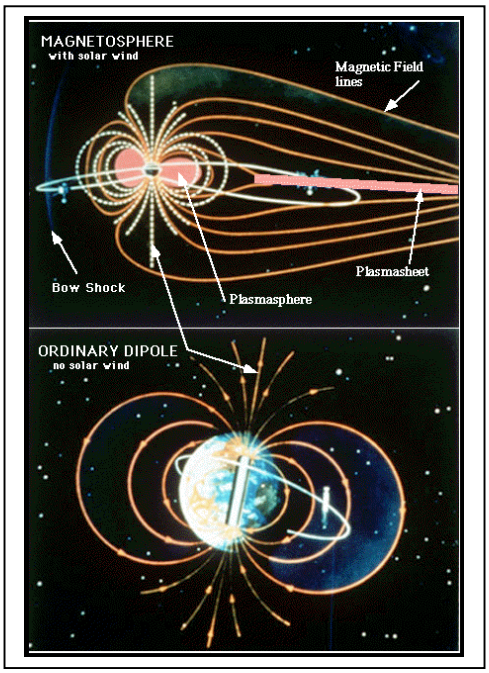
Earth's Magnetosphere Internet Field Trip



Time:
2 1/2 - 3 1/2 hours

Objective:
The purpose of this activity is to give students exposure to the concepts involving the Earth's Magnetosphere. Students will learn key vocabulary related to the Earth's Magnetosphere and create a cutout magnetosphere. Students will also navigate the Internet to investigate the Earth's Magnetosphere and its importance as related to the sun-earth connection

Content Standards:
Science as Inquiry
- abilities necessary to do scientific inquiry

Earth and Space Science
- earth in the solar system

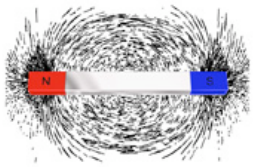
Science and Technology
- understandings about science and technology

Equipment, Materials, and Tools:
- Notebook paper
- Pencils/pens
- One computer per student (or teams of students)
- Scissors (1 pair per student)
- Crayons/Markers/Colored Pencils

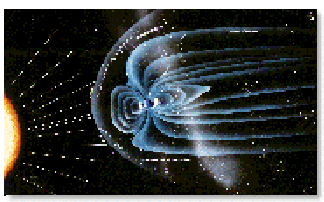
Materials to reproduce
- Earth's Magnetosphere cutout & instruction sheet (1 copy per student)
- Earth's Magnetosphere Vocabulary worksheet (1 copy per student)

Prerequisite Skills:
Internet navigation skills

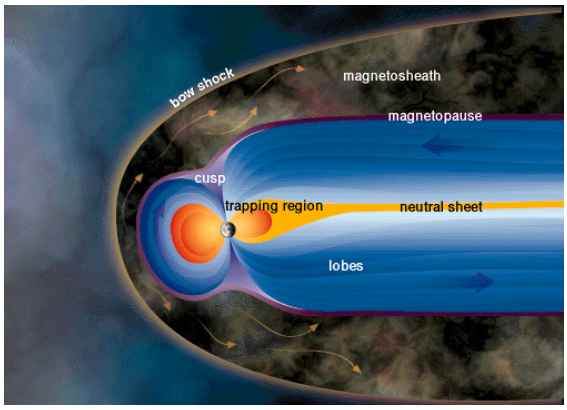
Background Information:
The Earth has a strong internal magnetic field. It is through the use of special instruments that we know this magnetic field exists. The earliest used instrument and probably the simplest is a magnetic compass. The Earth's core, made up of nickel and iron, acts as a giant dipole bar magnet. Its' magnetic field affects the needle of the compass. Without instruments, the Earth's magnetic field is invisible, only the effects on things we can see allow us to realize that it exists.



The Earth's magnetic field extends beyond the surface of the Earth. We know that its magnetic field extends thousands of miles into the area of space surrounding the Earth. The area of space controlled by the Earth's magnetic field is called the magnetosphere. With instrumentation that measures streaming particles, electromagnetic radiation and constantly changing electric and magnetic fields, we have been able to model what the magnetosphere looks like. The Earth's magnetosphere plays a very important part in protecting the Earth's environment as it helps to shield the Earth from the Sun's solar wind.



