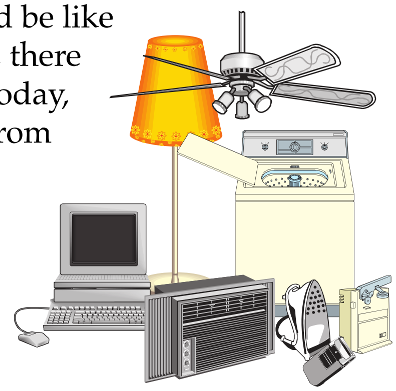
Introduction

It is difficult to imagine what our lives would be like without **electricity**. As little as 100 years ago, there was little *electricity* in homes and factories. Today, we depend on electricity to run everything from small radios to satellite tracking stations. Most of this electricity is produced by using *magnets*. *Magnetism* and electricity involve the forces of **attraction** and **repulsion**. Some of the general properties of electricity and magnetism will be introduced in this unit.



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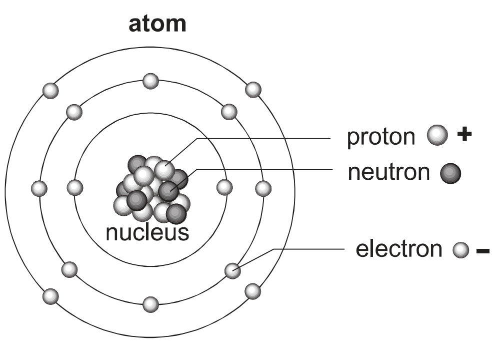
Electric Charge and Force

Electricity is a form of **energy**, **electrical energy**, in which **electrons** are flowing. All **matter** contains some electricity. *Matter* is made from **atoms**. *Atoms* contain **protons** that have a **positive charge** (+), **neutrons** that are **neutral** or have no charge, and *electrons* that carry a **negative charge** (–).

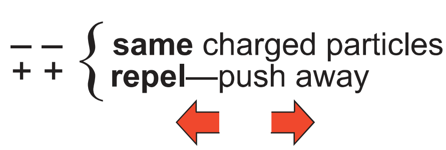


Most matter has the same number of *protons* as it does electrons; this makes the matter *neutral*. An atom can gain or lose electrons. If an atom gains extra electrons, it will become *negatively charged* (–). A loss of electrons will create a *positive charge*. Between any objects with electric charges, there is always an **electric force** of *attraction* or *repulsion*.

When charged particles come near one another there is either a push or pull (**force**) between the charges.

- A *force* that pulls is the force of attraction between *oppositely* charged particles.

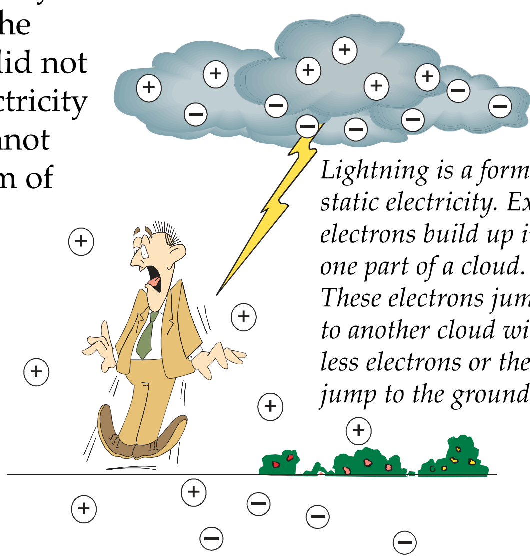
- A force of repulsion occurs when particles of the *same* charge push away from each other.



For example, the attraction of tissue paper to a negatively charged comb or the repulsion of two balloons are examples of this *electric force*. In fact, it is these electrical forces within **molecules** and atoms that cause most observable forces. Your ability to throw a ball, the blooming of a flower, and the working of your car are also examples of forces in action. Each of these can be traced back to electrical force. Electric force does not require that objects touch. This force can happen over a distance. How? Charged particles have **electric fields** around them. An *electric field* is an area over which an electric charge exerts a force.

