Magnetic Fields Part 1

STARFINDER

PROGRAM 22

Instructional Objectives

After viewing the program and participating in the accompanying activities, the student will be able to:

1. describe the role of atoms in magnetic domains and electrical current,
2. describe the reciprocal relationship between magnetism and electricity, and
3. diagram the magnetosphere and Van Allen Belts which surround the earth.

Synopsis

Program 22 begins with "HST Data Stream." Eric Chaisson shares some of the latest information received from the Hubble Space Telescope.

This program on magnetic fields begins with ancient misunderstandings of magnetism. It presents the uses of lodestone, a naturally occurring magnetic mineral. As early as 1100 A.D., sailors used the properties of this magnetic substance to aid in their navigation, but it was not until William Gilbert shaped a piece of lodestone into a "terrella," or little earth, that scientists concluded that the earth itself was a giant magnet.

Graphics are used to depict the role of electrons in creating magnetic domains. Viewers are reminded that electrons whirl rapidly about their nuclei. Electrons in most elements normally spin on their axes in random directions. When the electrons all spin in the same direction, they create a magnetic domain.

Viewers are introduced to the discoveries of Hans Christian Oersted, Michael Faraday, and Joseph Henry and see demonstrations of experiments which involve the reciprocal relationship of magnetic fields and electrical current. Oersted's initial failure to detect a change in the magnetic field of an electric current presents the idea that scientists do not always find a solution to their theories on the first try.

The naturally occurring magnetic and electrical fields surrounding the earth are discussed. The solar wind is presented as a source of electrically charged particles. These are often trapped inside two layers surrounding the earth called the Van Allen belts. The program ends with the spectacular light display called the auroras borealis and australis. These auroras are created by charged particles reacting with atmospheric gases in the polar regions.

In "The People Behind the HST," we meet Karen Lezon, a Senior Software Engineer with the Space Telescope Science Institute. Karen discusses her enthusiasm for being a part of the Hubble's scientific mission.

Vocabulary

Attraction - The power to draw together.

Aurora - Rapid and irregular displays of colorful light in the night sky of a planet, caused by the leakage of charged particles from the magnetosphere into the atmosphere. At the North Pole, these displays are called the aurora borealis. At the South Pole, they are called the aurora australis.

Compass - An instrument with a swinging magnetic needle, used to show direction.

Deflect - To make something turn to one side.

Domain - The permanently magnetized regions in which the magnetic fields of the atoms are aligned.

Electrical Current - The flow of electrons.

Faraday, Michael (1791-1867) - A self educated British physicist and chemist. He was one of two scientists who discovered that an electric current could be produced by a rapidly moving magnetic field.

Geographic poles - The northern and southern ends of the earth's rotational axis.

Gilbert, William (1544-1603) - Personal physician to the Queen of England. Gilbert did a great deal of experimenting with magnetism, and developed the theory that the earth is a magnet.

Henry, Joseph (1797-1878) - An American physicist. Henry is believed to be the first to discover that magnetism could produce electricity.

Ion - An atom that has had one or more electrons removed or added, resulting in the atom having a positive or negative charge.

Lodestone - A naturally occurring mineral that has magnetic properties. Lodestone is now known as magnetite

Magnetic Field - The area of space around a magnet or electric current which contains magnetic effects.

Magnetic Poles - Either ends of a magnetic axis. The opposite forces of a magnet, labeled north and south. The magnetic poles of earth are not precisely aligned with the geographic poles.

Magnetism - An attractive or repulsive influence that a magnet or electric current exerts on another magnet or charged particle.

Magnetite - Current name for lodestone.

Magnetosphere - A region of space above a planet's atmosphere where charged particles are magnetically deflected and/or trapped.

Magnetotail - Part of the magnetosphere. The solar wind causes the magnetosphere to compress on the side facing the sun and elongate into a tail-like projection on the opposite side.

Oersted, Hans Christian (1777–1851) - Danish physicist who discovered the magnetic effect produced by the flow of electricity. This discovery linked the two forces of electricity and magnetism to one another.

Solar Wind - A stream of energetic, charged particles of matter that constantly escape the sun.

