Moving Electrons and Charges

In electricity, negative charges build and then move to the positive region. Electricity is related to charges, and both electrons and protons carry a charge. The amount of the charge is the same for each particle, but opposite in sign. Electrons carry a negative charge while protons carry positive charge. The objects around us contain billions and billions of atoms, and each atom contains many protons and electrons. The protons are located in the center of the atom, concentrated in a small area called the nucleus. The electrons are in motion outside of the nucleus in orbitals. The protons are basically trapped inside the nucleus and can't escape the nucleus. As a result, it is moving electrons that are primarily responsible for electricity.

There aren't a lot of places that you can see electricity. The most commonly- observed form of electricity is probably lightning. Lightning is a big spark that occurs when lots of electrons move from one place to another very quickly. There are three basic forms of lightning, cloud to cloud, cloud to surface, and surface to cloud. All are created when there is an unequal distribution of electrons. You can also see smaller sparks of electricity in science labs that contain Van de Graff generators, and can see even smaller arcs of electrons at home when you scuff your feet and then touch something like a metal doorknob (static electricity).

Electricity Around You

It's easy to see the uses of electricity around you. In fact, there are charges around your computer, your house, and your city. Electricity is constantly flowing through all of the wires in your town. There is also electricity in your flash light. That kind of electricity created by batteries is called direct current. The other major type is found in the outlets of your house. That household form of electricity is called alternating current.

Separating Charges

The belt of a van de graff generator deposits positive charges. Atoms start out with the same number of negative charges (electrons), and positive charges (protons). Under certain conditions, electrons can be removed from, or added to atoms. Removing electrons would leave the atom with more positives than negatives, and we call this a positive ion (An ion is a charged atom). Conversely, adding electrons to an atom would result in a negative ion. If you do this enough times, you can make an object positive or negative.

Friction is one of the ways to separate charge. Have you ever had a science lab where you rub fur on glass rods, or try to make static cling? When you do that rubbing, you are actually rubbing electrons off one object and onto another. When you scuff your feet on the rug, especially in the winter, you can often charge yourself. Clothes tumbling in the dryer often cling together and crackle when you separate them. Lightning is produced, in part, because of air blowing over land. You can also use batteries to separate charge.

Static Charges

Charges build but do not move in a world of static electricity. Electrons can move more easily in some objects than in others. If you put a charge on things like glass, plastic, rubber, and wood, that charge stays where you put it. We say the charges are static, and we call this static electricity. Materials like glass and plastic are called insulators, or nonconductors. Static electricity can happen on a dry winter day when you walk across a carpet. You are actually building up loads of electrons on your skin. Charges don't "want" to stay separated, however. There is always a tendency for charges to return to their original locations, and all that is needed is a pathway for charges (electrons) to use. When you touch a metal doorknob, for example, electrons can jump and give you a shock. Static charges build up on clouds until they can hold no more. At that point, lightning can occur. The study of electricity where the charges are not moving is called electrostatics.

Conductors and Conductivity

The smoother top path shows a good conductor. The bottom shows a poor conductor. There are many materials that allow charges to move easily. They are called conductors. Conductors have the quality of conductivity. I guess that's not a lot of help for you. The reality is that you just need to understand the difference between those two words. The conductor is the object that allows charge to flow. Conductivity is a quality related to the conductor. A material that is a good conductor gives very little resistance to the flow of charge. This flow of charge is called an electric current. A good conductor has high conductivity.

Different Types of Conductors

1. Metals are traditional conducting materials. You see them around the house all of the time. It's a metal wire or one of the metal prongs in an electric plug. There are a lot of free electrons in metallic conductors. Free electrons are electrons that are not being held in atoms, and so, can move easily. Some of the best metallic conductors are copper (Cu), silver (Ag), and gold (Au).

Charges easily move along conductive wires to reach positive regions. (2) There are some conductors that are not metals. Carbon is the best example.

(3) You've probably seen ionic conductors in a lab or in an experiment. When you think about ionic conductors, think about solutions and molten conductors. A solution such as saltwater has a lot of free ions floating around. Those ions (charged atoms) can flow easily, and ionic solutions are very good conductors. One of the reasons you need to get out of the water if there is lightning around, is that water normally contains dissolved ions, and if lightning hits the liquid (solution), it might conduct electricity long distances and electrocute you.

(4) Semi-conductors are the conductors that make your computer possible. If it weren't for semi-conductors, most electronic doodads couldn't be made. Semiconductors have free electrons, but not as many as conductors, and they are not as easy to get moving. Semiconductors have low conductivities. Examples are elements like silicon (Si) and germanium (Ge).

Let Them Move

Positive and negative charges are attracted to each other while two similar charges are repulsed. So what happens if you have separated charges and you connect them with conducting material? Providing a path for charges to move, and making that path out of materials that allow easy movement, results in a flow of charge (electrons) called a current. The electrons will flow from a location that is negative to one that is positive. This can happen quickly and then stop, as with a spark. Or, in the case of a battery connected to a conducting loop (called a circuit. ), it continues to happen until the battery runs out of energy. If the current goes in one direction all the time, it is called DC, or direct current. In your home, however, the same charges move back and forth, so this is called AC, or alternating current.

Force of Charges

Electric force increases as the distance between two charges decreases. Scientists discovered that opposite charges attract, and like charges repel. So positive-positive and negative-negative would repel, while positive-negative would attract. Physicists use the term electric force to describe these attractions and repulsions. The electric forces are much stronger when negative charges are closer to positive charges. The further apart two charges are, the weaker the electric force. Also, the greater the charges, the greater the electric force will be.