Static Electricity

When there is a transfer of electrons from one object to another, but no further movement, we call this **static electricity**. *Static electricity* is a build-up of electric charges on an object. Run a brush through your hair. Take a nylon shirt out of a dryer. What happens? You feel a small shock or hear a crackle. This indicates static electricity. At first, there was a charge, but the electrons did not move. Then, when you heard the crack or felt the shock, the electrons moved. This electricity did not move in a path. Because static electricity does not move along a path, it cannot run appliances. Lightning is a form of static electricity. Extra electrons build up in one part of a cloud. These electrons jump to another cloud with fewer electrons or they jump to the ground. When this happens, the air is heated and the sky is filled with bright light. Lightning is dangerous and kills or disables hundreds of people every year.



Lightning is a form of static electricity. Extra electrons build up in one part of a cloud. These electrons jump to another cloud with less electrons or they jump to the ground.

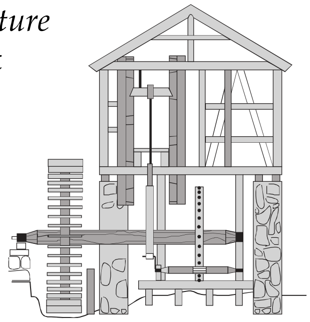
Most usable electricity is different from static electricity. It moves along a flowing path. The flow of electrons causes an electric **current**, which runs in a flow or a stream. It is the kind of electricity that we use to run appliances.

Producing Electricity

There are many different sources of electricity. Some electricity comes from **cells** or batteries. A *cell* is a device that uses chemical reactions to store and produce electricity. The kind of **battery** used in a flashlight is formed from two or more cells. These cells are usually dry. That is to say that the chemicals in them are not dissolved in water. A dry cell has a carbon rod set in the center of a zinc can. The rest of the can is filled with a special paste or gel. The chemicals in the paste react with the zinc. Electrons are released and flow to the carbon rod. This flow of electrons is electricity.

The kind of battery used in a flashlight is formed from two or more cells.

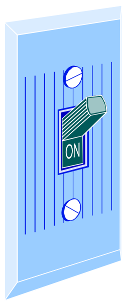
A **generator** also produces electricity. It contains *magnets* and a large coil of wire called an **armature**. The *armature* turns between the magnets. As the armature turns, it moves across the *magnetic field*, producing electrical *current* in the coil. This process is called **electromagnetic induction**. *Generator*s rely on the fact that electricity and magnetism are two aspects of the same force. Just as we use magnets to produce electricity, we use electricity to make magnets. Generators change the **mechanical energy** of different sources into electricity. They can be turned by different sources of energy, such as steam, solar, atomic, and even water. When a generator stops turning, it no longer produces electricity.


Generators can be turned by different sources of energy, such as steam, solar, atomic, and even water.

Circuits

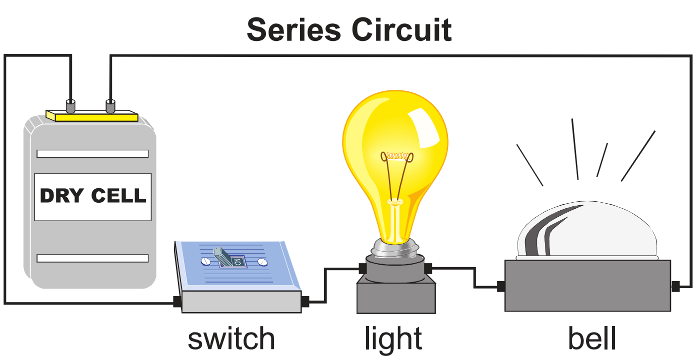
You know that electricity is a flow of electrons. Current electricity must follow a path. The path a current follows is called a **circuit**.

An electric *circuit* can be either *open* or *closed*. A **closed circuit** will allow electricity to move through it. A *closed circuit* is a complete path. An **open circuit** will not allow electricity to move through it. An *open circuit* is an incomplete path. Turn on the light switch in the room. The circuit is complete and electricity will flow. Turn the light switch off. The circuit is open and no electricity will flow.



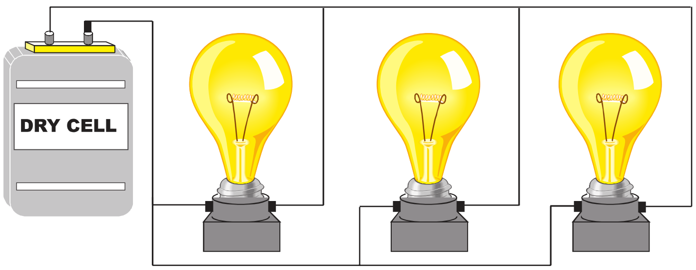
Turn on the light switch in the room. The circuit is complete and electricity will flow. Turn the light switch off. The circuit is open and no electricity will flow.