Terrella - Little earth. A piece of lodestone shaped into a sphere by William Gilbert, used to simulate the earth as a giant magnet.

Van Allen Belts - Zones of intense radiation surrounding earth's mid-section, caused by charged particles trapped in earth's magnetic field.

Previewing

Review the basic properties of the atom and electricity. Point out that while electrons whirl around the nucleus on specific energy levels, they also rotate randomly about their own axes.

Sprinkle iron filings over many differently shaped magnets. Discuss how the pattern of the filings is influenced by the shape of the magnet. Highlight the fact that normally the filings can only be viewed on a flat plane. Help students envision what the fields would look like if they could be represented in three dimensions.

Set up a compass activity for students. Give student groups a compass and list of directions that, if followed precisely, will get them to a special treat at a specific location.

Ask if any students have ever seen the aurora borealis, or northern lights. Have them describe what they saw.

Emphasize the idea that the discoveries which led to our knowledge of magnetism and its applications were made on different parts of the earth at different times in history. Prepare students to take note of the various people highlighted in this program. Either before or after the program, you may wish to use this as a springboard to discuss the need for communication and sharing among scientists.

Postviewing

Draw on the board a diagram of the atoms in both magnetic and nonmagnetic substances, indicating the + and — poles. Have students identify which arrangement represents a magnetic domain.

Ask students to name the scientists highlighted in the program, and discuss their contributions to our understanding of magnetism. Let student groups research biographies and contributions of these and other scientists who contributed to the understanding of magnetism and electricity. Encourage students to learn about the lives of these people. For example, Michael Faraday is someone who, despite a childhood of poverty and little formal education, became one of the foremost scientists of his time. Find out about the work of contemporary scientists who are making new discoveries about the magnetic fields of other planets and stars.

Develop a time line for the discoveries involved in magnetism.

Sailors noted, and William Gilbert investigated, the downward dip of a compass needle. Discuss the angle of dip, which is the angle between a dipping compass or magnetized needle and a horizontal surface. The degree of the angle depends upon geographic location. It is 0 at the magnetic equator. The angle usually falls within 60 to 75 in the United States, and increases in degrees the farther north the location. Have students find out what the angle is at their location.

Ask students to describe the reciprocal relationship between magnetism and electricity. Let students know that in the next program, they will see more about the reciprocal nature of these two forces as they learn about electromagnetic radiation.

The "left-hand rule" helps to remind an observer of the 90° angular difference of electron flow and magnetic fields. When the direction of electron flow is known, and the left hand is placed on a wire in such a way that the thumb points in that direction, the fingers will automatically curl around the wire in the same direction as the magnetic field.

Magnetic Fields Part 2

Bring some magnetite (lodestone) to class to let students experiment with this naturally magnetic material. Have students pick up pieces of iron with the magnetite, place it on a raft in a basin of water and watch it align in a north-south direction, or run a compass over the magnetite and watch the needle dip.

In the middle ages, sailors believed that there were magnetic islands in the sea. They were afraid that magnetic forces would pull the nails out of their ships. Have students discover some of the superstitions and misconceptions that arose about the mysterious properties of magnetic fields.

Encourage students to find news clippings about two NASA spacecrafts, Galileo and Ulysses. Galileo was launched from the shuttle Atlantis in October, 1989 and Ulysses was launched from the shuttle Discovery in October, 1990. Ulysses will reach Jupiter in 1992 and then travel on to the sun. There it will orbit around the polar regions of the sun and compile information on the solar winds. Galileo was designed to measure the distribution and intensity of Jupiter's magnetosphere.

Have students make a diagram of the path of charged particles from the sun to and around the earth. Make sure they identify the solar wind, magnetosphere and magnetotail, and Van Allen Belts.

Describe the Van Allen Belts as a source of protection to people on earth. The Belts deflect and trap the charged particles emanating from the solar wind.

Have students trace the history of discovery surrounding the Van Allen Belts. Some may wish to report on James Van Allen and the first experiments done on Explorer I in 1958. Subsequent information was obtained through Explorer III, Explorer IV, Pioneer I, and Pioneer III.

