ELECTRICITY

Basic Concepts

Electricity is the most widely used form of energy, ranging from miniature batteries in your wristwatch to large arc furnaces for melting steel. It's important to understand electricity's basic principles to see how to use it wisely and safely. One of the first discoveries of electricity began about 600 B.C. with the observed attraction between materials and amber rods rubbed with other materials. This is how the name electricity was derived.

Thales of Miletos made a series of observations on **static electricity** around 600 BC, from which he believed that friction rendered amber **magnetic**, in contrast to minerals such as **magnetite**, which needed no rubbing. Thales was incorrect in believing the attraction was due to a magnetic effect, but later science would prove a link between magnetism and electricity.

Ironically, electricity must be converted to other forms of energy such as heat, light, or mechanical power to be useful. In fact, Thomas Edison himself never thought electric power could be sold, since power itself had no "value".

What is Electricity?

What is electricity? It's a lot easier to describe what it does than what it is. For example, electricity operates our lights, runs our refrigerators and powers our electric motors.

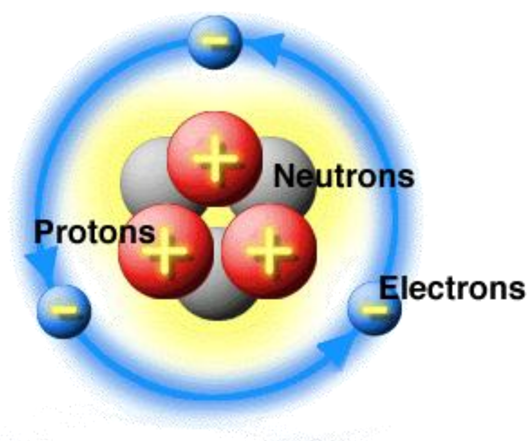
The word "electric" comes from the Greek word "amber" and has been used to describe a wide range of related phenomena. We can't see electricity, but we can see its effects, such as light.

Electricity can exist in a number of forms, but there are two types of commonly used electricity:

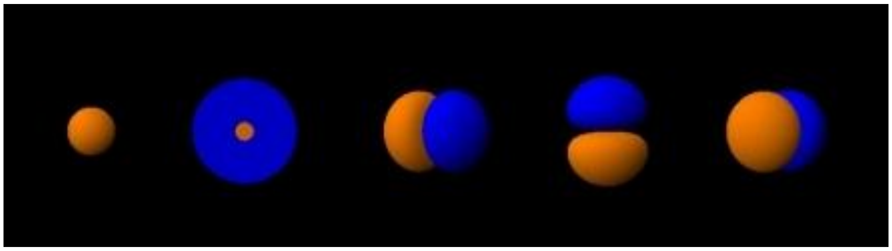
1. **Direct Current**, which is provided by batteries.
2. **Alternating Current**, This is the type of current in home wall circuits, which is provided by electric utilities or other power generators in the form of electrons -- called current -- flowing through a wire -- called a conductor.

Electrons

To gain an insight into how electricity flows through a material, we need to understand the structure of "Atoms" (nature's building blocks). All matter is made up of Atoms (or their particles). We are most familiar with the elements of matter such as Carbon, Hydrogen, Gold, and Silver. All atoms have protons.

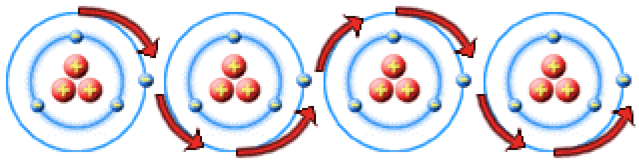


And the number of protons determines the element. Thus, hydrogen always has 1 proton, helium has two lithium has three. Most atoms also have neutrons. Protons are positively-charged, neutrons, have no charge and electrons are negatively-charged. The protons and neutrons form the "nucleus" of the atom, and the electrons are sometimes described as traveling in "orbits" around the "nucleus" much like the Earth travels around the Sun.



Despite the obvious analogy to planets revolving around the Sun, electrons should not be described as solid particles. In addition, atomic orbitals do not closely resemble a planet's elliptical path in ordinary atoms. A more accurate analogy might be that of a large and often oddly-shaped "atmosphere" or cloud where the electrons are likely to be found.

Protons and Electrons follow specific Laws of Attraction. Since they have opposite charges, they "attract" one another similar to the north and south (opposite) poles of magnets. If an atom has the same number of protons as electrons, then the atom is balanced with no net charge. The orbiting electrons remain in orbits around their protons and neutrons in the nucleus as long as nothing upsets the balance. When something upsets this balance, some of the electrons become "knocked out of their orbits". They are now called "free electrons” and these free electrons can readily move to another nucleus. As defined earlier, when these electrons move from atom to atom, we call this “electricity”. The free electron condition can be caused by many different things including rubbing cat's fur on amber (static), passing a wire through a magnetic field (generator), or using two very specific chemicals together (Dry Cell Battery).



