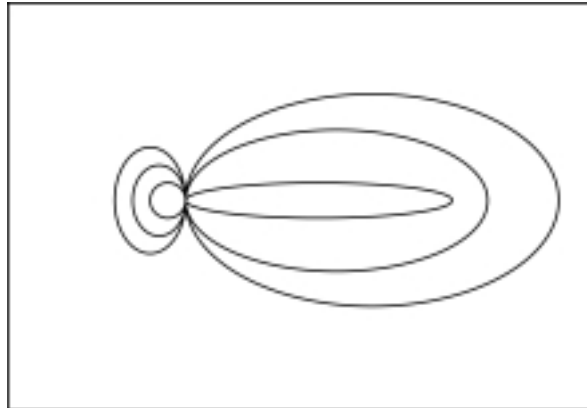
Background: Scientists often designate regions of interest by the geometric shape that they occupy and a Latin or Greek root detailing the property of interest that motivated the designation. Around the spherical Earth, one finds the spherically shaped atmosphere (see the word sphere along with the Greek atmos in "atmosphere"). The Earth's atmosphere can be subdivided into many other regions based on a particular physical property of interest. We are going to concern ourselves with the Earth's magnetosphere. The magnetosphere is not part of the atmosphere. It is actually much larger, and physical processes that happen because of the magnetosphere are as influential to our lives as the presence of oxygen in the lower atmosphere, or troposphere. The troposphere extends to about 16 kilometers above the Earth. The magnetosphere extends about 10 Earth radii (an Earth radius is 6400 km) on the Sun side of the Earth to about 100 Earth radii on the side of Earth away from the Sun.

1. Review homework maps. Student homework was to predict maps of various configurations. If time permits, you might spend some time using the magnetometers to verify the fields seen due to the suggested arrangements of dipoles. It is of pedagogic value to point out that the various configurations can be seen as stretching of the basic arrangements mapped in class the previous day. Certain maps ought to merge into others if you imagine shifting a magnet. One should not see anti-parallel lines next to each other. One should not see magnetic field lines crossing. It is suggested that consensus be reached on the homework predictions through discussion and logic. The testing of predictions is left to the teacher's discretion.
2. Following resolution of homework, a deformed magnetic field map is presented for student analysis (following pages).

3. **Main Activity**—hand out *The Earth's Magnetic Field From Space* activity.

Given a magnetic field map, can we say something about the number and type of dipoles needed to produce such a map?

Consider this map:



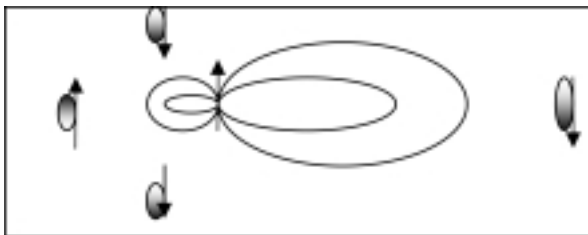
Let us assume that this is a representation of an actual magnetic field. This is similar to a dipole field, but shows a clear deformation. The minimum field of any magnetic configuration is dipole. Thus, somehow, at least two dipoles are combining to form the above representation.

4. Ask the students to form groups and create a scenario that would provide a hypothesis about how such a field might be formed. Budget 10-15 minutes for this activity. Students should be ready to present ideas in a "Board Meeting" format. Ask groups to present hypotheses on large sheets of paper or white boards. Allow 1-2 minutes for presentations. Presentations should consist of statements of known facts and logical extensions of the known facts that would, in combination, lead to the above field configuration.

Suggested answer: A subject pole is producing the expected symmetric field, oriented tangentially to the line along which all the field map ovals touch (the axis joining the poles of the subject dipole.) Two other dipoles are situated off the diagram, one to the right and one to the left. The one to the left is parallel to the

subject and produces a repulsive field interaction with the subject dipole causing the subject field to be compressed from the left. The one to the right is anti-parallel to the subject dipole and produces an attractive field interaction causing the subject field to be stretched to the right.

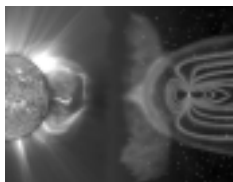
To explain the vertical compression on the left a set of two dipoles could be placed above and below the subject dipole (top and bottom of image page) so that there were repulsive interactions at each pole.