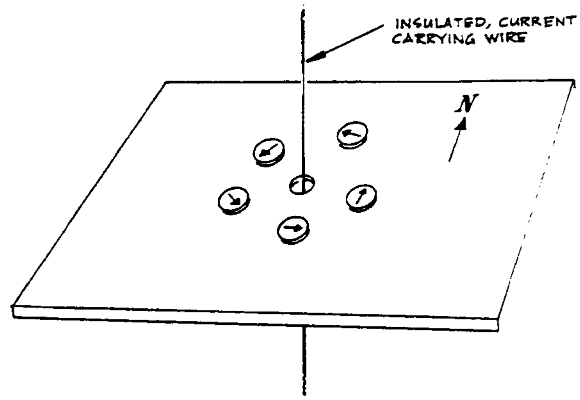
Help students make the connection between solar activity and the auroras. Ask students to locate pictures of the auroras. Art students may wish to produce pictures with water colors.

Active Involvement

Have students make a magnet by stroking a needle with a magnet thirty to fifty times in the same direction. Use the needle to pick up a pin or paper clip. Rap one needle on a hard surface and attempt to pick up the same pin or paper clip. Heat another needle and test its magnetic properties. Ask students how they think the magnetic domains were formed and what happened to the domains when the needles were jarred or heated.

Students can make their own compass with a magnet, a needle, a cork, and a bowl of water. Magnetize the needle by stroking it about fifty times in one direction. Push the needle through the cork and float the cork on the surface of the water. A drop of dish detergent in the water will help to keep the cork in the center. The needle will align itself in a north-south direction. Have students use a compass to check which end of the needle is pointing north.

Use a compass and an insulated current carrying wire to note the strength of the magnetic field around an electric current. Place a compass on a flat surface north of a current carrying wire. The wire should be perpendicular to the surface. Using peg board will allow you to pass the wire through a hole and secure the wire at a perpendicular angle. Before the current is turned on, determine and



indicate north. When the current is turned on, the compass needle will be affected by the magnetic field around the wire. Have students experiment with the intensity of the magnetic field by moving the compass closer and farther from the wire. Next, have students place a group of compasses around the wire to indicate the path of the magnetic field around the wire.

Have students create a magic show to present to an elementary school class. There are many phenomena that appear magical unless the underlying scientific principles are understood. Get students started by teaching them the following trick. Have a magnet concealed behind an overhang. Tie a paper clip on a thread that has been taped to a piece of card stock. Make the paper clip "float" by placing it near to the concealed magnet.

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See for Yourself: Experiments/Projects

Demonstrating Electromagnetism

Hans Christian Oersted, Michael Faraday, and Joseph Henry were among the scientists of the 1800s who believed that there was a reciprocal (similar or equal, but reversed or inverted, just as 2/3 is the reciprocal of 3/2) relationship between magnetism and electricity. With only a few materials, you can carry out some simple experiments which will demonstrate the reciprocal properties of magnetism and electricity.

1. Oersted's first try

▶ MATERIALS:

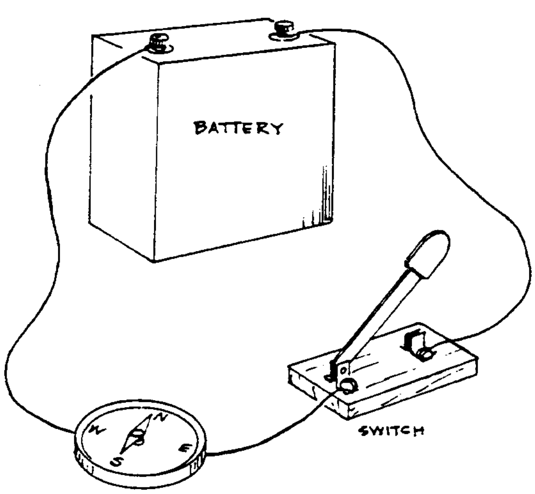
- one compass
- two pieces of insulated copper wire, 1/2" of each end stripped of coating
- 6 volt lantern battery
- switch

▶ DIRECTIONS:

Oersted believed that he would be able to detect a magnetic field around an electric current by using a compass and a current carrying wire. The first time that he set out to prove his theory, Oersted placed the wire across the east-west axis of the compass. The compass needle was perpendicular to the wire.

