A HISTORY OF ELECTRICITY

Bolded capitalized words are in the Glossary at the end.

I. Static Electricity

There are two forms of electricity, **STATIC ELECTRICITY** and current electricity. Current electricity is also called **ELECTRIC CURRENT**. Both forms of electricity involve electrons. **In static electricity, the electrons stay in one place. They are stationary or "static." In electric current, electrons are constantly moving along a wire like a current of water in a river.**

You have probably felt the effects of static electricity. Walking across a carpet on a cool, dry day can make electrons build up in your body. These extra electrons are called **ELECTRIC CHARGE**. When you touch a door knob or anything else made of metal, you feel a shock as the extra electrons leave your body.

The study of static electricity has a long history. **Electric current has been used to run electrical appliances only since the late 1800s. By contrast, people have experimented with static electricity for thousands of years.** Ancient inventors hoped they could harness it to run machines, but harnessing static electricity for machines was nearly impossible. Machines need electric current do useful work. Indeed, most of what we know about electricity was discovered by people working with static electricity.

II. Early Experiments with Static Electricity

The first person known to have experimented with static electricity is the Greek philosopher Thales of Miletus around 600 BC. No doubt there were others before him who are now forgotten. Thales did experiments with amber, the fossilized resin of pine sap. He noticed that amber rubbed with wool cloth attracted bits of straw. Thales had no idea what caused this attraction. He assumed that the amber released an invisible force which became known as "élektron," the Greek word for amber.

In the late 1500s, William Gilbert, personal physician to Elizabeth I of England, experimented with static electricity. He made a device called a "versorium," with tiny metal arrow pivoting freely on a needle, much like a modern compass. Rubbing some materials, such as amber, gems, and certain rocks, with wool cloth made them exert an attraction on the arrow of the versorium. When he held one of these charged objects near the versorium, the arrow pivoted in the direction of the object. He called these materials "electrics." Other materials, especially metals, could not be made to attract the arrow no matter how hard or how long he rubbed them, and he called these materials "nonelectrics."

In the 1500s, researchers believed that some invisible substance flowed into electrics when they were rubbed with cloth. They called this invisible "fluid" electricity. The idea of electricity as a fluid lasted into the 1800s. **Electricity is now known to be the particles called electrons, not a fluid.**

III. Benjamin Franklin's Ideas about Electricity

As false theories tend to do, the fluid theory of electricity became ever more complicated with the passing years. Eventually there were thought to be two electric fluids. Benjamin Franklin experimented with static electricity around 1750, and concluded that there was only one electric fluid, and that all matter contained a certain amount of it. He believed that matter with a normal amount of electric fluid had no electric charge and did not exert a force of attraction.

According to Franklin, since all matter contains electric "fluid," **the total electric charge in the universe must be constant. This statement is now known as the LAW OF CHARGE CONSERVATION.** He realized that electric charge can neither be created nor destroyed. It can be only transferred from a place with too much charge to another place with too little. **When God created the universe, He created an equal number of electrons and protons. Ever since He finished the creation (Genesis 2:1), this number has been balanced.** Electrons and protons are matter, and matter cannot be created or destroyed. Since electrons and protons are also electrically charged, there must also be a certain number of negative and positive charges in the universe.

He used a + sign to stand for surplus "fluid," and a - sign for a lack of "fluid." Scientists later discovered that negatively charged matter has too many electrons, not too few, but Franklin was correct in his basic idea that electricity is due to a single phenomenon. Franklin's "positive" and "negative" terminology lives on, for in electrical work the conventional direction of electric current is taken to be that of the positive charges, i.e., the direction opposite the actual electron flow. Franklin also explained electrostatic attraction and repulsion. His work led to **the Law of Electrical Attraction and Repulsion, which can be summarized by saying, "Like charges repel and opposites attract."**

IV. Detecting Static Electricity

An ELECTROSCOPE is a device for detecting static electricity. Of course, you can detect static charge by seeing if you can "shock" yourself, but the shock can sting. A large enough shock could be deadly, although simply walking across the floor is never dangerous. In their effort to see if ways could be found for static electricity to run machines, early investigators sometimes experimented with large static charges. These experimenters wanted a way of detecting static charge without injuring themselves. The electroscope was the answer.

