8.1 Electricity

Mass is one of the more obvious properties of matter. However, matter has other properties that are often hidden. Electricity and magnetism are two of matter's hidden properties. All matter has electrical (and magnetic) properties because the atoms that make up matter are held together by electromagnetic forces. Electromagnetic forces also bond atoms together into molecules and hold molecules together in solids and liquids.

Electric and magnetic forces

Attraction and repulsion

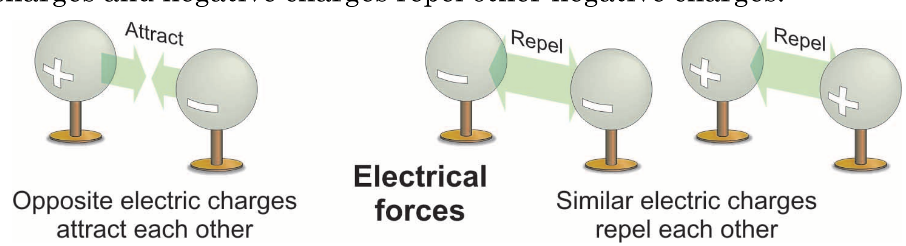
What happens when two magnets get near each other? Like gravity, magnets exert forces on each other, even when they are some distance apart. Unlike gravity, the force between magnets can either attract or repel. Magnetic forces can attract or repel because there are *two kinds of magnetic poles*, called **north** and **south**. Gravity is always attractive because there is only one kind of mass.

Opposite poles attract and similar poles repel

Whether magnetic forces attract or repel depends on which poles are closest. Opposite poles attract each other. A north pole attracts a south pole and a south pole attracts a north pole. Similar poles repel each other. A north pole repels another north pole and a south pole repels another south pole (Figure 8.1).

Opposite charges attract and similar charges repel

Electric charge is another property of matter. Like magnetism, electric charge comes in two types. We call them **positive** and **negative**. Like magnetic poles, opposite charges attract each other. A positive charge attracts a negative charge and vice versa. Two similar charges repel each other. Positive charges repel other positive charges and negative charges repel other negative charges.



VOCABULARY

north, **south** - the two kinds of magnetic poles.

positive, **negative** - the two kinds of electric charge.

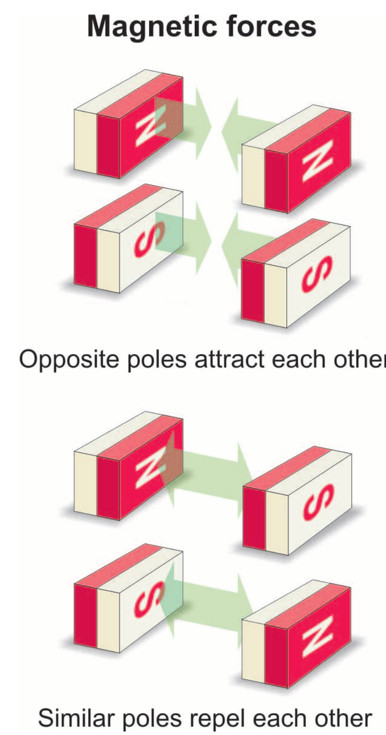


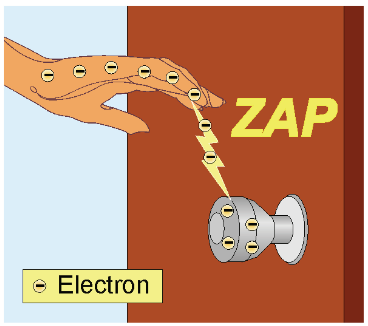
Figure 8.1: *The two ways magnets can interact with each other.*

Electric charge

Two types of charge

Both electricity and magnetism are caused by electric charge. **Electric charge**, like mass, is a fundamental property of virtually all matter. Unlike mass, electric charge is usually well hidden inside atoms. Charge is hidden because atoms are made with equal amounts of positive and negative charges. Inside the atom, the attraction between positive and negative charges holds the atom together. Outside the atom, the electrical forces cancel each other out (Figure 8.2). The forces from positive charges are canceled by the forces from negative charges, the same way that +1 and –1 add up to 0. Because ordinary matter has zero *net* (total) charge, most matter acts as if there is no electric charge at all.

