Chapter 19 Electricity and Magnetism

A bolt of lightning cuts across the sky during a thunderstorm. A severe storm may produce hundreds of lightning bolts. How do you think lightning is like turning on a light switch?

Learning Objectives

- Show the relationship between electrons and electricity.
- Explain what causes static electricity.
- Describe what happens when lightning occurs.
- Explain how batteries and generators work.
- Compare electrical conductors and insulators.
- Describe an electrical circuit.
- Describe magnetism and magnetic fields.
- LAB ACTIVITY: Identify materials that are conductors and insulators.
- SCIENCE IN YOUR LIFE: Compare how much electricity different appliances use.

Words to Know

electricity	a form of energy caused by the movement of electrons
static electricity	the electricity caused when objects with opposite charges are attracted to each other
discharge	the throwing off of static electricity
electrical conductor	a material that electricity travels through easily
electrical insulator	a material that electricity does not travel through easily
battery	a device that changes chemical energy into electrical energy
generator	a machine that changes some other kind of energy into electrical energy
circuit	an unbroken, circular path that an electrical current flows through; includes a source of energy, such as a battery
fuse	a weak link in an electrical circuit; made of metal wire that has a low melting point
magnet	a solid substance that attracts iron or steel
magnetic field	the area around a magnet in which a magnetic force is active

19-1 All Charged Up

Words to Know

electricity	a form of energy caused by the movement of electrons
static electricity	the electricity caused when objects with opposite charges are attracted to each other
discharge	the throwing off of static electricity

What Is Electricity?

Imagine living without TV, radio, hair dryers, computers, washing machines, light bulbs, or telephones. Only a short time ago, people did not have any of these things. That is because all of these tools run on **electricity.** Electricity is a form of energy caused by the movement of electrons. Until about 100 years ago, people did not know how to control electricity.

In Chapter 14, you learned that every atom has a nucleus. Inside the nucleus of an atom are protons, which have a positive (+) charge. Circling the nucleus are electrons, which have a negative (−) charge. Most of the time, atoms have the same number of protons as electrons. These atoms are *neutral*. This means that they have no charge at all.

Electrons, though, can be separated from their atoms. For example, suppose you rub a balloon on a wool sweater. Electrons from the atoms in the sweater rub off onto the atoms in the balloon. The sweater will now have fewer electrons than protons. It will have a positive charge. The balloon will have more electrons than protons. It will have a negative charge.

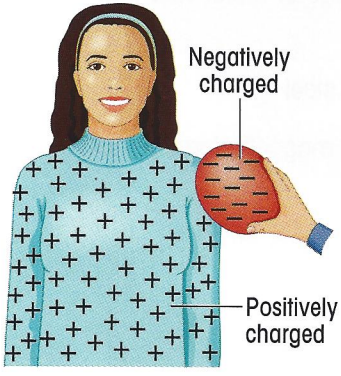


Figure 19-1 *Electrons are rubbed off the sweater and onto the balloon. The balloon becomes negatively charged.*

If you hold the balloon to the wall, it will stick there. The negative charge in the balloon will be attracted to the positive charge in the wall.

The loss or gain of electrons creates an electrical charge. Electricity is produced in the process.

✓ What causes electricity?

Static Electricity

Have you ever heard crackling as you brushed your hair? Or felt a small shock when you touched something metal? You may have noticed how clothes that have been in a dryer stick together. Sometimes they make a crackling sound when you pull them apart. All these things are caused by electricity.

Negatively charged objects have extra electrons. When two objects are both negatively charged, they *repel* one another. This means that they push each other away or try to move apart.

Objects that have too few electrons are positively charged. Two positively charged objects will also repel each other.

Objects that have opposite charges *attract* each other. This is what causes the crackling sounds when you take clothes out of a dryer. It is what causes clothes such as socks to stick to jeans. **Static electricity** holds them together. Static electricity is the electricity caused when objects with opposite charges are attracted to each other.

Most charged objects do not keep their charges for long. Negatively charged objects try to give up their extra electrons. Positively charged objects take on needed electrons to become neutral again.

Safety Alert

Never use electrical appliances while you are in water or when your hands are wet. You become a *grounding object*. This means that electrons can move freely from the source of electricity to the ground. The electricity will pass right through your body and give you a harmful, even deadly, shock.