There are two basic kinds of circuits. Circuits may be either series or parallel. In a **series circuit**, electricity only has one path to follow. Connect a switch, a light, and a bell to a battery. Close the switch. The bell and the light will work. What happens if the light burns out? The circuit will be open. The electricity cannot get past the burned-out light. The bell will not work. When one thing in a *series circuit* burns out, everything else in the series will also stop working. They are not damaged; however, no electricity will flow, so they still will not work. Imagine what would happen if everything in your school was connected to one series circuit.



A **parallel circuit** has more than one path for electricity to follow. The current splits up to flow through different branches. *Parallel circuit*s have the advantage that when one branch of the circuit is opened, such as when you turn off a light, the current continues to flow through the other branches. If one thing on a parallel circuit burns out, the rest of the things will keep working. It is the kind of circuit used in homes and offices.

Parallel Circuit



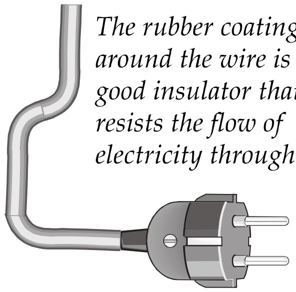
Currents

There are two kinds of currents. One type is **direct current (DC)**. The second type is **alternating current (AC)**. A *direct current* flows in only one direction. A dry cell or *battery* produces a direct current. Direct currents can lose power if they travel long distances through a wire. Remember that *electromagnetic induction* produces a current using a *magnetic field*. The magnetic field produced by a *DC* current is aligned in only one direction. If you use a **compass**, you can detect the direction in which the field is aligned. When you place the *compass* along the path the electrons follow, it will always point the same way.

Alternating currents (AC) change direction many times every second. This is the type of current used in homes and offices. Most household current changes direction 60 times each second. This means that the charges change 60 times each second. Alternating currents can be sent long distances through wires without losing much power. The magnetic fields produced by AC currents are different from those of DC. Because the direction of the current changes, so does the direction of the magnetic field. The result of this is that the field moves away from the wire in first one direction and then another. This varying direction of the electricity and the magnetic field creates an *electromagnetic wave*. This form of energy moves away from the circuit. Because it moves away from its source, we say it radiates.

Conductors and Insulators

Electricity flows. Can it go everywhere? No, it cannot. A material that allows electricity to pass through it is called a **conductor**. An **insulator** will not allow electricity to flow through it.



The rubber coating around the wire is a good insulator that resists the flow of electricity through it.

Think about the wire that carries electricity to your television set. What keeps the electricity in the wire? The rubber coating around the wire is a good *insulator*. It resists the flow of electricity through it. Glass, rubber, and plastic are good insulators. There is no perfect insulator, however, so remember to use caution.

Electricity will travel through a *conductor*. Copper wire is a good conductor. Silver wire also conducts electricity very well, but is more costly to use than copper. Most metals will conduct electricity. Air and water will also conduct electricity.

Safety

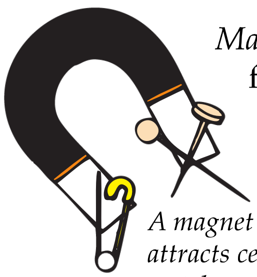
Wires that carry electric power can be dangerous. If you touch bare wires, enough charge may flow through your body to hurt you. You may even be **electrocuted** by it. Electrocution means death by exposure to electricity. If you are reading this, you have not been *electrocuted*, but you may have been shocked. Electricity at home must be used with care. Never use anything with loose or broken electric wires. When there is lightning outside, stay off the telephone and away from electrical appliances. The lightning can send an electric current through these various wires and then through you!

Magnetism

Magnetism is a special type of force. *Magnetism* is a special property of matter. Magnetic forces, like electric forces, involves attractions and repulsions. Magnetism is a force that affects many areas of everyday living.

What Is a Magnet?