The solar wind is composed of particles ejected from the Sun. These particles flow from the Sun out into space and can encounter other solar bodies as they move out through the solar system. The Earth's magnetosphere acts as an obstacle to the solar wind particles just as rocks act as obstacles to the flowing water in a river. The particles must move around the obstacle. The solar wind particles are moving at a great velocity that means they cannot move around the obstacle easily. Their movement is disrupted by the magnetosphere and a bow shock region is created and their direction is abruptly changed. The solar wind particles squash the Earth's magnetic field on the solar side and seem to stretch the magnetosphere on the side away from the Sun.



The speed and motion of the particles are changed with most of the particles moving around the magnetosphere in the area known as the magnetosheath, effectively shielding the Earth from the solar wind. Although the solar wind particles cannot travel across the Earth's magnetic field lines, they can travel along them. After passing through the shock wave created at the bow shock, some of the solar wind particles travel along the Earth's magnetic field lines and enter the Earth's upper atmosphere through funnel shaped areas known as the polar cusps. As they hit the upper atmosphere, they release tremendous amounts of energy emitting varying colors of visible light, the auroras.

The magnetosphere is a complex configuration of regions and is a dynamic, constantly changing system guided by the Earth's magnetic field. Within the magnetosphere, we find cold plasma from the Earth's ionosphere, hot plasma from the Sun, and even hotter, highly accelerated plasma entering the Earth's upper atmosphere causing the auroras. The magnetosphere's many regions are; the bow shock, magnetosheath, magnetotail, plasmasheet, lobes, plasmasphere, radiation belts, and many electric currents.

Through the use of spacecraft bourn instruments, we are able to chart the Sun's activity and the responses of the magnetosphere and upper atmosphere over long periods of time. We are striving to understand the physical processes that control this vast, dynamic system, looking for the magnetic link between the Earth's magnetosphere and its atmosphere. The better we understand the processes governing interactions in the solar system, the better we will be able to forecast and accommodate future events that can drastically affect life on Earth.

Lesson Plan:

1. Give every student a copy of the *Vocabulary = Earth's Magnetosphere Student Worksheet* and *Earth's Magnetosphere cutout/instruction sheet*. Write vocabulary terms on the board. Provide approximately 5-10 minutes for students to brainstorm ideas about what the vocabulary terms mean. Read the correct definitions to the students.
2. Instruct students to locate the vocabulary words that are included in the *Earth's Magnetosphere cutout*. As vocabulary words are introduced, students can color in those areas per the *Earth's Magnetosphere instruction sheet*. The students can take notes if they want but do not have to complete the vocabulary worksheet at this time.
3. Explain to students that they will be embarking on an Internet Field Trip of the Earth's Magnetosphere. The purpose of this field trip is to have a better understanding of the Earth's Magnetosphere and its importance to us.
4. Direct students to start at either http://www.windows.ucar.edu/tour/link=/earth/Magnetosphere/overview.html&edu=elem or http://science.nasa.gov/SSL/PAD/SPPB/Edu/magnetosphere/ to begin the on-line Earth's Magnetosphere tutorial. Permit students to explore this site at their own pace but remind them to complete all parts of the tutorial.
5. Encourage students to take notes and to find the definitions for the vocabulary words that were presented earlier in the lesson. Tell students to pay particular attention to these vocabulary words:
   - subsolar point
   - inner radiation belt
   - low latitude boundary layer

   Challenge them to individually find the definitions for these words using the Internet.
6. Make sure that students complete the on-line tutorial for each site. While students are still at their computers, make sure to facilitate a discussion concerning their findings. If a "Smart Board" (electronic white board) is available or a projector is available, use the visual source to complete as a whole group activity.
7. Using the *Earth's Magnetosphere instruction sheet* (you may have to model for students the correct way to build the cutout model) assemble the *Earth's Magnetosphere cutout*. Allow time for students to put together their own models. Provide teacher assistance and/or peer assistance as necessary to complete the model.
8. When students are done with the model, discuss the project with the students as a group. Be sure to include discussion about the on-line tutorial as well. Some questions to ask:
   - How did the on-line tutorial/model give you a clearer picture of the Earth's Magnetosphere?
   - Was one site more helpful than another one? Why or why not?
   - What vocabulary words are easy for you to remember?
   - What vocabulary words are you having difficulty understanding?
   - If you could make your own model of the Earth's Magnetosphere how would it be different or similar to the on-line models or cutout models?
   - What kinds of other materials could you use to make a different model of the Earth's Magnetosphere?
   - What part of the magnetosphere would you like to learn more about?

