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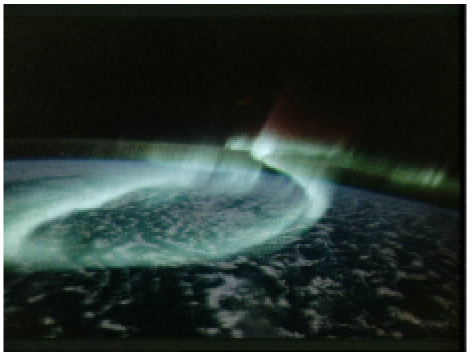
Tidy Up Those Sloppy Force Fields!



This image of the Southern Lights was taken from the Space Shuttle.

Imagine the entire night sky filled with shimmering, dancing curtains of colorful light. If you knew nothing of the Aurora Borealis, also called the Northern Lights, the sight of them might make you think the end of the world was near. But, no, these light shows have been appearing near Earth's North and South Poles since long before there were any people around to notice. (Near the South Pole, they are called the Aurora Australis, or Southern Lights.)

The Sun's Night-time Performances

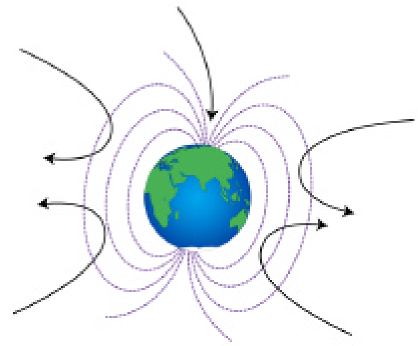
What causes these weird draperies of light?

The Sun is constantly throwing off charged particles, which travel at around one million miles per hour! But, thankfully, Earth is like a starship with its shields up! Otherwise, Earth would not be a very friendly place for life as we know it.

What provides this shield for Earth's surface?

Earth acts as a giant magnet. Magnetic lines of force extend from the north and south magnetic poles (which, by the way, are offset a bit from the North and South Poles that mark Earth's axis of rotation). These lines of force bend and form a magnetic field around the planet. Scientist think the magnetism may be caused by Earth's rotating liquid metal core.

Most of the high-speed charged particles from the Sun are deflected around Earth's magnetic field, but some of them do get trapped inside it. These trapped particles glow, or fluoresce, in Earth's upper atmosphere near the magnetic poles, and people in the far north and far south see them as the beautiful and eerie Aurora.



Earth's magnetic field deflects most of the fast-moving, charged particles from the Sun. Some particles interact with Earth magnetic lines of force near the North and South Poles to produce the beautiful Auroras.

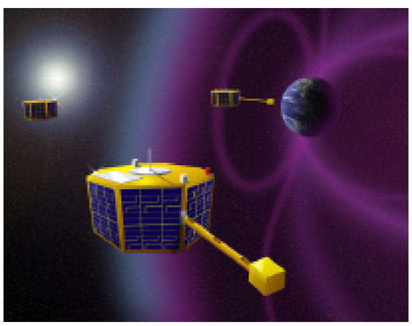
Sizing Up the Playing Field

The magnetic field of Earth is weak compared to that of some planets, such as Jupiter. Other planets, such as Venus, have little or no magnetic field at all. The Sun also has its own huge magnetic field. Understanding natural magnetic fields and how they interact is a very important part of understanding our planet, our solar system, and the rest of the Universe.

Many spacecraft have instruments to detect magnetic fields. These instruments are called *magnetometers*. Magnetometers must be very sensitive to changes in magnetism as the spacecraft orbits within Earth's magnetic field or as it travels to other destinations within the influence of the Sun's magnetic field.

One new mission of NASA's is Space Technology 5 (ST5), which will put three miniaturized spacecraft into Earth orbit. The primary goal of the mission is to make very small, lightweight, and power-efficient spacecraft that function just like their full-sized counterparts and then to test them in a space environment. As part of the testing, these spacecraft will use miniaturized magnetometers, smaller than the box that contains a roll of 35-mm film (5 x 5 x 3 centimeters or about 2 x 2 x 1 inches). These tiny magnetometer sensors will collect magnetic field data and send the results to the ground where scientists will analyze them for future missions.

The trouble with magnetometers, though, is that if you're not careful, you will end up measuring the magnetic fields generated by the spacecraft itself! That is why magnetometers are always placed on booms that extend out from the spacecraft, as you can see in this artwork of ST5. In this case, the extended booms are about 79 centimeters (about 32 inches) long.



Space Technology 5 spacecraft keep their magnetometers at a distance.