An object with static electricity is said to be "charged." The charged object itself is called an "electric charge" or simply a "charge." When static electricity leaves the object by touching a conductor, we say the object has "discharged." A simple electroscope has a small insulator (e.g., a small rubber ball) hanging by a thread. Bringing a charged object near the insulator makes the insulator move: the charge exerts an electrical force. This happens while the charge and the insulator are not touching. Electrical force travels through empty space like gravitational force.

V. Static Electricity Generators

Early experimenters with static electricity had a problem. They could not produce an electrostatic charge large enough for adequate examination. They could make electricity by rubbing glass or amber rods, but this electricity was discharged too easily and too quickly. If ever static electricity were to run machines and do useful work, this obstacle would have to be overcome.

However, electrons are all negatively charged. Like charges repel. The more static electricity the experimenters tried to build up in an object, the more the repulsion of the extra electrons became. Adding each additional electron became harder and harder. There seemed to be a limit to the amount of static charge an object could hold.

In the 1660s, Otto von Guericke, mayor of Magdeburg, Germany, was an active researcher. In 1663, he invented an **ELECTROSTATIC GENERATOR** capable of producing stronger static charges than ever before. He mounted a sulfur sphere on a crank so it could be rotated. A leather strap rubbed against the rotating sphere and generated an electrostatic charge by friction.

Men such as Isaac Newton and Charles François Du Fay made improvements on von Guericke's electrostatic generator during the next 200 years. However, even this type of generator did not make sufficiently strong charges to power machines.

In 1882, James Wimshurst, an English engineer, invented the Wimshurst generator. In a Wimshurst generator, two glass disks are mounted on a single axle but rotate in opposite directions. Metal brushes rub these glass plates and generate an electrostatic charge by friction. The charge is concentrated in metal segments embedded in the glass.

The disks are arranged so a segment with a negative charge (electron surplus) on one disk matches a segment with a positive charge (lack of electrons) on the other disk. By building up a charge on both disks, the Wimshurst generator produces large amounts of static charge. The static electricity is discharged through cone-shaped metal contacts.

It is almost possible to imagine the Wimshurst generator producing enough electricity to power machinery. However, by the 1880s when Wimshurst was active, electrical current was on its way to being used worldwide. Edison had invented the first practical light bulb in 1879, and it required electric current. As a matter of fact, financier and industrialist J.P. Morgan was the first person in the world to have electric lighting throughout his mansion in 1882, the very year Wimshurst invented his generator. Static electricity would have to wait for several decades to find important applications in modern technology.

During the late 1800s and early 1900s, European-born scientist Nikola Tesla also experimented with static electricity. He built spark coils known more commonly as "Tesla coils" capable of producing possibly the largest static discharges on record.

VI. Storing Static Electricity

Ewald von Kleist was a church official in the town of Kamman, Pomerania, now Kamien Pomorski, Poland. In 1745, he built a device to "trap" electricity. Von Kleist's "static trap" was a glass jar with a cork fitted into the top. A metal sphere was connected to the cork by a metal rod. Von Kleist intended to "bottle" electricity exactly as we would use a bottle to store water.

Von Kleist then connected the metal sphere to an electrostatic generator and began making static electricity. After a few minutes, he touched the metal sphere. He expected only a small spark to jump from the sphere to his finger, but what actually happened nearly killed him. An intense discharge knocked von Kleist almost unconscious. After recovering, he abandoned further electrical experiments.

A year later, Pieter van Musschenbroek at the University of Leyden, Holland, tried to develop a better electricity storage bottle. His device was similar to von Kleist's, but he lined his glass bottle with metal foil. He then charged it with static electricity. In a letter to a friend, von Musschenbroek described what happened next: "... I tried to draw sparks from [it]; all at once my right hand was struck so violently that all my body was affected as if I had been struck by lightning. ... I thought it was all up with me."