Try this yourself.

Make a circuit by connecting one wire from the battery to the switch and the other wire from the second connector of the battery to the other end of the switch (see diagram).



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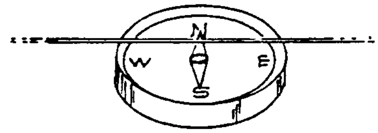
Place the compass on a flat surface and let the needle settle into its north-south alignment. When you are sure that the compass is steady, place the wire over the compass, perpendicular to the needle so that it falls along an east-west line.

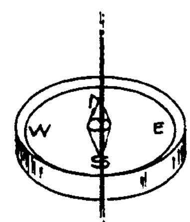


WIRE ALONG E-W AXIS

Push down the switch to complete the circuit. Watch the compass needle for movement. Record your observations. If you had been Oersted, what would you have concluded about the relationship between electrical current and magnetic fields?

2. Oersted's proof

Some time later, Oersted tried his experiment again. This time, he made one important change to his set up. He placed the wire in line with the north-south axis of the compass.



WIRE ALONG N-S AXIS

Try the experiment again, setting it up as Oersted did the second time. Settle the compass on a flat surface and determine the north-south line. Place the wire directly over, and in line with, the compass needle. Push down the switch to complete the circuit. Watch what happens to the needle. Record your observations.

3. Making an electromagnet

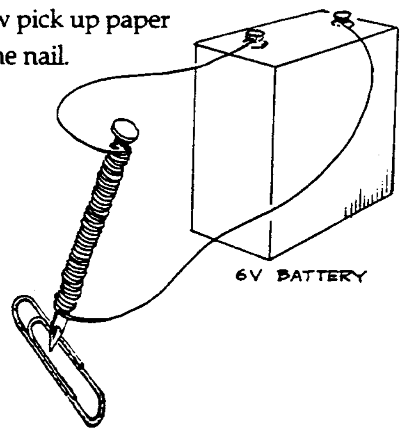
An electromagnet is an example of putting Oersted's findings to practical use. Electromagnets use electricity to produce magnetic fields, but their magnetic properties remain only as long as the electric current is turned on. They are made by wrapping a coil of wire, called a solenoid, around a piece of iron. Because electromagnets can be large and very powerful,they are a useful tool in industry. You can make a simple electromagnet with a nail, some wire, and a battery.

▶ MATERIALS:

- iron or steel nail
- insulated copper wire with 1/2" of each end scraped clean of the covering
- 6V battery
- paper clips or steel pins

▶ DIRECTIONS:

Wind the wire tightly around the nail, about 30-50 times. Securely connect the ends of the wire to the battery. See if you can now pick up paper clips with the nail.



Disconnect the wires from the battery. Can you still pick up the paper clips? *Note: If you wish, you can use a switch to turn the electric current on and off.*

What do you think happens to the orientation of the atoms when the electric current is present? What do you think happens to the magnetic domains when the electric current is interrupted.

4. Find out about the uses of electromagnets

Doorbells and telephones are just two examples of small electromagnets at work. Check your classroom or library for books that diagram how these work. If you can, take apart a simple doorbell and a telephone ear piece. What other devices can you find that use magnets and electromagnets?

5. Demonstrating that magnetic fields produce electric current

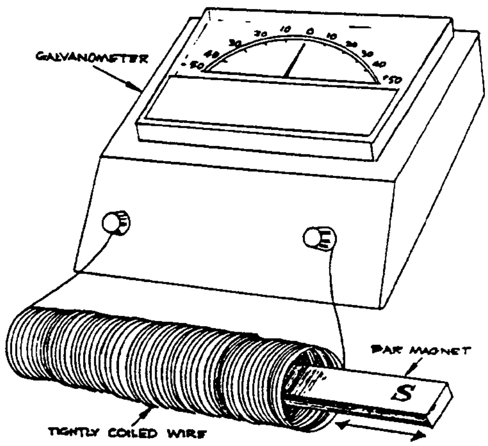
Faraday and Henry extended Oersted's findings that demonstrated there was a relationship between magnetic fields and electrical flow. You can produce these results with a similar experiment.