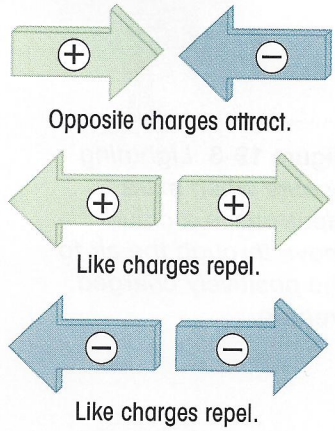


Figure 19-2 *Opposite charges attract, and like charges repel.*

Think again of your laundry. If you pulled socks and jeans apart in the dark, you might see little sparks. You might hear a crackling noise. The sparks and noise are the **discharge**, or throwing off, of static electricity. The socks and jeans are returning to their neutral states.

✓ **How is static electricity caused?**

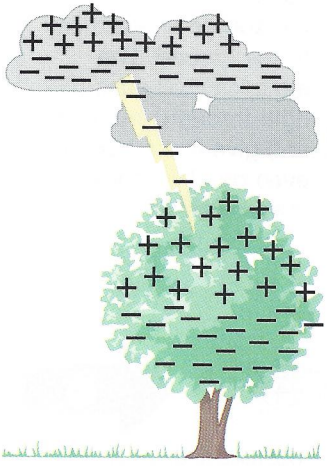


Figure 19-3 *Lightning occurs when extra electrons in a cloud move through the air to the positively charged treetop.*

Lightning

Lightning is a huge electrical discharge. It is really just a giant spark between a cloud and the ground. This discharge can also take place between two clouds with opposite charges or within the same cloud.

Here is how lightning can occur. First, a cloud builds up a lot of electrons. It gets a large negative charge. Then the cloud becomes attracted to something with a positive charge, such as a treetop. Suddenly, the extra electrons in the cloud "jump" to the treetop. This creates a lot of light and heat. The light is the bolt of lightning. The heat warms the air and causes it to expand very quickly. This quick expansion causes the loud boom called *thunder*.

✓ **What causes lightning?**

Lesson Review

1. Which part of the atom moves in electricity?
2. Why do clothes stick to each other when you take them out of a dryer?
3. How does lightning cause thunder?
4. **CRITICAL THINKING** Suppose you rubbed two balloons on a wool sweater. Would the balloons attract or repel each other? Why?

Great Moments in Science

BENJAMIN FRANKLIN AND LIGHTNING

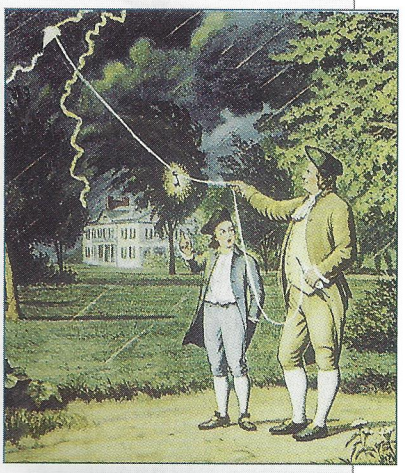
Benjamin Franklin was a great American statesman and scientist of the 1700s. He played an important role in forming the United States. He was also one of the first scientists to experiment with electricity.

Franklin believed that lightning was a form of electricity. He came up with an experiment to test this idea. In 1752, he tied a key to the string of a kite. Franklin let the key hang near the ground. He then flew his kite during a thunderstorm. A bolt of lightning struck the kite. Electricity traveled down the string toward the ground. Franklin put his hand near the key and felt a spark. This showed that lightning is an electrical discharge.

Franklin also invented the lightning rod. Lightning rods are long metal poles that are often placed on the tops of buildings. They are designed to attract lightning. The charge from the lightning passes from the rod to a grounding wire and safely into the ground.

Many of the electrical terms we use today were first used by Franklin. For example, he was the first to use the terms *positive* and *negative* to describe opposite charges.

CRITICAL THINKING How is a lightning rod like the kite that Franklin flew during a thunderstorm?



Benjamin Franklin experimented with electricity.

