Electrical Tech Note — 210

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Atoms, Charge and Current

This Tech Note provides a brief description of the composition of matter and atoms. Atoms and objects can become electrically charged and how this occurs is important for an understanding of the flow of electricity in metals and a class of materials called semiconductors. The movement of a subatomic particle called the **electron** causes the flow of electricity, *but the flow of electricity is actually the flow of electrical charges through a conductor*. More about the interaction of electrical charges is discussed in *Tech Note 211.*

The Nature of Matter: All matter in the universe is composed of atoms. Certain atoms group together to form molecules. Molecules and atoms group together in various ways to form everything we see. Thus far there are 92 different atoms that exist naturally to form the universe. These atoms are called **elements**. There are other atoms or elements that can be made artificially most of which exist for only a short time before they decompose. *There are three components that make up atoms and they are the **proton,** the **electron,** and the **neutron**. The proton and the electron have what is known as an electrical charge* that can exert an influence on other protons and electrons. *Protons and electrons are attracted to each other. The electrical charge of a proton is positive (+), and the charge of an electron is negative (-).* Even though the proton is much more massive than an electron their charges are considered to be equal in strength. The **charge of one proton is +1, and the charge of one electron is -1.** When an equal number of protons and electrons combine to from an atom the charges are considered to be neutralized to the outside world and the charge of an atom is considered to be zero (0). *Figure 210.1* is a representation of an atom.

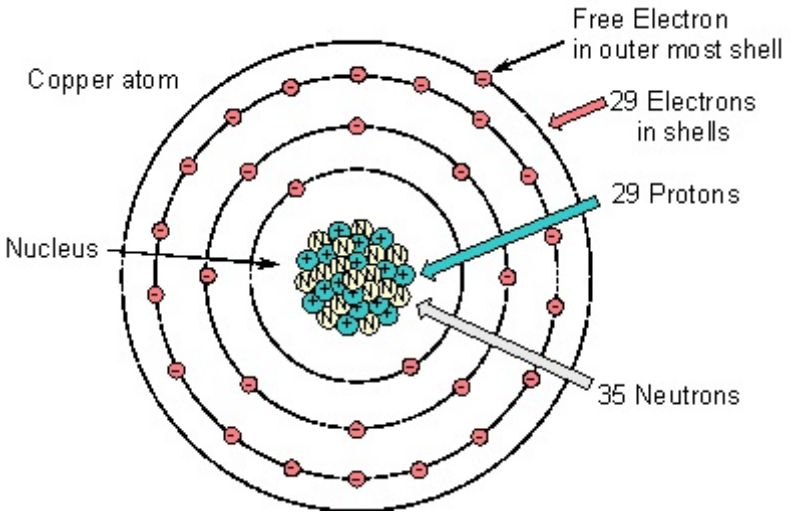

Figure 210.1 *An atom consists of a nucleus made up of positively charged protons and neutrons with no charge and electrons in constant motion in shells or orbits around the nucleus. This is a representation of a copper atom with 29 protons and 35 neutrons in the nucleus and 29 electrons in orbits around the nucleus.*

Atoms consist of a central sphere made up of protons and neutrons similar to the diagram of *Figure 210.1.* A neutron has about the same mass as a proton, but a **neutron does not have a charge**, and does not exert an influence on other objects like protons and electrons. This central sphere of the atom is called the **nucleus**. Negatively charged electrons are attracted to the positively charged protons in the nucleus, but they do not touch each other. The *electrons are in constant motion and orbit the nucleus* in a spherical shell or orbit. For an atom there is an orbiting electron for every proton in the nucleus. *The electrical charge of an atom is neutral or zero.*

In general the number of protons in the nucleus of an atom remains constant, although some elements are unstable and in time the nucleus splits apart and breaks down into other elements with smaller nuclei. The number of neutrons in the nucleus of an atom can change, but that has little or no effect on the charge of the nucleus. For practical everyday life the number of protons in the nucleus of an atom is considered to be constant and the positive charge of the nucleus remains unchanged. Electrons orbiting the nucleus are located in specific spherical shells at a fixed distance from the nucleus. The farther from the nucleus electrons are located from the nucleus the less tightly the electron is held in place. This is what gives rise to the flow of electricity. One or two of these outer electrons may be removed from the atom. When this happens the atom is left with a positive charge equal to the number of electrons that were removed. If one electron is removed, the atom is left with a charge of +1. Entire objects can become electrically charged by friction where one object gains electrons from another object. An example is when a person walks across a carpet and creates a spark by touching a metal door knob.