Static electricity and lightning



Static electricity

However, electric charge doesn't *always* cancel out. Sometimes there is a little more of either positive or negative. Then the effects of electric charge can be felt. If you have ever received a shock while touching a doorknob on a dry day, you have felt electric charge yourself. A tiny imbalance in either positive or negative charge is the cause of **static electricity**.

Electric current

You get a shock from static electricity because charge of one type strongly attracts charge of the other type. When you walk across a carpet on a dry day, your body picks up excess negative charge. When you touch a doorknob, some of your excess negative charge moves to the doorknob. Because the doorknob is metal, the charge flows quickly. The moving charge makes a brief, intense **electric current** between you and the doorknob. Electric current is caused by moving electric charge. The shock you feel is the electric current moving negative charge through your skin to the doorknob. Electric current is also one of the most useful ways in which the electrical properties of matter show themselves.

VOCABULARY

electric charge - a fundamental property of matter that can be either positive or negative.

static electricity - a tiny imbalance between positive and negative charge on an object.

electric current - a flow of tiny particles that carries electrical energy in wires and machines. The particles (usually electrons) are typically much smaller than atoms and can flow around and between atoms even in solid matter.

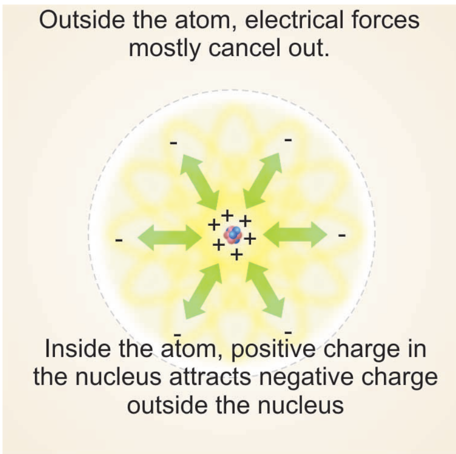


Figure 8.2: *Electromagnetic forces hold atoms together on the inside but (mostly) cancel each other out outside of the atom.*

Electric current

Electric current is moving electric charge

The electricity you use every day is *electric current* in wires, motors, light bulbs, and other inventions. Electric current is what makes an electric motor turn or an electric stove heat up. Electric current is almost always invisible and comes from the motion of electric charges that are much smaller than atoms. In fact, the moving charges in a wire are so small they move around and between the atoms in solid copper metal. These charges are called *electrons* and we will talk more about them in Chapter 13.

Electric current and water current

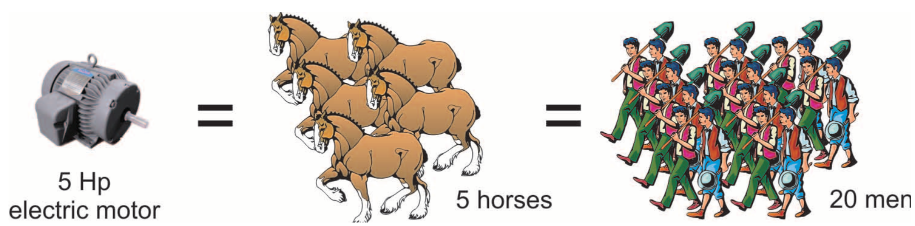
Electric current is similar in some ways to a current of water. Like electric current, water current can carry energy and do work. For example, a waterwheel turns when a current of water exerts a force on it (Figure 8.3). A waterwheel can be connected to a machine such as a loom for making cloth, or to a millstone for grinding wheat into flour. Before electricity was available, waterwheels were used to supply energy to many machines. Today, the same tasks are done using energy from electric current. Look around you right now and probably you will see wires carrying electric current into buildings.

Electric current is measured in amps

Electric current is measured in **amperes** (A), or amps, for short. The unit was named in honor of Andre-Marie Ampere, a French physicist who studied electricity and magnetism. A small, battery-powered flashlight uses about 1/2 amp of electric current (Figure 8.4).

Electricity can be powerful and dangerous

Electric current can carry great deal of energy. For example, an electric motor the size of a basketball can do as much work as five big horses or twenty strong people. Electric current also can be dangerous. Touching a live electric wire can result in serious injury. The more you know about electricity, the easier it is to use it safely.