There may be many other answers given. The basic guide to "correctness" is that the directionality of the field interactions is respected, and students are able to cite the observations they have made in previous mapping activities.

An objection to this procedure may arise. To make a truly smooth field map, one might need many small magnets to overcome the little bumps and variations in the field one might expect where there are gaps between the outer magnets. This objection, whether stated by a student or brought in by the teacher, is needed. Use it to bridge to the idea of the solar wind as the carrier of magnetic field and the source of interaction with Earth's dipole field that produces a magnetosphere shaped somewhat like the above field diagram.

5. Discuss readings



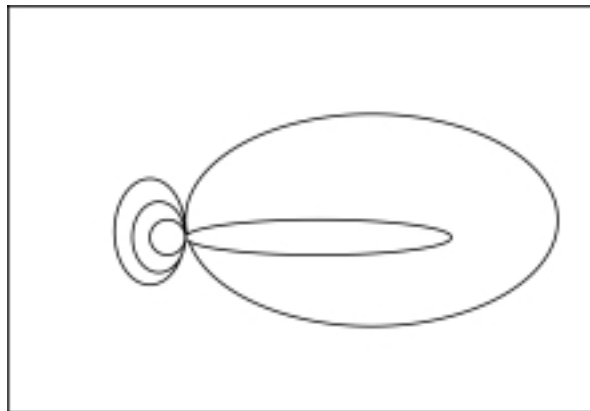
Student Activity 4

The Earth's Magnetic Field from Space

Goal: How does the interaction between solar wind and Earth's magnetic field influence the shape of Earth's magnetosphere?

Given a magnetic field map, can we say something about the number and type of dipoles needed to produce such a map?

Consider the following map:



Let us assume that this is a representation of an actual magnetic field. This is similar to a dipole field, but shows a clear deformation. The minimum field of any magnetic configuration is dipole. Thus, somehow, at least two dipoles are combining to form the above representation.

Working in small groups, propose an arrangement of magnets that would provide a hypothesis about how such a field might be formed. Prepare sufficient notes to enable a group representative to present the group solution to the rest of the class. The presentation should last just a minute or two. Presentations should consist of known facts and logical extensions of the known facts that would lead to the above field configuration.

The Earth has a magnetic field, as you know. Close to the surface of the Earth, it looks like a dipole field, although it is offset from the rotation axis. Satellite observations have shown that the magnetosphere of the Earth, several thousand miles above the surface of the Earth, looks like the magnetic field you just tried to model.

In small groups, develop a written explanation for the observed shape of the Earth's magnetic field. Your explanation must allow for a nearly dipole shape near

the surface of the Earth and a highly deformed field far from the surface of the Earth. Your explanation must:

- Include an account of the various forces involved,
- Identify the objects or processes that could or might be providing the force.

Homework:

Visit the following Web sites to explore the Sun-Earth connection

- Space Weather
<http://sunearth.gsfc.nasa.gov/sehtml/tut.html>
- Making Sun-Earth Connections
<http://sunearth.gsfc.nasa.gov/sunearthday/NewPresSplash.htm>
- Solar Terrestrial Probes and Living With a Star Education
http://stp.gsfc.nasa.gov/educ_out/educ_out.htm

Visit the following Web sites to learn about the solar wind.

- Solar wind & interplanetary magnetic field (IMF)
<http://www oulu.fi/~spaceweb/textbook/solarwind.html>
- Cosmic and Heliospheric Learning Center
A resource on the solar wind with links to research data-driven activities.
<http://helios.gsfc.nasa.gov/sw.html>
- Solar Physics, Science Directorate, Marshall Space Flight Center
A resource about particular features of the solar wind.
<http://solarscience.msfc.nasa.gov>

Visit the following Web sites to learn about the Earth's Magnetosphere

- The Earth Magnetosphere Art Gallery;
A series of scientific images of the magnetosphere.
<http://image.gsfc.nasa.gov/poetry/>
- Exploring Earthspace: The Magnetopause.
A detailed and reasonably complete discussion of the interaction between the solar wind and the magnetosphere.
<http://www-spof.gsfc.nasa.gov/Education/lxplre.html>