Assessment:

- Students will work individually on this assignment.
- The students will create an original model of the Earth's Magnetosphere.
- They are to provide accurate labels for each aspect of the model.
- **No paper drawings will be accepted**. Invite students to use their imagination to create the Earth's Magnetosphere models (Computer models, 3-D models, cutout models are some examples).

- This assignment could be an in-class assignment or a homework assignment at the teacher's discretion.

Assessment Criteria for Models:

- The Earth's Magnetosphere model has all components and is labeled accurately.
- Students have created an original model (not copied).

Extensions:

Students may visit the site or find sites on their own to explore further the Earth's Magnetosphere.
http://www-istp.gsfc.nasa.gov/Education/wms1.html

Teacher key - Vocabulary terms and definitions (see student worksheet):

Atmosphere: The layer of gas surrounding the earth or other planets. The *upper* atmosphere is the region of the Earth's atmosphere above the troposphere (which extends to about 20 km). Regions of the upper atmosphere are the stratosphere, mesosphere and thermosphere.

Bow Shock: a sharp front formed in the solar wind ahead of the magnetosphere, marked by a sudden slowing-down of the flow near Earth. It is quite similar to the shock forming ahead of the wing of a supersonic airplane. After passing near Earth, the slowed-down flow gains speed again, to the same value as the surrounding solar wind.

Convection (magnetospheric): large-scale plasma flow, circulating in the magnetosphere and driven by the solar wind. Plasma physics requires such circulation to be associated with an electric field. Assuming that the electric field propagates along magnetic field lines (as it would along good conductors of electricity) and reaches the polar ionosphere, corresponding electric fields should be observed above the polar caps, and such fields exist.
In the view proposed in 1961 by Axford and Hines, plasma near the flanks is dragged tailwards by the adjoining solar wind flow, through the action of "viscous-like forces"; in the view suggested that same year by Dungey, plasma travels tailward on "open" field lines following reconnection. Evidence suggests both processes contribute. In both models the plasma returns earthward in the plasma sheet near midnight, a process that could be not continuous but intermittent, associated with substorms.

Cusps (of the magnetosphere)**:** two regions of weak magnetic field, on the sunward boundary of the magnetosphere, one on each side of the equator. They separate magnetic field lines closing on the front from those swept into the Earth's magnetotail.

Electron: a lightweight particle, carrying a negative electric charge and found in all atoms. Electrons can be energized or even torn from atoms by light and by collisions, and they are responsible for many electric phenomena in solid matter and in plasmas.

Electromagnetic Field (EM field)**:** the regions of space near electric currents, magnets, broadcasting antennas etc., regions in which electric and magnetic forces may act. Generally the EM field is regarded as a modification of space itself, enabling it to store and transmit energy.

Ion: usually, an atom from which one or more electrons have been torn off, leaving a positively charged particle. "Negative ions" are atoms that have acquired one or more extra electrons and clusters of atoms can also become ions.

Ionosphere: a region covering the highest layers in the Earth's atmosphere, containing an appreciable population of ions and free electrons. The ions are created by sunlight ranging from the ultra-violet to x-rays. In the lowest and least rarefied layer of the ionosphere, the D-layer (around 70 km or 45 miles), as soon as the Sun sets the ions and electrons recombine, but in the higher layers, collisions are so few that its ion layers last throughout the night

Magnetopause: The boundary of the magnetosphere, separating plasma attached to Earth from the one flowing with the solar wind.

Magnetosheath: the region between the magnetopause and the bow shock, containing solar wind that has been slowed down by passage through the bow shock. As the magnetosheath plasma streams away from the bow shock, it gradually regains its former velocity.

Magnetosphere: The region around Earth, bounded by the magnetopause, whose processes are dominated by the Earth's magnetic field.

Magnetotail: The long stretched-out nightside of the magnetosphere, the region in which substorms begin. It starts about 8 Earth radii (RE) nightward of the Earth and has been observed to distances of at least 220 RE.

Particle: in general, a charged component of an atom, that is, an ion or electron.

Plasma: a gas containing free ions and electrons, and therefore capable of conducting electric currents. A "partially ionized plasma" such as the Earth's ionosphere is one that also contains neutral atoms.

Plasma Sheet: a near-equatorial layer of denser plasma in the tail of the Earth's magnetosphere. It separates the two tail lobes, the two bundles of magnetic field lines connected to the regions around the Earth's magnetic poles.