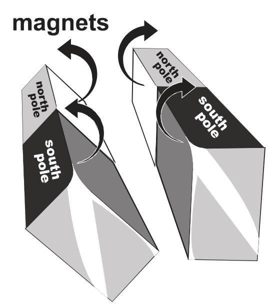
A **magnet** is a substance that *attracts* or *pulls* on other substances. Iron, cobalt, and nickel are **magnetic** metals because they are *attracted* to a *magnet*. Anything that is not attracted to a magnet is **nonmagnetic**. Tin, copper, paper, and wood are *nonmagnetic*.



A magnet only attracts certain metals.

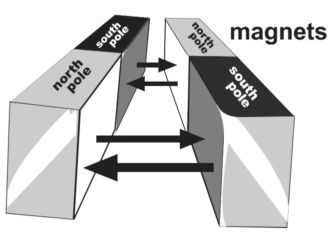
Magnetic force can also *repel*. Two magnets can *push* away from each other when their ends are put together. The ends of a magnet where the force is strongest are called **poles**. The *poles* of a magnet are found by determining which ends have the strongest force. Pass a bar magnet over a box of pins. Most of the pins will stick to the ends of the magnet.

One pole, or end of a magnet, is called the **north pole**. The other end is called the **south pole**. All magnets have a *north pole* and *south pole*.



The same poles, or like poles, of a magnet will repel each other.

Pick up two magnets. Put the north pole of one next to the north pole of the other. What happens? They *repel* each other. Try placing a south pole next to a south pole. Again, the magnets will repel each other.



The opposite poles, or unlike poles, of magnets will attract each other.

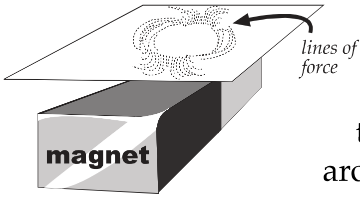
Now put a north pole next to a south pole. Do they repel each other? No, they attract each other. This is called the **law of magnetic poles**. The same poles, or **like poles**, of a magnet will repel each other. The opposite poles, or **unlike poles**, of a magnet will attract each other.

Explaining Magnetism

You know that atoms make up matter. Some atoms are like little magnets. In cobalt, iron, and nickel, the atoms may line up in a special way. When most of the atoms face the same way, the material will be magnetic. In nonmagnetic material, the poles cancel each other out. This is because they are not lined up in the same direction. All magnetism is produced by moving electric charges.

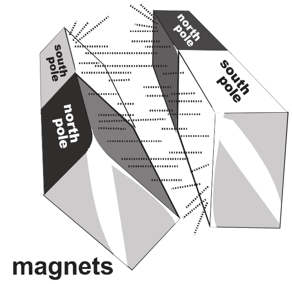
Magnetic Field

You already know that the force of a magnet is strongest at the poles. The rest of the magnet also has some force. Put a piece of paper over a bar magnet. Place some iron filings on top of the paper. Shake the paper slightly. The iron filings will make a pattern. The lines you see are called **lines of force**. The whole pattern is the **magnetic field**. A *magnetic field* is the space around a magnet where a force is noticeable.



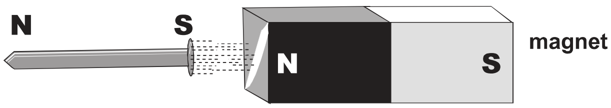
When you get too far away from a magnet, the force will not be noticeable. Although magnetism seems like a strong force, we see that it quickly gets weak with distance.

What would the *lines of force* look like in attracting magnets? What would happen to the lines of force if two like magnets were placed together? Remember, opposite forces attract and like forces repel.



Making a Magnet

Magnetism can be **induced**, or created, in some materials. There are three ways to make a magnet. Place an iron nail against the north pole of a magnet. The force in the magnet will begin to pull at the atoms in the nail. They will line up in straight lines. This will make the nail temporarily magnetic. The end of the nail closest to the magnet's north pole will become the south pole. The other tip of the nail will be the north pole.

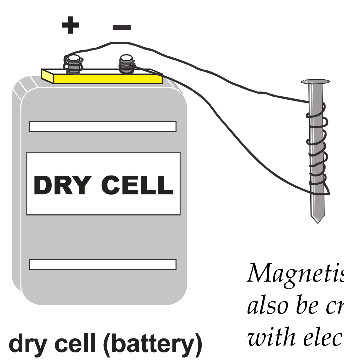


Magnetism can be induced, or created, in some materials.