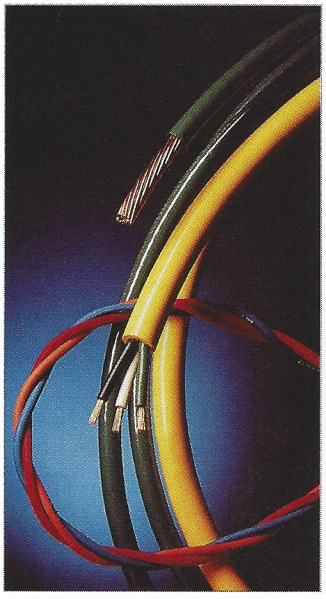
Safety Alert

NEVER TRY FRANKLIN'S EXPERIMENT YOURSELF! It was very dangerous. The charge from the lightning could have killed Franklin. It did kill some of the other scientists who tried the experiment.

19-2 Electrical Currents

Words to Know

electrical conductor	a material that electricity travels through easily
electrical insulator	a material that electricity does not travel through easily
battery	a device that changes chemical energy into electrical energy
generator	a machine that changes some other kind of energy into electrical energy



For safety reasons, electrical wiring is almost always covered with plastic or rubber.

You already learned that heat moves through some materials better than others. The same is true for electricity. A material that electricity travels through easily is called an **electrical conductor.**

Metals are excellent conductors. Metal wire is often used to conduct electricity. Many other substances can conduct electricity. Even your body can conduct electricity.

An **electrical insulator** is a material that electricity does not travel through easily. Rubber and plastic are good electrical insulators. The rubber coating on the wire leading from your TV to the plug is an insulator. It protects you from the electricity running through the electrical conductor inside.

To get electrons to move through a conductor, people often use a **battery.** A battery is a device that changes chemical energy into electrical energy.

One kind of battery is a *wet cell.* A wet cell, such as a car battery, is actually made up of a series of wet cells. Each cell contains two kinds of metal plates and an acid solution. Chemical reactions between the plates and the acid cause electrons to build up at the cell's negative pole. When the negative and positive poles are connected, electrons flow. This is an electrical current.

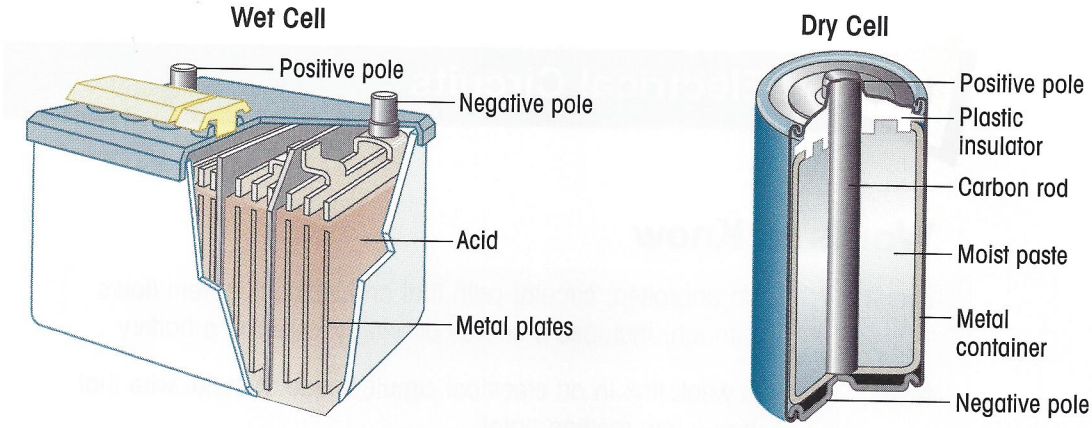


Figure 19-4 *A wet cell and a dry cell are two kinds of batteries.*

Another kind of battery is a *dry cell*. Most batteries you use for flashlights, smoke alarms, and CD players are dry cells. A dry cell uses a paste instead of an acid solution. A chemical reaction between the metal case and the paste causes electrons to build up on the metal, making it negative. The rod in the middle of the cell becomes positive. Current flows when the two poles are connected, such as by a wire or other conductor.

A **generator** is sometimes used instead of a battery to start the flow of electrons. A generator is a machine that changes some other kind of energy into electrical energy. Some generators turn mechanical energy into electrical energy. Other generators turn heat energy into electrical energy.

✓ **What do batteries and generators do?**

Lesson Review

1. What makes metal a good electrical conductor?
2. How are wet cells and dry cells similar? How are they different?
3. **CRITICAL THINKING** Why might it be helpful to own a small generator?