VOCABULARY

ampere - the unit of electric current.

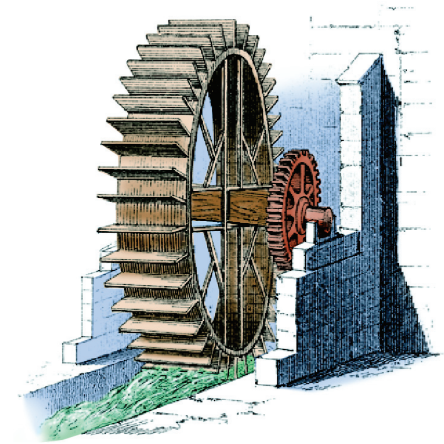


Figure 8.3: *A waterwheel uses the force of flowing water to run machines.*

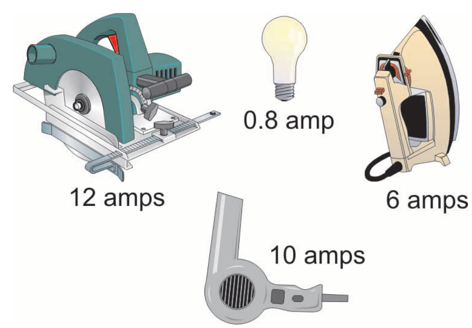


Figure 8.4: *The amount of electric current used by some common devices.*

Voltage

What does a battery do?

If you touch a piece of wire to a light bulb nothing will happen. Add a battery to the same piece of wire and the bulb lights up. What does the battery do that makes the bulb light? If you leave the light on for too long, the battery "dies" and the bulb goes out. What is the difference between a "charged" battery and a "dead" battery?

Electrical potential energy is measured in volts

The difference is *energy*. It takes energy to make light and the battery is a source of electrical *potential* energy. "Potential" means the energy is stored and *could* be released. The energy in a battery is released by attaching wires and allowing current to flow. An ordinary battery makes 1.5 **volts** (V) of electrical potential energy. Think about a battery lighting a bulb in two steps. First, the voltage of the battery (potential energy) causes electrical current to flow. Second, the current carries energy and makes the bulb light.

Current flows from high voltage to low voltage

Current flows from higher voltage to lower voltage. It is a *difference* in voltage that makes electrical current flow just as a difference in height makes water current flow (Figure 8.5). A "charged" battery uses its energy to keep a voltage difference of 1.5 volts between its positive terminal and the negative terminal. A "dead" battery has used up its energy and the voltage difference drops close to zero. No current flows when there is zero voltage difference, which is why a dead battery won't light a bulb.

Current (amps) flows and does work.

A voltage difference causes current to flow.

Current and voltage

We make electrical energy useful by creating a voltage difference then using the voltage to push electric current. Current is what actually flows and does work. A difference in voltage provides the energy that causes current to flow. Current and voltage are two essential ideas of electricity, and they are different! Voltage is potential energy, energy that *could become* active. Flowing electrical current *is* active energy, energy that is moving and doing work.

VOCABULARY

volt - the unit of electrical potential energy.