Von Kleist and van Musschenbroek had invented the first electric "capacitor," a device for storing electric charge. Capacitors are used in nearly every modern electronic appliance to store electrical charge until it is needed. Without capacitors, most electrical appliances could not work. Modern capacitors have many designs, but they all work on the same principles as the capacitors of the 1700s.

Unlike von Kleist, van Musschenbroek continued research to improve his capacitor. **The van Musschenbroek capacitor became known as a "Leyden jar" after the University of Leyden where he taught.** The Leyden jar was a glass bottle coated inside and outside with metal foil. A metal rod extended from a metal knob through a cork or rubber stopper. A chain connected the metal rod with the inner foil.

With the Leyden jar, researchers could do better experiments with electricity. Electricity could be stored and transported as long as no one touched the foil or the sphere of the Leyden jar. Although the Leyden jar made research easier, however, scientists still could not produce a continuous flow of electricity. When a source of electric current was discovered, the study of static electricity was pushed to the background for a time.

Living with Electricity and Without

With Electricity	Without Electricity	Extra Time Needed Without
Air conditioning	Virtually impossible	-----
Computers	Impossible	Time for writing by hand
Dishwasher	Hand-washing dishes	Time to hand wash
Electric heat	Fireplaces, wood heaters	Hours to get wood
Electric light	Lanterns	Time for cleaning
Electric stove	Wood burning stove	Hours to get wood
Electric washer	Wash basin and washboard	Several hours per load
Modern airplanes	Impossible	-----
Radio, TV	impossible	Weeks or months for news
Refrigeration	None for most people	Days for canning
Running water	Wells for most people	Time to draw water

VII. Modern Uses of Static Electricity

Many modern appliances use static electricity in ways undreamed of in the 1800s. **An "electrostatic precipitator" uses static electricity to clean the dust from air.** A fan pulls dusty air into the electrostatic precipitator, and dust particles pass over wires charged with static electricity. The dust particles then become negatively charged. Positively-charged metal plates nearby attract the dust particles, removing them from the air, and the air coming out of the electrostatic precipitator is free of dust. With an electrostatic precipitator, there are no messy filters to clean.

Large electrostatic precipitators have been used for decades to clean factory air. They are installed in factory "smoke stacks" to remove dust and other pollution. **The white "smoke" coming from "smoke stacks" in modern factories is really clouds of harmless steam, not pollution.** For home use, there are small electrostatic precipitator "air cleaners."

Even more common than electrostatic precipitators are electric photocopiers used at school and office, first introduced around 1960. A photocopier works by reflecting an image of the page to be copied on a metal drum charged with static electricity. Parts of the drum where the image is brightest lose their charge, but parts of the drum not so brightly lit keep some or all the charge. Charged areas of the drum attract dry powder "toner." Paper strongly charged with static electricity passes by the drum, and the charged paper attracts particles of toner to make the copy. The toner is fixed into a permanent image by a heater that melts the toner onto the paper. Modern computer-controlled photocopiers store an image in computer memory. The image can be retrieved for additional copies without re-scanning the original document.

VIII. Electric Current

As we can all imagine, going without electricity all the time would change our lives drastically. It is easy to think of the time- and labor-saving appliances we would have to do without, and some of these are listed in the table above. However, the changes brought about by the use of electricity go much deeper than this.

God made mankind with an internal "clock" set on a 24-hour cycle. This matches the daily cycle of day and night. With the invention of the electric light bulb, people no longer had to go to bed at sunset. On the other hand, the light bulb would have been a forgotten curiosity like the Leyden jar without efficient ways of generating electric current. **Both of these inventions -- the light bulb and efficient electric current generation -- happened about the same time.**

Electric light allowed productive indoor activities after dark. A flick of the electric switch provided light which in previous millennia only lanterns could give. Since lanterns were dangerous, people did not use them as freely as people use electric lights today. The lantern flame could start a fire, and many a person of several generations ago could tell of escaping a burning house in the middle of the night because a malfunctioning lantern set the house aflame.