Solar Corona: the outermost layer of the Sun's atmosphere, visible to the eye during a total solar eclipse; it can also be observed through special filters and best of all, by X-ray cameras aboard satellites. The corona is very hot, up to 1-1.5 million degrees centigrade, and is the source of the solar wind.

Solar Flare: a rapid outburst on the Sun, usually in the vicinity of active sunspots. A sudden brightening (only rarely seen without special filters) may be followed by the signatures of particle acceleration to high energies--x-rays, radio noise and often, a bit later, the arrival of high-energy ions from the Sun.

Solar Wind: hot solar plasma spreading from the solar corona in all directions, at a typical speed of 300-700 km/sec. It is caused by the great heat of the corona.

Tail lobes: the two bundles of nearly parallel magnetic field lines which stretch into the magnetotail, on opposite sides of the plasma sheet. The northern lobe contains field lines entering the North Polar Region of Earth, while the southern lobe contains lines emerging from the southern polar region.

Name: _____ Period: _____ Date: _____

STUDENT WORKSHEET
VOCABULARY - EARTH'S MAGNETOSPHERE

Atmosphere:

Bow Shock:

Convection:

Cusps:

Electron:

Electromagnetic Field:

Ion:

Ionosphere:

Magnetopause:

Magnetosheath:

Magnetosphere:

Magnetotail:

Particle:

Plasma:

Plasma sheet:

Solar corona:

Solar flare:

Solar wind:

Tail lobes:

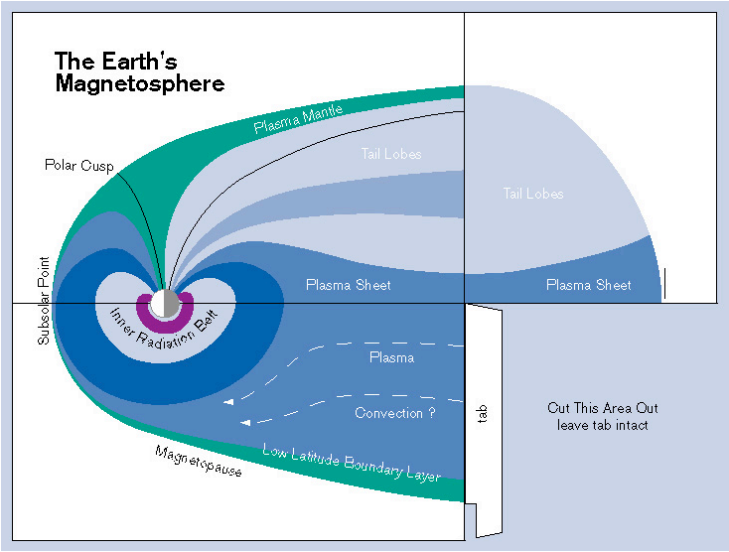
Folding Paper Model of the Magnetosphere

Below are instructions for making a simple paper model of the magnetosphere, out of a single sheet of paper.

Print the image, and then fold the printout or a Xerox copy of it (preferably, one copied onto thick "construction" paper) according to the instructions.

Instructions

- If the black-and-white image is used and you wish to color different regions, do that first. Colors may distinguish the Plasma Sheet (including area marked "Plasma Convection?"), Plasma Mantle and Low Latitude Boundary Layer (use same color), Tail Lobes and Inner Radiation Belt. The region outside the magnetosphere (in the solar wind) may be left white or given a light color. You may link to the color image above and use it as a guide.
  - **Note** that lines on the bottom of the model (the part which will be horizontal after assembly) are boundary lines between regions, while lines on the long vertical section are magnetic field lines. However, those field lines that connect to boundary lines on the bottom piece also form part of the region boundaries.
- Using a straightedge, score the paper by drawing hard lines along the two main crossed lines with a ballpoint pen (preferably black) or with a stylus.
- Cut out the area marked "Cut Out" but leave tab intact.
- Crease along the scores, and then fold to produce a three-sided corner with the printed picture on the inside.
- Use tape to attach the tab to the backside of the panel carrying the words "Tail Lobes" and "Plasma Sheet," to hold the paper in its folded position. If no tape is available, carefully cut a slot in the marked place to the right of the words "Plasma Sheet" and insert the end of the tab.



Sample of color version available on web at
http://istp.gsfc.nasa.gov/Education/figures/cutout2.jpg

The Earth's Magnetosphere Cutout/Instructions courtesy of:
http://istp.gsfc.nasa.gov/Education/wfold.html

Student Worksheet – The Earth's Magnetosphere - Cutout