Field Basics

Electrons move towards a positive charge and away from a negative charge. Scientists understood why forces acted the way they did when objects touched. The idea that confused them was forces that acted at a distance without touching. Think of examples such as gravitational force, electric force, and magnetic force. To help them explain what was happening, they used the idea of "field". They imagined that there was an area around the object, and anything that entered would feel a force. We say, for example, that the Moon has a gravitational field around it, and if you get close to the Moon, it will pull you down to its surface.

Electric Fields

An electric field describes the funky area near any electrically-charged object. Scientists don’t use the word "funky", but it works. It could also be called an electrostatic field. Any other charge that enters that area will feel a force, and the original object will also feel that force (Newton's Third Law). It's kind of like a spider sitting at the center of a web.

Magentic field lines of repulsion. A normal field is a vector, and is represented by arrows. The Earth's (or any planet's) gravitational field would be drawn as arrows pointing toward the ground. A field vector shows the direction of the effect on an object entering the field. Gravity acts downward.

For an electric field, things are a little more complicated, since there are two kinds of charges, and some combinations attract while others repel. In order to be in agreement with each other, physicists decided that they would always use positive charges to determine the direction of the effect of a field. So, if the central charge was positive, and you put another positive charge near it, that second charge would be repelled outward. So the field vectors for a central positive charge point outward. If the central charge is negative, a positive charge placed nearby would be attracted toward the center charge, so the field vectors for a central negative charge point inward.

Electric fields increase in strength as charged particles move closer to each other. Since fields are directly related to the forces they exert, their strength decreases with distance, and increases with the size of the charge producing the field. When you put charges near one another, their fields interact and change shape. This results in changes in the PE of the objects, and generates forces of repulsion or attraction.

Electric fields can also be created by magnetic fields. Magnetism and electricity are always connected. We'll talk about magnetic fields in the next section.

Magnetic Field Basics

.Magnetic fields are different from electric fields. Although both types of fields are interconnected, they do different things. The idea of magnetic field lines and magnetic fields was first examined by Michael Faraday and later by James Clerk Maxwell. Both of these English scientists made great discoveries in the field of electromagnetism.

Magnetic fields are areas where an object exhibits a magnetic influence. The fields affect neighboring objects along things called magnetic field lines. A magnetic object can attract or push away another magnetic object. You also need to remember that magnetic forces are NOT related to gravity. The amount of gravity is based on an object's mass, while magnetic strength is based on the material that the object is made of.

If you place an object in a magnetic field, it will be affected, and the effect will happen along field lines. Many classroom experiments watch small pieces of iron (Fe) line up around magnets along the field lines. Magnetic poles are the points where the magnetic field lines begin and end. Field lines converge or come together at the poles. You have probably heard of the poles of the Earth. Those poles are places where our planets field lines come together. We call those poles north and south because that's where they're located on Earth. All magnetic objects have field lines and poles. It can be as small as an atom or as large as a star.

Attracted and Repulsed

You know about charged particles. There are positive and negative charges. You also know that positive charges are attracted to negative charges. A French scientist named Andre-Marie Ampere studied the relationship between electricity and magnetism. He discovered that magnetic fields are produced by moving charges (current). And moving charges are affected by magnets. Stationary charges, on the other hand, do not produce magnetic fields, and are not affected by magnets. Two wires, with current flowing, when placed next to each other, may attract or repel like two magnets. It all has to do with moving charges.

Earth's Magnetic Field

The Earth's magnetic field extends from the north to the south pole. Magnets are simple examples of natural magnetic fields. But guess what? The Earth has a huge magnetic field. Because the core of our planet is filled with molten iron (Fe), there is a large field that protects the Earth from space radiation and particles such as the solar wind. When you look at tiny magnets, they are working in a similar way. The magnet has a field around it.

As noted earlier, current in wires produces a magnetic effect. You can increase the strength of that magnetic field by increasing the current through the wire. We can use this principle to make artificial, adjustable magnets called electromagnets, by making coils of wire, and then passing current through the coils.

Flowing Electrons

Comparing paths of low current and high current. Electric current is very similar to a flowing river. The river flows from one spot to another and the speed it moves is the speed of the current. The size of the current flow is related more to the size of the river than it is to the speed of the river. A river carries more water each second than a stream, even if both flow at the same speed. With electricity, current is a measure of the amount of charge transferred over a period of time. Current is a flow of electrons, or individual negative charges. When charge flows, it carries energy that can be used to do work. Scientists measure current with units called amperes.

Current and Heat

The smoother path on the top generates less heat than the difficult bottom path. One of the results of current is the heating of the conductor. When an electric stove heats up, it's because of the flow of current. The electrons have a mass (however small), and when they move through the conductor, there are collisions that produce heat. The more electrons bumping into the atoms of the conductor, the more heat is created, so higher current generally means greater heat.

Scientists used to think that the flow of current always heated up the object, but with modern superconductors, that is not always true, or at least not as true as with normal materials. Superconducting materials seem to have less interaction between atoms and current, so the moving charges lose much less energy.

Spaces Between Atoms

Everything that is matter can conduct electricity, but not everything does it well. Scientists use the terms conductors, insulators, and semi-conductors. The labels are used to describe how easily energy is transferred through the object by moving charge. The spaces between the atoms, as well as the type of atoms, determines whether an object a good conductor or a good insulator (poor conductor).

Usable Current

Current direction in direct and alternating currents. There are two main kinds of electric current, direct current (DC) and alternating current (AC). They are easy to remember. Direct current is a flow of charge always in one direction. Alternating current is a flow of charge back and forth, changing its direction many times in one second. Batteries produce DC current, while the outlets in our homes use AC current.

Be very careful if you work with electricity. NEVER touch the plugs in your house. That electricity is very powerful and it can hurt you… badly. Electricity from batteries can also injure you. We have burned ourselves when working with batteries and electromagnets, so we know what can happen. To be safe, go get an adult to help you with any experiments.