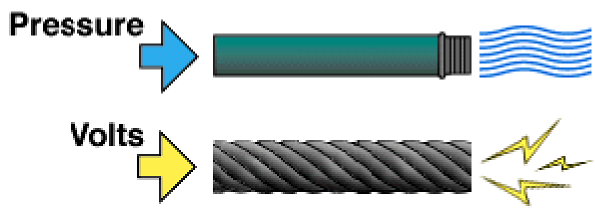
The free electrons are attracted to atoms where there is an electron missing and will fill the space just vacated by the first free electron. When this conditions occurs continuously, the movement of electrons becomes the basis for the flow of electrical energy we call "current".

An electrical **conductor** is a material which contains movable **electric charges**. In metallic conductors, such as **copper** or **aluminum**, the movable charged particles are **electrons** (see **electrical conduction**). Positive charges may also be mobile in the form of **atoms** in a lattice that are missing electrons (known as holes), or in the form of **ions**, such as in the **electrolyte** of a **battery**. Insulators are non-conducting materials with fewer mobile charges, which resist the flow of electric current.

All conductors contain **electric charges** which will move when an electric potential difference (measured in **volts**) is applied across separate points on the material. This flow of charge (measured in amperes) is what is meant by *electric current*. In most materials, the **direct current** is proportional to the voltage (as determined by **Ohm's law**), provided the temperature remains constant and the material remains in the same shape and state.

Voltage

Voltage is the electrical force that causes free electrons to move from one atom to another. Just as water needs some pressure to force it through a pipe, electrical current needs some force to make it flow. "Volts" is the measure of "electrical pressure" that causes current flow. Voltage is sometimes referred to as the measure of a potential difference between two points along a conductor.



Voltage is typically supplied by either a generator or battery. Generators are analogous to a water pump in a water piping system, and batteries are similar to water towers. Both systems have a potential difference between the source of the power and someplace downstream from the source.

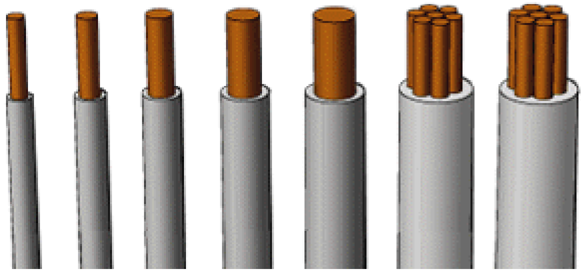
The scientific symbol for voltage is an "E", dating to early days of electricity when it was called the "Electromotive force". Scientists and engineers use the "E" symbol for voltage, while electricians and wiring books use "V" as the voltage symbol. This can create some confusion, since either may be encountered.   We will use the practical symbol "V" for voltage.

Current

Current is a measure of the rate of electron flow through a material. Electrical current is measured in units of amperes or "amps" for short. This flow of electrical current develops when electrons are forced from one atom to another.

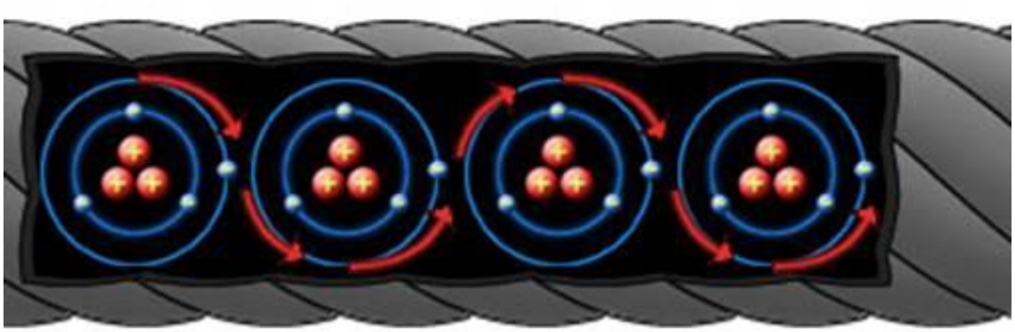
One amp is defined as 6.28 x 10 18 electrons per second.

When current flows in a conductor, heat is produced. This happens because every conductor offers some resistance to current flowing. That is why the amperage flow in a circuit is important, since the more amps flowing, the more heat is produced. Most people notice this heating effect when the cord of any appliance or electrical device heats up after the device has been running for an extended period. Recognizing this heat production is important in specifying wire sizes. When a wire carries more amps than it can handle without overheating, we say it is "overloaded". Overloaded wires can melt the insulation and create shocks or even fires.



The scientific symbol for amperage is an "I", dating back to the early days of electricity. It is still used by scientists and engineers. Electricians and wiring guides use "A" as the amperage symbol.

