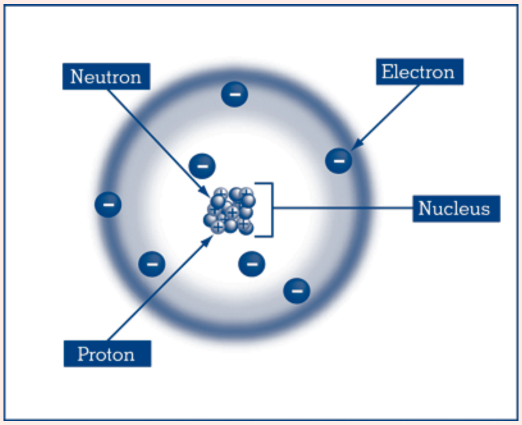
More About Electricity

You have transformed the energy from several different sources into electricity, and examined how generators produce it. In order to understand how energy is transformed into an electrical form, and how electricity is transmitted and used, it's helpful to understand more about electricity.

Charging It Up

Electrical energy—electricity—is simply the flow of charged particles. These charges are present in all matter because all matter is made up of atoms. An atom, in turn, is made up of protons, which have a positive charge; neutrons, which have no charge; and electrons, which have a negative charge. Neutrons and protons move around in the nucleus, and electrons revolve around the nucleus (see **Figure 2.5**). When an object or chemical is charged, there is a difference between the number of its electrons and protons. An object that is neutral—having an equal number of protons and electrons—has no charge. Opposites attract when it comes to charges, and like charges repel. Thus, an atom that has a negative charge is attracted to an atom with a positive charge.

Figure 2.5: An Atom



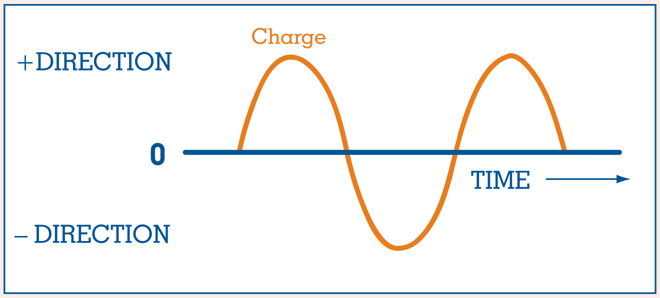
Electrons can skip easily from one atom to another, and when they do, a charge is created. When you shuffle across a carpet in your socks and feel a shock, for example, your feet are picking up extra electrons and generating a charge. You generally don't go around getting shocked by objects, however, because all matter in its natural state is neutral in charge.

Amps: The Flow

Most electrical devices and circuits involve a steady flow of charge in a loop. The movement of electrical charge is called the **current**, and the amount of current through a conductor at any given time is measured in **amperes (A)**, called "amps" for short. Current is given the symbol "I" (from the French word *intensite*, meaning current).

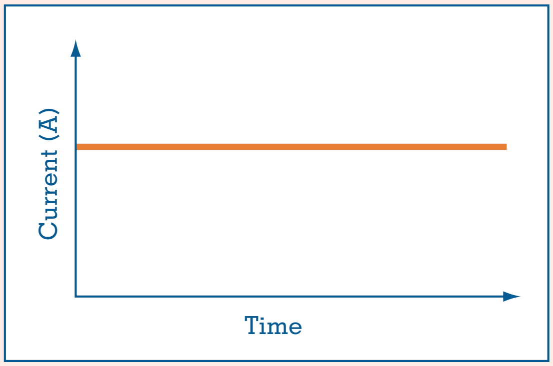
If the charge were water flowing through a pipe, the amps would correspond to the rate of the water flow. Fuses (safety devices that protect electric circuits from too much current) are designed to carry up to a certain amount of current; too much current will blow the fuse. Most fuses in a home are rated for 15 to 40 amps. Household electricity can be very dangerous, because current over 0.01 amps can give you a painful to severe shock, and current above 0.1 amps AC can be deadly.