An entire object can be made positively charged when many of the electrons are removed from the atoms by friction. Another object can be made negatively charged if that object gains electrons from another object. *Two objects that are electrically charged will be attracted to each other if one object is negatively charged and the other is positively charged.* This is illustrated in *Figure 210.2.* If the objects touch each other, electricity will flow as electrons from one object flow to the other object to neutralize the charge. If two objects have the same charge such as both positive or both negative, the objects will repel each other. *Opposite charges attract and like charges repel.*

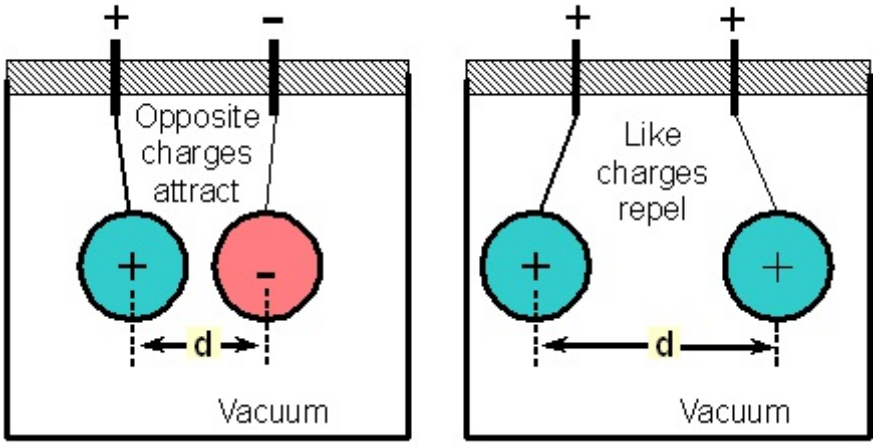

Figure 210.2 *This is a diagram of an experiment where objects are suspended by a wire in a vacuum chamber and a charge is placed on the objects. When the two objects have opposite charges they attract each other, and when the objects have the same charge, either both positive or both negative, the objects repel each other.*

What is Electricity? The force created around an electrically charged object is known as an electric field. The greater the charge on the object the greater is the electric field exerted. That electric field radiates straight out from the object in all directions. This is the principle of a radio antenna. An electric field is applied to a conductor when it is attached to a source such as a battery or plugging something into the wall.

How receptive a material is to the flow of electricity depends upon the way the electrons are arranged in orbits around the nucleus of the atom. Metals such as copper have only one or two electrons in the outermost shell or orbit. As the temperature of the metal rises these outer electrons absorb this energy and some break loose from the atom and drift freely through the metal. It's not long before another atom with a missing outer electron snatches it and pulls it into it's outer orbit. This breaking loose and recombining occurs continually. Materials that are poor conductors of electricity hold their outer electrons so strongly that it is very hard to break them loose from the atoms. If an external electric field is applied to a metal conductor the free electrons drifting randomly about the metal will move in the direction of the positive terminal of the electric field. The stronger the external electric field the greater the flow of electrons.

Think now about the positively charged atom left behind when the electron moves in the direction of the electric field. As negative charges (electrons) move in one direction, a positive charge moves in the opposite direction. The flow of electricity is the flow of electrical charges caused by the flow of electrons. Since opposite charges flow in equal quantity in both directions, electrical current flow can be defined as flow in either direction. Scientists and engineers define current flow from (+) positive to negative (-). Technical books describe electricity in the opposite direction, negative to positive. *When electrical flow is defined from positive to negative this is called* ***conventional current flow****.*

Direct Current: A direct current source has two terminals and something inside the electrical supply creates an excess of electrons at one terminal (negative) and a deficit of electrons at the other terminal (positive). In the case of a battery, this is a chemical reaction. A deficit of electrons leaves the atoms positively charged. If the polarity of the terminals of the source never changes, the electric field of this source applied to a conductor is always in one direction. *Direct current, therefore, only travels in one direction.* This type of current flow is called *direct current* or *dc*. In *Figure 210.3* the current is first shown flowing in only one direction. In order to get the current to flow in the other direction the terminals of the source must be reversed.