▶ MATERIALS:

- insulated wire
- cardboard tube that has a diameter wider than the width of the bar magnet (such as paper towel or mailing tube)
- bar magnet with north and south poles labeled
- galvanometer — one with 0 setting in the center of the dial.

▶ DIRECTIONS:

Coil the wire tightly around a tube. Make sure that the wire is wrapped tightly and always in the same direction. You can secure the wire with tape at each end or along one side. Remove the tube.



Attach the ends of the wire to the galvanometer. This is a device that will detect very small amounts of electrical current. Insert the north pole of the bar magnet part way into the coil of wire. Quickly move the magnet back and forth. Watch the needle of the galvanometer. Make note of which direction the needle moves when the magnet moves to the left. Make note of which direction the needle moves when the magnet moves to the right.

Insert the south pole of the bar magnet part way into the wire coil. Quickly move the magnet back and forth. Watch the needle of the galvanometer and make note of the directions the needle moves. Compare the direction of the needle's movement to how it moved when the north pole was inserted into the wire coil.

Repeat this procedure with a coil of wire that has been wrapped around the tube half as many or twice as many times. What differences does this make to the electric current?

Wrap a second layer of the wire back in the direction opposite to the way the first layer was wrapped. Repeat the procedure with the bar magnet. What effect did this method of wrapping have on the electric current?

Career Profile

Karen Lezon
Senior Software Engineer
Computer Science Corporation
Space Telescope Science Institute

Education: B.S. Mathematics
Graduate work in computer science

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Have you ever wondered how the people on the ground actually communicate their commands to the Hubble Space Telescope orbiting so far above the earth, or how the computerized information sent down by the telescope is processed so that it will be usable to the scientists? Karen Lezon's position as a Senior Software Engineer at the Space Telescope Science Institute provides a vital link between the astronomers and the Hubble Space Telescope. Karen works with about forty other software engineers on an enormous and complex piece of software called the Science Operations Ground System (SOGS). Because the HST only responds to computer commands, information from the ground is entered into the computer system so it can be relayed to the telescope. After an observation, data are processed by the computer system so that they are available to the scientists in a usable manner.

Karen is responsible for maintaining the SOGS relational database. A database is a collection of data that can be stored in a number of different ways. The term relational data base refers to the style in which the data are grouped. As a Senior Software Engineer, Karen's specialty is data base systems. Her job is both managerial and technical, often administrative and often "hands-on."

She serves as a technical lead for the people who work for her. If they are experiencing problems with their software, she is the one they contact. She is also the person responsible for "scoping" the work—that is, seeing what work needs to be done, how long each task will take, and then making up a schedule to ensure that each piece of work is completed within the necessary time frame. Sometimes astronomers have difficulty making queries, or questions, to the data base. Karen can help them construct their query in such a way that it will be accepted by the system.

Karen also works on the software itself. She may have to make changes to the data base or put together command files that build or change the data base. She must make sure that the documentation is always up to date.

A Typical Day

Karen starts each day by checking her electronic mail. People often notify her of problems they are experiencing with their portion of the computer system. She must respond to all of them.

Over the course of the day, she may hear of new problems and will need to be prepared to help with these also.

She spends part of her day making sure that people in her department are managing their assignments. She likes to make a special effort to check in with those people newly hired. They may have special questions about operations and procedures which she can help answer.

There are a certain number of tasks which Karen takes care of each week. Once a week, she scopes the upcoming work and readjusts the schedule for her staff. She also must update the development databases with the latest version of the SOGS database system. Of course, she then needs to warn all those working with the system of any changes that have been made. Weekly, she updates the documentation of her technical work. Karen may need to document the design for a new system requirement, or a new solution to a computer problem.

Career Viewpoint

Karen admits that often the field of science appears overwhelming or intimidating. However, she has discovered that once you learn that you can take tough concepts one step at a time, you find that you can do anything you want.

People in the sciences are in the forefront of what makes life exciting. Working in the sciences is a positive way to make everyone's lives better. No matter how large or small a part you may play in a scientific project, or whether it is environmental or astronomical, you can take satisfaction in the fact that you have made a contribution.

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