Although, the boom holds the magnetometer some distance away from the spacecraft's own magnetic fields, this distance isn't always far enough to solve the problem.

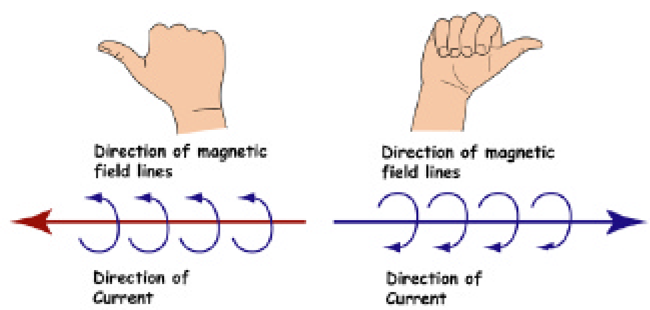
Why do spacecraft themselves generate magnetic fields?

Electric current flowing in a wire produces a magnetic field. This is how electromagnets work. Electromagnets are really just ordinary pieces of metal until electric current is made to flow through or around them. Then they become magnets and can do all sorts of useful things, from picking up and releasing heavy loads to operating your telephone.

Spacecraft instruments and devices use electricity generated from the Sun by solar cells and stored in batteries located onboard each spacecraft. When the electric current flows from the battery to an onboard computer, for example, and back to the battery (to complete the circuit), a magnetic field occurs around the wire carrying the electric current. Just turning on an instrument can cause a spike (a sudden increase, then decrease) in the magnetic field around the spacecraft. The magnetometer wouldn't be able to tell whether it had just passed through a stronger magnetic field line in space or whether the spike was caused by an operation on the spacecraft.

Solving the Problem: A Helpful Fact

When current flows through a metal wire, the direction of the magnetic lines of force depends upon the direction the current is flowing. Here's the "Rule of Thumb:" Hold up your right hand, point your thumb to the left, and curve your fingers. If the current is moving to the left, the magnetic lines of force will "wrap" around the wire in the direction your fingers point. If you point your right thumb to the right, the lines of force represented by your fingers wrap around the wire in the other direction.



Here's an experiment your class can do together to see how electricity and magnetism go hand in hand (so to speak).

What you need:

All these items can be purchased inexpensively at an electronics hobby store. One set-up for the class is adequate.

- Electrical wire (22 gauge is fine), two pieces about 18 inches long, or two 18-inch-long test leads with alligator clips
- Two AA, C, or D-cell (1.5-V) batteries
- Battery holder (for the two batteries)

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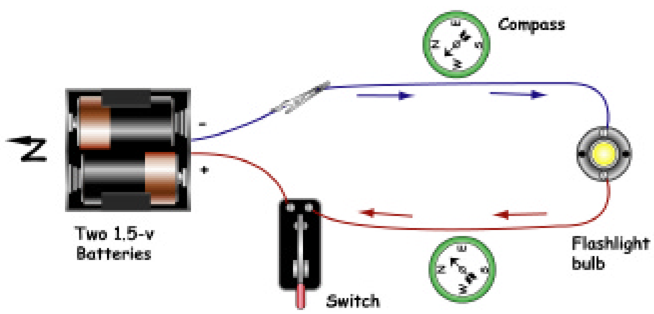
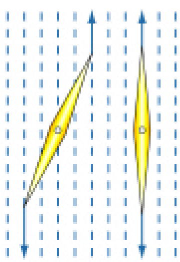
- 1.5 V flashlight bulb and bulb holder
- Small compass
- Small switch (optional)

Experiment 1:

Using the wires, connect the batteries to the light bulb. Through the electrical wire, we can think of the current flowing from the negative terminals of the batteries to the positive terminals.



Using the compass to tell you which way is north, orient the wires so they are running north and south. Tape the wires to a table or desk, as shown in the drawing.



Note that the compass needle (a magnet) lines up with Earth's magnetic lines of force, unless another nearby magnetic field is stronger.

If you have trouble finding a spot where the compass needle is stable, you are probably standing in the middle of some interfering magnetic fields. These can be caused by telephones, computers, and electrical wires. You may have to go outside!

With the circuit open (that is, the switch is open or the wires are not connected to form a closed loop), place the compass over one of the wires.

Now, switch on the light bulb (that is, close the circuit so current flows through the wire).

What happens to the needle of the compass? Note the direction the needle moves.

Now, turn off the light bulb, and place the compass over the other wire.