By the late 1900s, mankind's internal "clock" was on a 25-hour cycle. The reason for the longer cycle is that over the 1900s, electric light had lengthened the period of "daylight" for most people. While there is more time to do productive work, surveys have also shown that, in America at least, people get about 20 percent less sleep than a century ago. Electricity has changed even our bio-rhythms!

Until the 1800s, electricity had few practical applications. Researchers could generate and store huge amounts of static electricity, but when the storage devices discharged, the charge was gone in an instant. For electricity to light a bulb, run a motor, or power a computer, there must be a continuous flow of electrons called an electric current, but no one had invented a way to make this happen.

In 1791, Luigi Galvani, an Italian biologist, noticed that the leg muscle of a dissected frog twitched when touched with two different metals at the same time. It was as if the muscle had been stimulated by a charge of electricity from a Leyden jar.

Galvani realized that the contractions were caused by some type of "animal electricity." Somehow the metals were producing electricity which made the muscle move.

In 1800, Alessandro Volta, another Italian scientist, devised a way to make a continuous electric current. He made an ELECTROCHEMICAL CELL, a device in which a chemical reaction produces electricity. Instead of using metals placed against moist animal tissue, his electrochemical cell had a zinc and copper disk separated by cloth soaked in a salt solution. The liquid between the disks was an "electrolyte," a solution which conducts electricity. Volta ran a metal wire from one disk to the other. Electricity flowed in the wire; he had made an electric current.

To produce a greater electron flow -- more electric current -- Volta stacked several electrochemical cells into a pile which came to be known as a "voltaic pile." In the pile, copper and zinc disks alternated with each other. A cloth soaked in electrolyte solution separated the disks.

Today a voltaic pile is called a **BATTERY**. The "lead-acid" battery used to start automobiles is a battery with six to twelve cells. The cells in a voltaic pile or a lead-acid battery are called "wet cells" because they contain wet liquid electrolyte which helps the cell work.

Scientists of Volta's day had no idea what caused the electric current in a voltaic pile. It would be nearly a century before scientists discovered that electrons moving from one metal to another generate it. Undeterred by lack of knowledge, however, researchers began to find practical uses for electric current immediately after Volta's invention.

One of the first uses of electric current was to separate certain compounds into their elements by "electrolysis." Before about 1800, some scientists thought that water was an element. The reason was that no way had been found to decompose water directly into its elements, hydrogen and oxygen. The break down of water by electrolysis showed that water is not an element.

Electrolysis is used today to purify elements that otherwise would be extremely rare in pure form. Aluminum is the most common metal in the earth's crust. However, there was a time in the 1800s when pure aluminum was more costly than silver, gold, or platinum. Then a process was worked out to purify aluminum from its ore by electrolysis.

Now aluminum is one of the least expensive but most useful metals. Unlike iron, it does not rust, but is strong enough to be used in making airplane bodies and wings. Modern automobiles also contain many lightweight, rustless aluminum parts.

Though electrolysis remains an important metal purification process, most electric current is used in electric **CIRCUITS**. The electrons in electric current flow though a wire like water flowing through a pipe. **The current is like the flow rate of water in a pipe.**

IX. Electric Current Generation

An electric generator is a machine which converts mechanical energy to electric energy. Electric generators produce **ALTERNATING CURRENT** (AC). This is why AC is the most common type of current. (By contrast, electrochemical cells and batteries produce **DIRECT CURRENT** or DC.) British scientist Michael Faraday made the first electric generator in 1831. How did this come about?

By the early 1800s, scientists knew that electricity in a wire produces magnetism. That is, **every wire with current in it is surrounded by a little magnetism.** This magnetism is too tiny even to attract small objects like paper clips. Coiling the wire around an iron bar concentrates the magnetism from a lot of wire into a compact space resulting in an "electromagnet." **Turning off the current to an electromagnet makes it quit working, since there is magnetism around a wire only so long as there is current in it.**

Faraday believed that since electricity produces magnetism, magnetism should also be able to make electricity. He connected a coil of wire to a "galvanometer," an instrument for detecting electric current. When he placed a bar magnet inside the coil, the galvanometer showed that an electric current had been produced, but it immediately stopped. As Faraday pulled the magnet out of the coil, a momentary electric current was again produced. He concluded that a moving magnetic field produced an electric current. This effect is called "electromagnetic induction."