Resistance



"Electrical Resistance" is defined as the "characteristics of the material that prevents the flow of electricity through the material." Even the best electrical conductors, (i.e. Gold) have some resistance to the flow of electricity (electrons) through them. Think of Resistance as a measure of how loosely or tightly a material holds onto its electrons. Materials that allow their electrons to move easily (conductors) have “low resistance to the flow of electricity” and materials that hold tightly to their electrons (insulators) have “high resistance to the flow of electricity”.

The Electrical Resistance of a material is measured/quantified in units called "ohms". The lower the Resistance of a material in ohms, the better the material acts as a conductor. For example, Copper has a lower Electrical Resistance than Aluminum so Copper is the better Conductor. The "resistance value" for most materials can be looked up in physics or science books. In this manner, by comparing the “Ohm Value” of copper to aluminum, it can be determined how much better copper is as a conductor compared to aluminum.

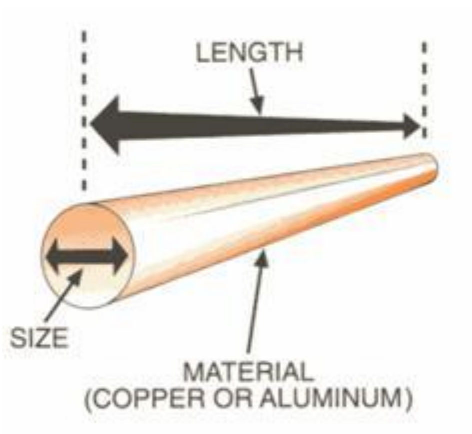
We can use Resistance to flow in a water piping system as an analogy. The Resistance in the Water Pipe to the flow of water comes mainly from the size of the pipe, rust and corrosion inside the pipe, and the number of "bends" and fittings used which all add up to increase the Resistance to the flow of water through the pipe. The more resistance to the flow of water through the pipe, the bigger the pressure loss when moving water through the pipe.

The same is true of current flow in an electric circuit. The Resistance to flow in an electrical circuit comes from factors including the material the wire is made of (and impurities), the diameter of the wire, and the length of the wire.

* Aluminum Wires have more Resistance than Copper Wires for the same diameter and length.

* Smaller Wires have more Resistance than larger diameter Wires for the same material and length.

* Longer Wires have more Resistance than shorter Wires for the same material and diameter.



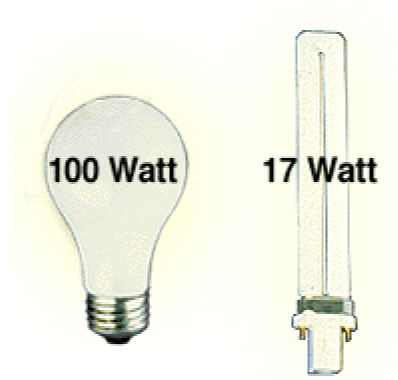
When electricity flows through any Resistance, energy is dissipated in the form of heat. If the heat becomes intense enough, the conductor/wire could become hot enough to "glow". This is exactly how an incandescent light bulb works. The filament of the light bulb is made of a material that will resist the current enough to heat up and "glow".

The scientific symbol for Electrical Resistance, which is measured in "Ohms," is the Greek letter "Omega". Electricians and practical Wiring Books typically use an "R" to represent Resistance. So in this course, we shall use the practical symbol "R" to represent Resistance in "Ohms".

Power

Power is a measure of the amount of work an electric current can accomplish in a specified period of time. The most common unit of electrical power measurement is the watt, or kilowatt, which is 1,000 watts. Power is the rate at which electrical energy is converted into some other form of energy such as light, heat or mechanical work or horsepower.

For any electrical device, the higher its power rating in watts, the greater its consumption of electrical energy, not necessarily the amount of work it produces. For example, consider a 100-watt incandescent light bulb. The 100 watts does not represent how much light it produces, but how much electrical power it uses. A 17-watt fluorescent lamp may produce much or even more light, while using only 17% of the power.



Appliance manufacturers normally indicate how much electrical power an appliance uses in units of watts. Electric utilities measure the power consumption of their customers in kilowatts, thousands of watts, and measure the power produced by a generator or power plant in units of megawatts, or millions of watts. U.S. motor manufacturers still rate motors in units of horsepower where one horsepower equals 746 watts. The symbol for "power" is a capital "P". The kilowatt is shown as "kW" with a little k and capital W. The megawatt is shown as "mW" with a little m and capital W.

OHM’s Law

Ohm's law states that the current through a conductor between two points (typically the beginning of a circuit and the end) is directly proportional to the potential difference or voltage across the two points, and inversely proportional to the resistance between them.

The mathematical equation that describes this relationship is:

$$I = \frac{V}{R}$$

where I is the current through the conductor in units of amperes, V is the potential difference measured across the conductor in units of volts, and R is the resistance of the conductor in units of ohms.

For example: If you had a typical current of 20 amps in circuit running through an electric curling iron operating on 120 volts, what is the resistance in the curling iron in ohms?

20 = 120/resistance

Rearrange

resistance = 120/20

6 Ohms = 120/20