19-3 Electrical Circuits

Words to Know

circuit	an unbroken, circular path that an electrical current flows through; includes a source of energy, such as a battery
fuse	a weak link in an electrical circuit; made of metal wire that has a low melting point

Many things in your home are powered by electricity. Lamps, dishwashers, computers, and TVs are a few examples. However, the electricity to power these appliances must be controlled. You would not want electrical charges shooting around your home.

Remember
Electricity is the flow of electrons through a substance.

The trick to making electricity useful is getting it to flow in a certain direction. Electricians set up paths that electrical currents flow through. These paths are circular. They flow in a circle and come back to the place where they start without being broken anywhere along the way. Such a path is called a **circuit.** A circuit always includes a source of energy, such as a battery.

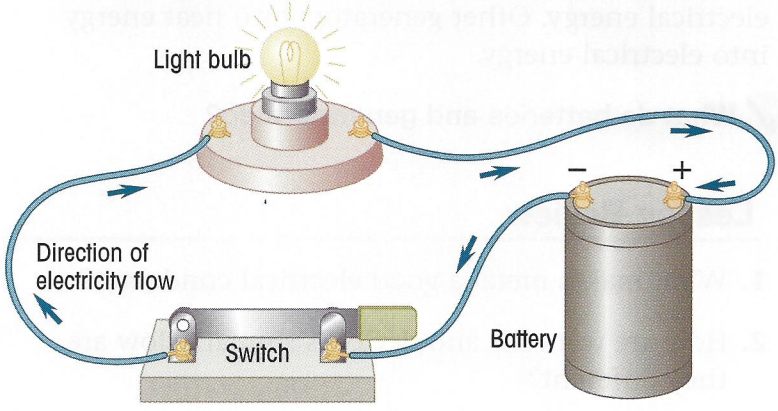


Figure 19-5 *This closed electrical circuit connects a battery to a light.*

Look at the picture on page 288 of a closed electrical circuit. It connects a battery to a light. The battery produces the electricity, which flows through the wires. As it passes through the light bulb, the electricity heats a piece of material called a *filament*. The filament gets so hot it glows. This produces light. The electricity continues along the circuit back into the battery.

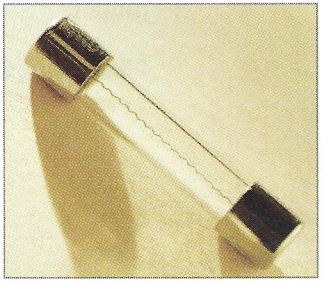
Some of the electricity used to light the filament turns into heat energy. That heat energy is lost from the circuit. Before long, the battery will run out of energy.

Some circuits have switches. If the switch is turned off, the circuit is *open*. This means that a gap is formed in the circuit. The electricity cannot flow. If the switch is turned on, the circuit is *closed*. Now the electricity can flow.

When too many electrical appliances are put on one circuit, it can become *overloaded*. Too much electricity is running through the wire. An overloaded circuit can cause the wire to get too hot and start a fire.

Fuses are used to prevent overloaded circuits from causing fires. A **fuse** is a weak link in an electrical circuit. It is made of metal wire that has a low melting point. When too much electricity flows through the wire, the fuse melts. When the fuse melts, the circuit is broken, and the flow of electricity stops.

How are closed circuits different from open circuits?



A fuse has a metal filament.

Science Fact

Most new homes are protected by circuit breakers instead of fuses. A circuit breaker has a switch that turns off when too much electricity flows through the circuit.

Lesson Review

1. What shape do all circuits have?
2. What does a switch do?
3. **CRITICAL THINKING** Why is it a bad idea to replace a melted fuse with a piece of wire that will not melt easily?

19-4 Magnetism

Words to Know

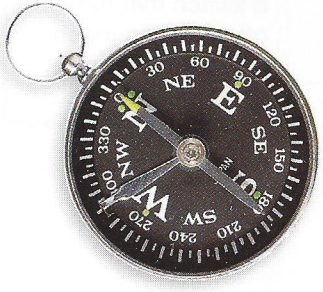
magnet	a solid substance that attracts iron or steel
magnetic field	the area around a magnet in which a magnetic force is active

What Is a Magnet?

