Electric Current and Circuits

In order for electric charges to move, as in lightning, there must be a potential difference. **Potential difference** specifically refers to the difference in electric potential between two points. This is the electric version of water flowing downhill. Water has to be uphill before it can flow downhill, a potential difference due to location.

We have used lightning as a sudden and short-lived movement of electric charges, electrons usually. One of the major scientific and technological advances of the nineteenth century was the harnessing of the flow of electrons along conductors, or an electric circuit. In a **circuit**, electric charge flows due to the movement of free electrons in the conductors, usually metal wires. The flow of electric charge is caused by a potential difference in the circuit and is called electric **current**. The reason a circuit is different from an electric discharge is that there is an "electric charge pump" in the circuit, a voltage source, such as a **battery** (which is actually a series of electric cells). Think some more about the idea of water flowing. Specifically, let's look at a garden or park fountain. There is a reservoir of water that is pumped up and out through the fountain. The water falls back to the reservoir due to gravity and is again pumped up through the fountain. A battery works much like the pump in the fountain in that it "pumps" electric charge back up to a higher electric potential. The electric charge then "falls" through the circuit to the bottom of the charge reservoir (all the materials that compose the circuit provide the electrons) and is "pumped" back to a higher electric potential by the battery. The rate of electric current is measured in **amperes (A)**. One ampere is defined as one coulomb of charge passing a point in one second. The current in a circuit does not normally cause the circuit to be electrically charged. The electric charge that flows is part of the circuit, which is almost always neutral in charge to start with. Another interesting result of the electric charge being provided by all conducting parts of the circuit is that once the circuit is completed all parts of the circuit experience current at the same time. Unlike the flow a water, an electric current produces an almost instantaneous electric field and current at all parts of the circuit. Although the electric field nearly instantaneous, the individual electrons have a speed of about 800,000 m/s but move randomly and only move along the wire at a rate of about one meter every hour. This occurs in a circuit with a **direct current (DC)**, here the electric field lines are maintained in one direction in the circuit. In a typical household circuit the current is an **alternating current (AC)**, here the direction of the electric field is changed 180 degrees at a regular rate, much like a wave. In an AC circuit the electrons in the wires do not travel along the wires at all, but simply sway back and forth with the electric field.

The simplest electric circuit is composed of a **voltage source**, c**onducting material**, and a **resistor**. A voltage source is often a **battery**, which is a series of electric cells. There are two types of electric cells, wet and dry. Both involve chemical reactions between metal and a compound. A **wet cell** involves an aqueous electrolyte, usually an acid, and metal plates. The chemical reaction between the acid and the metal produces energy, which results in a potential difference between the metal plates, terminals, of the cell. A **dry cell** works basically the same but with a solid "paste" as opposed to a liquid. Everyday batteries are actually dry cells. In order to have a battery, by definition, you must have multiple cells. A "AA" battery is actually a "AA" cell. A **resistor** is just that, something that resists the electric current. Much like a pipe to water, the thicker and shorter a wire is, the less resistance it provides to the electric current. **Resistance** also varies with the specific material and the temperature of the material; copper is less resistant than steel and a higher temperature increases resistance. **Resistance** is measured in **ohms (Ω)** and is related to current and voltage according to Ohm's Law. **Ohm's Law** states that the current in a circuit is directly proportional to the voltage established across the circuit, and is inversely proportional to the resistance of the circuit. As written in the equation to the right: **I = current, V = voltage, and R = resistance**. Electrical devices such as light bulbs are resistors.

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

There are two basic types of circuits: **series** and **parallel**. In a **series circuit** there is only one path for the current to flow. The amount of current is the same in all parts of the circuit and the voltage is divided proportionally to the resistance of each part of the circuit. A 3 Volt battery will provide a voltage around 3 Volts, and the voltage drop across each resistor in the circuit will add up to that 3 Volts. A break anywhere in the circuit will cause the current to stop flowing in the entire circuit. The total resistance of a series circuit is equal to the sum of all the resistors in the circuit. The more resistors you have in series the more total resistance you have.

A **parallel circuit** provides multiple pathways for the current to flow between the same two points. As a result the voltage across each path is the same and is equal to the voltage source. Each path behaves as a separate series circuit and the current in each path is inversely proportional to the resistance of that path. As the number of paths increase the total resistance decreases and the total circuit current increases. A parallel circuit with three bulbs on three paths will drain a battery about three times faster than the same three bulbs in a series circuit. If one of the paths is broken (a bulb blows out) the current will remain in the other paths of the circuit. The total resistance of a pair of equivalent resistors is half the value of one of the resistors. For resistors of unequal values the total resistance is equal to the sum of their inverse values.

Another important aspect of electrical components is the electric **power**, the rate at which electric energy is used. Electrical power is simply the product of electric current and voltage within a circuit or electric device. The units still work out to be Watts. An ampere is a C/s and a volt is a J/C. When multiplied the coulombs cancel out, leaving a J/s or a Watt.

$$P = I \cdot V$$