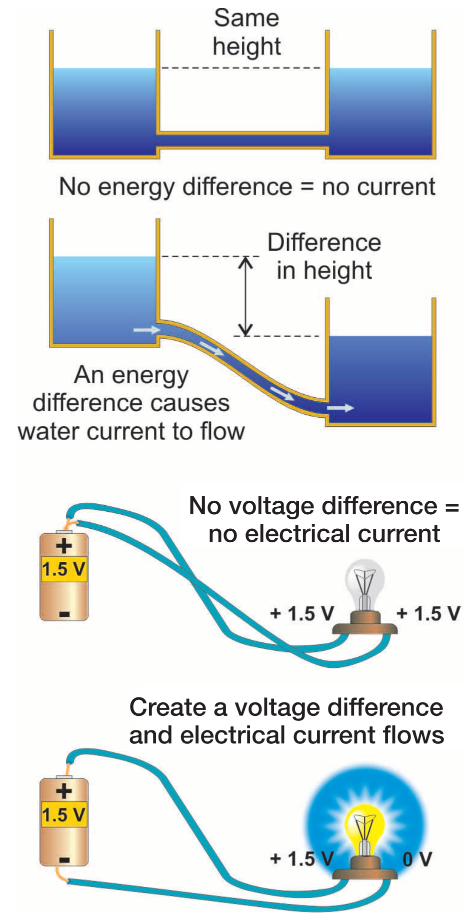
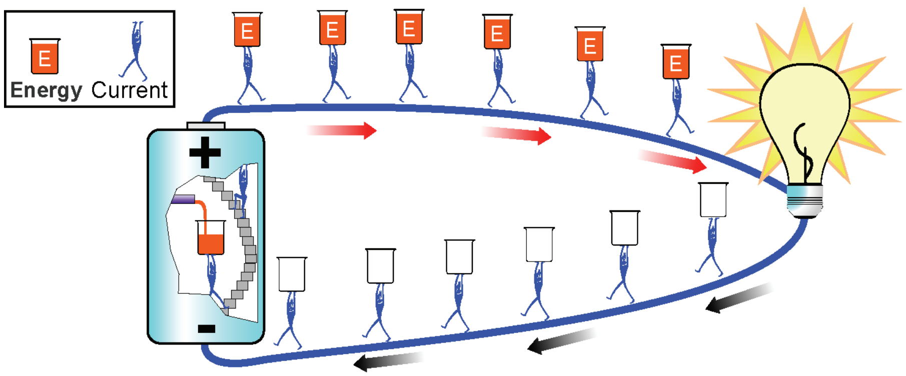


Figure 8.5: *A change in height causes water to flow. Current flows in a circuit because a battery creates a voltage difference.*

Batteries

How do batteries work? A battery uses stored chemical energy to create a voltage difference. Electrical current carries the energy to electrical devices such as a light bulb. The bulb *transforms* electrical energy carried by current into light and heat. The current returns to the battery, where it gets more energy. Since electric current in wires is invisible, think of a "current" of marchers, each carrying a bucket of energy (see diagram below). The battery refills the buckets with fresh energy and the bulb uses the energy to make light and heat



Batteries are like pumps A water pump makes another good analogy for a battery (Figure 8.6). The pump raises the water, increasing its potential energy. As the water flows down, its potential energy is converted into kinetic energy. In a battery, chemical reactions release energy by creating a voltage difference. Current carries the energy to electrical devices.

Current flows from positive to negative Examine any battery and you will always find a positive and a negative end. Electric current flows from positive to negative. The positive end on a AA, C, or D battery has a raised bump, and the negative end is flat.

Battery voltage Since batteries create voltage differences, they can be "stacked up" to make higher voltages (Figure 8.7). The first battery raises the voltage from 0 to 1.5 V. The second one goes from 1.5 V to 3V and the third from 3 V to 4.5 V. Each battery adds an additional 1.5 V.

A pump is like a battery because it brings water from a position of low energy to high energy.

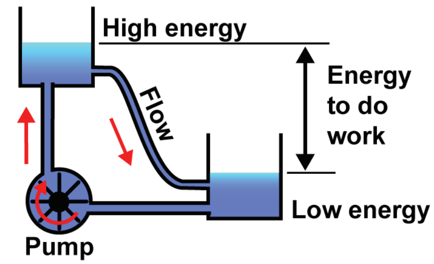


Figure 8.6: *A battery acts like a pump to give energy to flowing electrical current.*

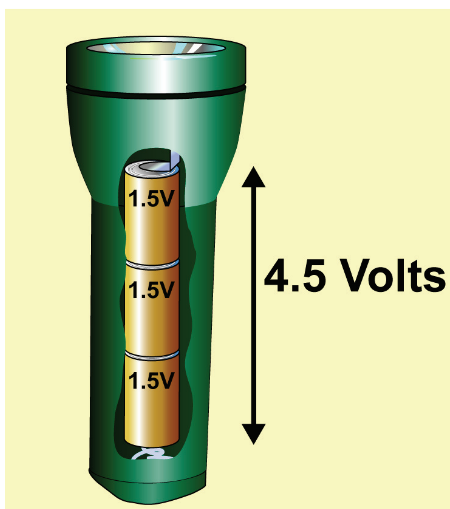


Figure 8.7: *Three 1.5-volt batteries can be stacked to make a total voltage of 4.5 volts in a flashlight.*