More than 2,000 years ago, the Greeks discovered that certain stones had special properties. These stones, called *lodestones*, naturally attracted each other. They also attracted iron. Any stone, piece of metal, or other solid substance that attracts iron or steel is called a **magnet.** You might use magnets to stick notes onto your refrigerator. Some people use them at their desks to hold all their paper clips together. *Magnetism* is the state of being magnetized.

All matter is magnetic. However, only the elements iron, nickel, and cobalt have strong magnetism.

✓ **Which three elements have strong magnetism?**



A compass helps you see what direction you are facing. The needle is a magnet that points toward the North and South poles.

Magnetic Poles and Fields

Each end of a magnet is called a *pole*. If you hang a bar magnet on a string and let it swing freely, one end of the magnet will point toward the north. The other end will point toward the south.

Magnetic poles act like electrical charges do. Poles that are the same are called *like* poles. Like poles repel each other. Opposite poles attract each other. The magnetic force is strongest at the poles. However, it can be felt all around the magnet. The area in which a magnetic force is active is called the **magnetic field.**

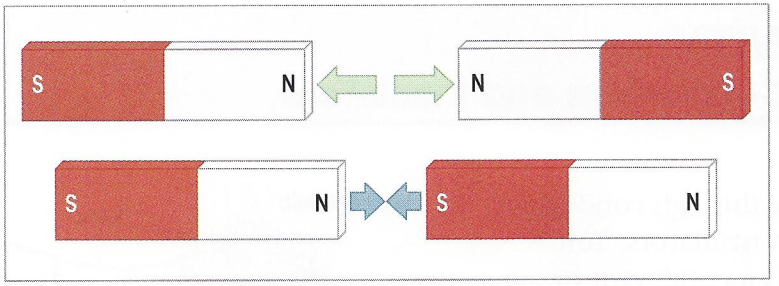


Figure 19-6 *Like poles repel, and opposite poles attract.*

Electrons are like tiny magnets. They spin around the nucleus of an atom in no particular order. So, their magnetic pull is in all different directions. When a piece of metal becomes magnetized, the electrons line up. The tiny magnetic fields turn so that all the north poles face north. Because the magnetic pull is all in one direction, it is a lot stronger.

You can stir up the tiny magnetic fields of a magnet's electrons by hammering or heating the object. This causes the object to lose its magnetism.

✓ **Where is a magnet's force active?**

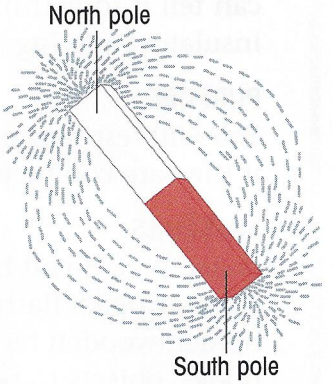


Figure 19-7 *The iron filings sprinkled around this magnet show its magnetic field.*

Lesson Review

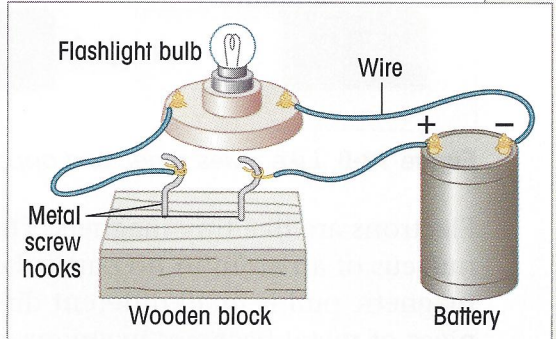
1. What are lodestones?
2. If you let a bar magnet swing freely, where do the ends point?
3. What happens to the electrons in a piece of metal when it becomes magnetized?
4. **CRITICAL THINKING** Why won't a compass work when you hold it near a strong magnet?

LAB ACTIVITY
Identifying Conductors and Insulators

BACKGROUND
Electricity travels easily through conductors but not easily through insulators. You can tell if something is a conductor or an insulator by using a simple circuit.

PURPOSE
You will test four objects to find out if they are conductors or insulators.