Figure 2.6: Alternating Current (AC)



The voltage in your home is AC; the electrons flow back and forth through the circuit at regular intervals. The current alternates, or switches directions, 60 times *each second!* This means that the two terminals (the two prongs of an electrical outlet, for instance) switch back and forth from positive to negative 60 times each second (see **Figure 2.6**). CD players, flashlights, and other types of portable or battery-powered devices generally use DC, which flows in one direction (see **Figure 2.7**).

Figure 2.7: Direct Current (DC)



Voltage: The Push

The pressure or force pushing these electrical charges along from one point in a circuit to another point is the **voltage**. Voltage is also called "potential difference" because it is the difference in the amount of electrical potential between two points, such as the positive and negative terminals of a battery.

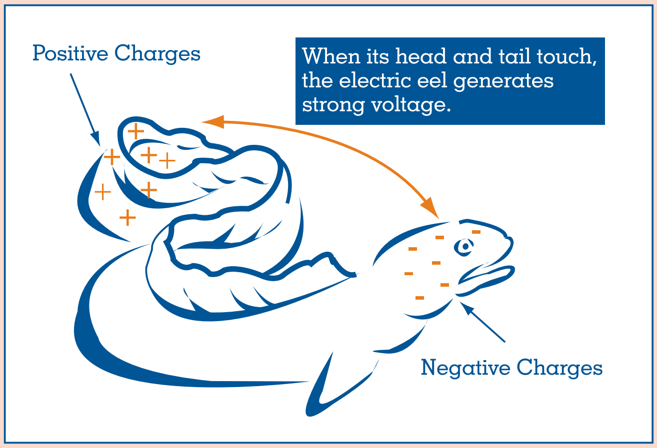
Current in a circuit is driven by voltage in roughly the same way that water in pipes is driven by a pump. The voltage of the water pump system would be the difference between the pressure of the water at its starting point and the pressure at its ending point. The water, or charge, will always move along its path as long as there is a force pushing it forward.

Because voltage is the potential difference, it is always a relative number, depending on the two points between which the current passes. A 6-volt battery, for example, could mean the electric potential at the negative terminal is 8 volts and at the positive terminal is 2 volts, or that at the negative terminal is 10 volts and at the positive is 4 volts.

In the United States, the standard voltage is maintained from electrical outlets at 120 volts of AC. Devices that run on DC, such as a flashlight, need relatively low voltage; 12 volts is generally the highest for DC output. The major advantage that AC electricity has over DC is that AC voltages can be transformed to higher or lower voltages with a device called a transformer. This means that a power station can send out a high voltage of electricity that can be reduced to a safe voltage in your home. The high-voltage power lines that carry electricity long distances across the country have voltages greater than 250,000 volts!

SHOCK OF THE EELS

In the Amazon River and other parts of South America lives a type of fish with a "shocking" feature. The electric eel *(Electrophorus electricus)* can generate a potential difference in the range of 450 to 650 volts—enough to stun a person, run a small motor, or kill a fish. This long, snake-like fish has numerous voltage-producing cells located along its tail, which is about four-fifths of its entire length. The cells carry the charge in one direction: The head acts as the positive end of the battery and the tail as the negative end. When the eel touches its tail and head to other animals, it sends an electric shock through their bodies.



The Resistance

When an electrical charge is flowing, the material it flows through offers some opposition or resistance. Resistance is measured in **ohms (Ω)**. Conductors, such as metals, have relatively low resistance, while non-conductors, such as plastics, have relatively high resistance.

Every item or component in an electric circuit will present some resistance; even the wires that connect the components offer a small resistance. The area, length, and type of material will all affect its resistance. In the water-pipe analogy, resistance could be a pebble stuck in the pipe or simply the friction of the metal against the moving water. A narrow pipe or wire will present more resistance—more friction—than a pipe with a large diameter.