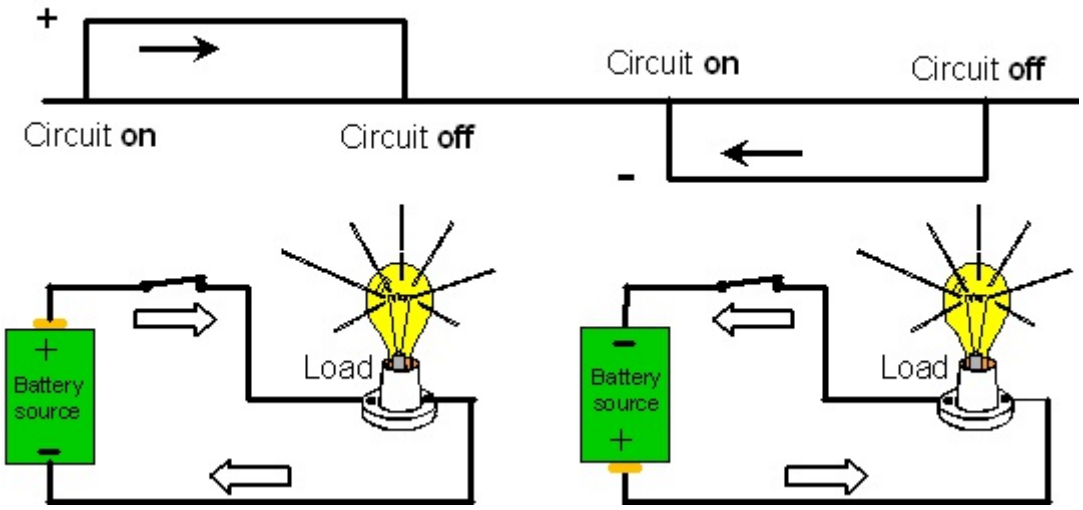

Figure 210.3 *In a direct current circuit current flows only in one direction unless the source terminals are reversed then current will flow in the opposite direction.*

Alternating Current: An electric field can be created in a wire by moving the wire through a magnetic field. This is how utilities generate electricity. They spin a magnet inside coils of wire in a manner similar to that shown in *Figure 210.4.* Each coil of wire is first exposed to the North end of the magnet than to the South end as the magnet spins. The electrons are first pushed in one direction and then pushed in the other direction. A graph of the current flow looks something like that shown in *Figure 210.5.* The shape of the wave shown in *Figure 210.5* is known as a sine wave. Since the current alternates back and forth in the wire, this kind of current is called *alternating current* or *ac*.

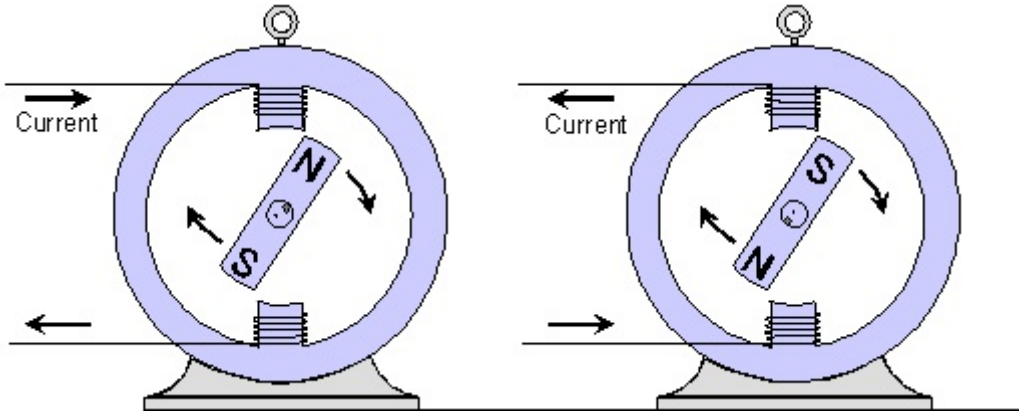

Figure 210.4 *The basic idea of generating alternating current is to spin a magnet or magnetic field inside a steel core with windings (stator). When a wire passes through magnetic field the energy is transferred to the electrons in the wire winding causes them to move, thus creating electrical flow.*

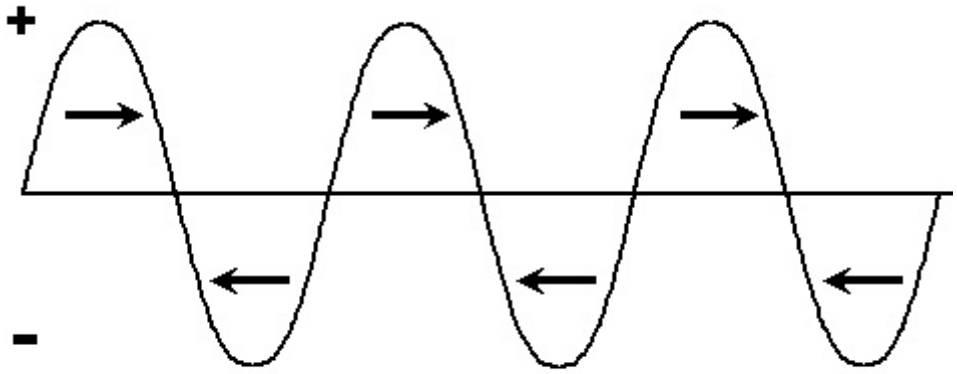

Figure 210.5 *The electrical current flow created by a magnet spinning inside a coil of wire first pushes the current in one direction then in the other, creating a pattern known as a sine wave.*

Summary: Electricity is the flow of electrical charge through a material. Electrons are the charged particles that move through the conductor, but when an electron leaves an atom and moves along the conductor, a positively charged atom is left in it's place. When electrons move in one direction a positive charge moves in the opposite direction. The direction of electrical current flow is the flow of charges, either positive or negative, and direction can be defined from positive to negative or from negative to positive. To understand some electrical concepts the direction of current flow must be defined.