You can also **magnetize** some materials by rubbing them with a magnet. Run a magnet along the side of a needle. Keep rubbing in the same direction. The atoms in the needle will begin to line up. This will make the needle into a magnet. The longer you rub, the stronger the magnetism will become. Both *induced* magnets will lose their magnetic force after awhile.

Magnetism can also be created with electricity. Connect a wire to the (+) side of a dry cell or battery. Coil the wire around a nail. Attach it to the (–) side of the dry cell.

This will create an **electromagnet**. Electrons travel through the coil of wire and induce a magnetic field causing the nail to act like a magnet. This kind of magnet has many advantages over ordinary magnets. *Electromagnets* can be turned on and off. Their strength can be controlled. This kind of magnet is used in doorbells, electric motors, and telephones.



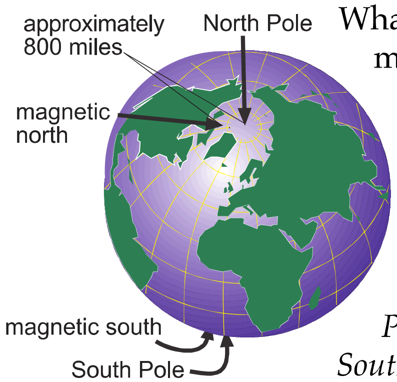
Magnetism can also be created with electricity.

The Electromagnetic Effect

You saw that in the first two examples, a magnet was used to create a new magnet. In this last example, we did not use a magnet. Instead, we used electricity. Electricity is electrons that are flowing in a particular direction. Because these particles are charged, when they flow past the nail it causes a magnetic field to be created. It is this field that makes the nail act as a magnet. When you unplugged the wires, the electrons stopped. This also shut off the magnet.

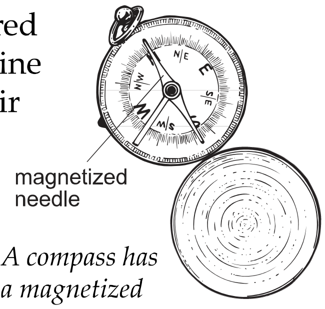
This effect was first described by Michael Faraday. He called it the **electromagnetic effect**. This means that, as we've seen, electricity can create magnets. Magnets, however, can also be used to create electricity, the flow of electrons. Electrons move from areas of negative charge to areas of positive charge. By moving magnets past a length of metal, electrons are made to move. This is how electricity is generated. The energy that results from the interaction of the electric and magnetic fields is called **electromagnetic energy**. Electricity and magnetism are closely related and are usually found together. In many ways, they cannot be separated and are just two versions of the same **electromagnetic force**.

Earth as a Magnet



What makes one pole of a magnet point north? It must be attracted to something. Earth can be thought of as a large magnet. Look at a globe that depicts the Earth. The very top is called the **North Pole**. The opposite side is called the **South Pole**. These spots are not the magnetic poles. **Magnetic north** is located almost 800 miles from the *North Pole*. **Magnetic south** is located near the *South Pole*.

Why is *magnetic north* important? Scientists discovered the magnetic force of Earth could be used to determine direction. Sailors began using compasses to find their way. A compass has a *magnetized* needle that points to magnetic north. Any direction can be located if you know which way is north. For advanced navigation, it is important to know that there is a slight shift in north as you approach the North Pole. This shift is called **magnetic variation**.



A compass has a magnetized needle that points to magnetic north.

Earth acts as a huge magnet. It also has a magnetic field. Earth's magnetic field is responsible for the phenomenon called the **northern lights**. Remember that magnets are closely related to electricity. Because of this, they have effects on charged particles. When charged particles come into Earth's atmosphere near the poles, they interact with the magnetic pole. The result is a release of energy. We see this energy as the *northern lights* or bright-colored areas in the sky.

Summary

Electricity is caused by a flow of electrons. Static electricity is caused by a transfer of electrons. Electrical forces exist between charged objects—this electric force can happen even if objects are not touching. Current electricity moves along a path or circuit. A circuit can be either series or parallel.

Magnetism is a force that attracts or repels substances. Magnets have north and south poles. Poles that are the same repel each other. *Unlike poles* attract. Lines of force surround a magnet. Magnets can be created when atoms line up. The *electromagnetic force* can be used to create magnets or electricity. Earth acts as a magnet. A compass helps locate direction by pointing to the magnetic north.