Pulling It All Together

It was German physicist Georg Simon Ohm who in 1827 proved how the amount of energy transferred in an electrical circuit, or the work done by the electrical charge, depends on the relationship between voltage, resistance, and current. Ohm found that current is directly proportional to the voltage and inversely proportional to the resistance. (This fact is now considered one of the fundamental laws of current electricity.) The relationship between these three factors is called Ohm's Law:

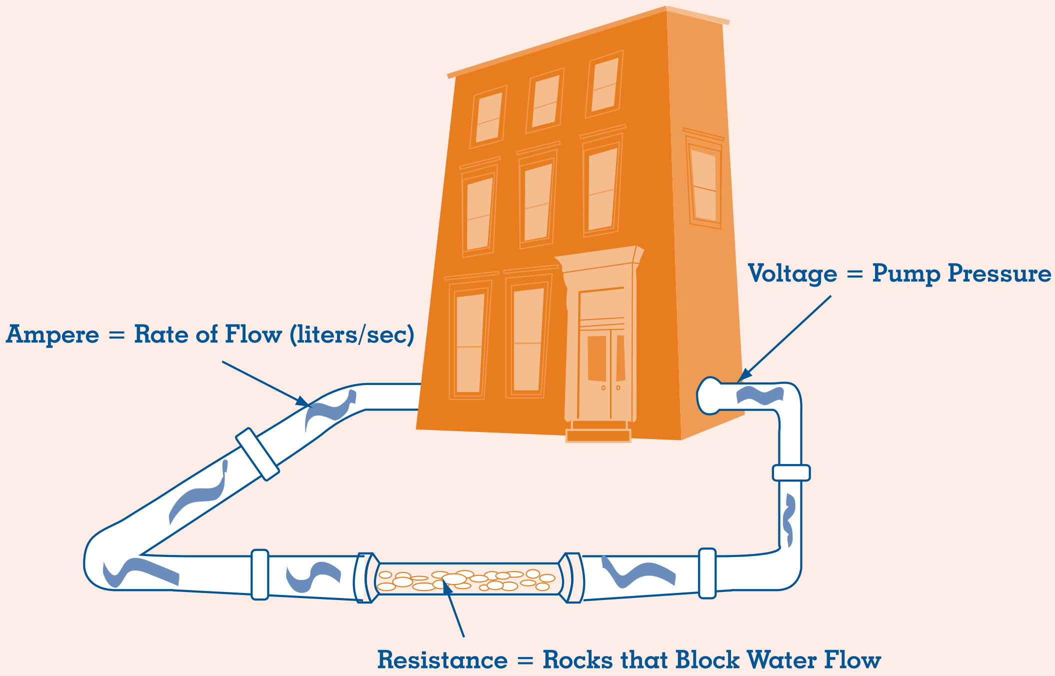
$$\text{Current (A)} = \frac{\text{Volts (V)}}{\text{Resistance } (\Omega)}$$

Written another way:

$$\text{Volts (V)} = \text{Current (A)} \times \text{Resistance } (\Omega)$$

Coming back to the water-pipe analogy, the water flowing in a pipe (the current, measured in amps) will increase if the water pressure (voltage) is increased. If the restriction (resistance) in the pipe is less, the water flow (amps) will increase (see **Figure 2.8**).

Figure 2.8: Volts, Amps, and Resistance: The Water-Pipe Analogy



If the resistance stays the same, a doubling of the voltage will double the current; if the voltage halves, then only half as many charges will flow through the circuit. By lowering the resistance in a circuit, you can lower the voltage needed and leave the current the same.

Questions for Reflection

1. What is electricity? What causes it to move from one object to another, such as from a cloud to the ground?
2. The manufacturers of light bulbs give the bulbs a certain resistance to get the right amount of current to produce the desired brightness. If a small bulb with a resistance of 12 ohms (Ω) is connected to a 9-volt battery, how much current will flow through the bulb?