MATERIALS
paper, pen, 6-volt battery, 3 wires with ends stripped, flashlight bulb in base holder, wooden block, 2 metal screw hooks, objects to be tested



Use this setup for testing conductors and insulators

WHAT TO DO
1. Copy the chart to the right. Add one row to the chart for each object you will test. A sample is given.
2. Connect the circuit as shown in the diagram. First, screw the hooks into the wood. Then connect the wires by wrapping the bare ends around the screw hooks, battery poles, and metal parts of the bulb holder.
3. Test the first object by laying it across the metal screw hooks. If the bulb glows, the object is a conductor. If the bulb does not glow, the object is an insulator. Record the results in your chart.
4. Repeat Step 3 for each of the other objects to be tested.

Object Tested	Conductor	Insulator
Metal spoon	Yes	No

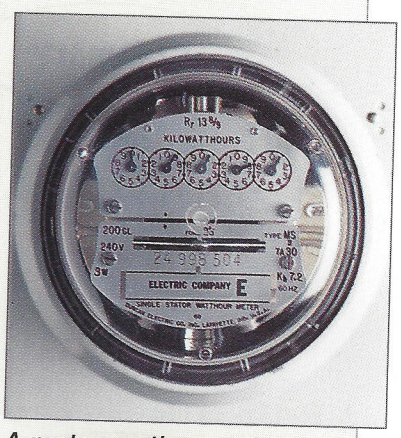
DRAW CONCLUSIONS
- Which of the objects you tested were conductors? Which were insulators?
- How can you determine whether an object is a conductor or an insulator?

SCIENCE IN YOUR LIFE
Using Electricity

Sarah's electric bill seems to get higher every month. She wants to see how her family can use less electricity.

First, Sarah went to the library to find out how much electricity each appliance in her home uses when it is on. The chart below shows some of this information. Electricity use is measured in kilowatt-hours (kWh). Next, she figured out how often each appliance is used in an average month. Finally, she multiplied the numbers in the second and third columns to find out how much electricity each appliance uses in a month.

Appliance	kWh per Use	Use per Month	kWh per Month
Refrigerator	5 per day	30 days	150
Washing machine	2.5 per load	10 loads	
Stove	2 per meal	60 meals	
Dishwasher	1 per load	30 loads	
TV	0.3 per hour	180 hours	



A meter on the outside of a building records how much electricity is used in the building.

Answer these questions.

1. How much electricity does each appliance use per month? Remember, multiply the numbers in the second and third columns for each appliance. The first one is done for you.
2. List the appliances, in order, from the one that uses the most electricity per month to the one that uses the least.

Critical Thinking

How might Sarah's family use less electricity? Give examples.

Chapter

19 Review

Summary

Energy in the form of electricity and magnetism is used in nature and to run machines that do work.

Lesson 19.1 Electricity is caused by the movement of electrons. Lightning is a large discharge of static electricity.

Lesson 19.2 Electricity flows well through electrical conductors. This flow is called a current.

Lesson 19.3 Electricity can be made to flow in a circular path called a circuit. People use electrical circuits to power appliances.

Lesson 19.4 A magnet attracts iron or steel. When electrons line up in a substance, they create a strong magnetic field.

Vocabulary Review

static electricity
discharge
electrical conductor
electrical insulator
battery
generator
fuse
magnetic field

Match each definition with a term from the list.

1. A material that electricity travels through easily
2. A device that changes chemical energy into electrical energy
3. The area of magnetic force around a magnet
4. The throwing off of static electricity
5. The electricity caused when objects with opposite charges are attracted to each other
6. A material that electricity does not travel through easily
7. A machine that changes some other kind of energy into electrical energy
8. A weak link in an electrical circuit

Chapter Quiz

Write your answers on a separate sheet of paper.

Test Tip
Make sure your paper has the same number of answers as there are questions on the test.

1. What is the relationship between electricity and electrons?
2. What type of charge does an object have if it has more electrons than protons?
3. What state does an object return to when it discharges static electricity?
4. Which part of the atom moves in a bolt of lightning?
5. Why are wires made out of metals instead of rubber?
6. What causes current to flow in a dry cell?
7. What does a generator turn mechanical energy or heat energy into?
8. How does an electrical circuit work?
9. What characteristic do the metals iron, nickel, and cobalt share?
10. Where is the magnetic force strongest around a magnet?

Research Project

The Earth is a giant magnet. It has magnetic poles just like those on a small magnet. Research the Earth's magnetism. Write down at least three facts about it. Then draw and label a diagram showing the Earth's magnetic field and where the magnetic poles are located.