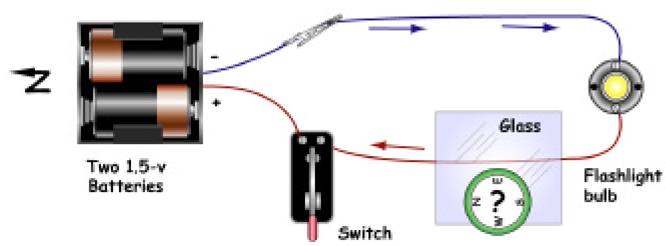
Turn on the light bulb again, and notice what happens to the compass needle this time. Which direction does it move? Is it the same or different from how it moved when placed over the other wire? Why?

Experiment 2 (optional):

In this experiment, you will find out what materials, if any, can insulate the wire and prevent the magnetic field from passing through. Since the magnetic field formed by this small current is weak and does not extend far from the wire, whatever you try for insulation should not be too thick. Otherwise, it won't be much of a test of the material itself.

You might try such materials as aluminum foil, plastic wrap, paper, cardboard, thin sheet of glass (like from a picture frame), thin sheet of aluminum (like a cookie sheet), or anything else you think might keep the magnetic field around the wire from "leaking out."

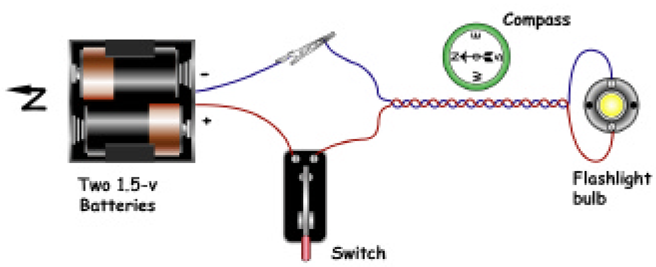
Try wrapping one or both wires with the test material, or laying a sheet of the material over the wire. Then place the compass on top with the wire directly underneath. Again let the current run through the wire.



What happens to the compass needle with each material? Do any of the materials seem to reduce the strength of the magnetic field produced by the current?

Experiment 3:

Now, twist the two wires together before connecting them to the batteries and the light bulb. Tape the wires down on the table so they again are oriented north and south.



With the light bulb off, place the compass over the center of the twisted pair of wires. Turn the light bulb on and watch the compass needle. What happens? What has changed to make the needle behave differently?

Making a Spacecraft "Magnetically Clean"

If you tried anything like stainless steel as an insulating material in Experiment 2, you may have noticed a drop in the magnetic field strength induced by the current flowing in the wire. However, as you might imagine, stainless steel wrapping around all the wires in a spacecraft would make it very, very heavy!

In Experiment 3, however, the magnetic field should have dropped off considerably. Why? Because the magnetic field lines surrounding the two wires are acting in opposite directions, so if you twist them together, they cancel each other out! This technique is easy to do and would not add any weight at all to a spacecraft. And, as a matter of fact, such a technique is used in ST5 to minimize the effects of the spacecraft's electronics on the magnetic field about the spacecraft.

This "technology" is very simple. However, ST5 will test several other size-, mass-, and cost-reducing technologies that have been much more difficult to achieve. As we see here on Earth, high-tech gadgets such as computers, cell phones, and digital cameras are getting better, yet smaller all the time. They are smaller because engineers are inventing amazing new materials and manufacturing techniques to pack more and more capability into smaller and smaller spaces on tiny chips. Space engineers have a huge challenge to take these techniques and use them to make spacecraft systems and instruments that can operate on very little power, in the vacuum of space, in extremely hot and cold conditions, with high doses of radiation and charged particles from the Sun.

ST5 is part of NASA's New Millennium Program, whose purpose is to develop and test new technologies in space. Once a new technology has been proven on one of these missions, scientists and engineers planning future space missions of discovery can rely on it as part of their designs.

What happened and why?

1. *What is the purpose of the magnetometers on the three Space Technology 5 spacecraft?*
2. *The direction of the magnetic field lines around a wire that carries electric current depends upon the _____________ the current is flowing.*
3. *What is an easy way to eliminate the magnetic fields produced by electric currents flowing through the wires in a spacecraft?*
4. *Why is Earth's magnetic field important to us?*

Find out more about ST5 and its efficient use of energy at The Space Place Web site, **spaceplace.nasa.gov**. Just type "ST5" in the search field on The Space Place home page.

This article was written by Diane Fisher, writer and designer of The Space Place website. Alex Novati did the illustrations, including the rendering of the ST5 spacecraft traveling through Earth's magnetic field. The article was provided by the National Aeronautics and Space Administration's (NASA's) New Millennium Program, managed by the Jet Propulsion Laboratory, California Institute of Technology.