Faraday's generator was based on the principle of electromagnetic induction. He rotated a wire loop between the two poles of a horseshoe magnet. When the loop cut through the magnetism of the horseshoe magnet, the magnetism made electrons in the wire move. The result was a continuous flow of electric current. As the conductor neared one pole of the magnet, the current flowed in one direction. As the loop neared the other pole, the current flowed in the opposite direction. Faraday's generator was producing AC.

Some modern generators use an engine to turn the wire loop. The engine may be a steam engine, an oil-burning engine, or a coal-fired engine. It each case, the generator converts the mechanical energy of the engine into electrical energy. Like Faraday's generator, modern generators produce AC unless they are specially modified to make DC.

Another source of energy for electric generators is water falling from the top of a dam. The energy of falling water makes the wire loop turn. Electrical energy generated this way is called **HYDROELECTRIC POWER**.

Faraday built the first practical motors alongside his invention of the generator. **An electric motor converts electrical energy into mechanical energy.** In a generator, mechanical energy turns a wire loop to make electricity. In a motor, electricity turns a wire loop to make mechanical energy. Motors require AC unless they are modified for DC.

Up to the late 1800s, early generators and motors were patterned after Faraday's design. His designs required a permanent magnet in which the wire loop turned. The size of available magnets limited how much electric current a generator could produce, or how powerful a motor could be. Yet factories needed increasingly powerful motors and an increasingly large supply of electrical current to run them.

After making the first successful light bulb in 1879, Edison worked at marketing an efficient system of electric current distribution to customers using his light bulbs. However, believing that DC was better than AC, Edison modified the AC output from his generators to make DC. A serious problem was that DC got weaker with distance from the generating plant. After a few miles, there was almost no current.

X. Nikola Tesla's Improvements Over Faraday and Edison

European-born inventor Nikola Tesla worked out answers to the problems of DC. He realized that AC leaving a generating plant could be processed with a **TRANSFORMER** to travel long distances without weakening so much as DC. He also knew that using AC was the only way to make electrical transmission practical over long distances. Tesla was eventually shown to be right. In 1891 at the International Electrical Exhibition in Frankfort, Germany, an AC line lost "only" 23% of the electrical energy input over 110 miles. DC could not compete with this.

In 1893, the decision to generate AC at Niagara Falls attracted worldwide attention, and the future of AC was assured. To this day, electrical energy is distributed across much of the world in an interlocking network of wires from thousands of generating plants everywhere. This network is called the **ELECTRICAL POWER GRID**. It functions largely with AC, with transformers making possible the supply of electrical energy over great distances from each plant.

Tesla also invented new designs for generators and motors. The basic principles behind motors and generators are the ones worked out by Faraday, but most modern generators and motors are based on Tesla's improvements. Tesla invented a way of producing a modified type of AC called "polyphase current." Polyphase current is the AC used everywhere today. It can deliver more energy than simple AC.

Tesla also invented the polyphase "induction motor" designed to use his polyphase AC. In an induction motor, the wire loop moves within an electromagnet, not a permanent magnet. The electromagnet can be designed to have any strength, so motors can be extremely powerful. **Without Tesla's improvements on the ideas of Faraday and Edison, the modern use of electricity would be only a dream.**

Glossary

alternating current = electric current with oscillating electrons
battery = two or more electrical cells wired in series.
circuit = closed conducting loop
direct current = electric current with unidirectional electron flow
electric charge = excess electrons
electric current = moving electrons
electrical power grid = electrical network linking generating stations
electrochemical cell = uses a chemical reaction to produce electricity
electroscope = device for detecting electric charge
electrostatic generator = device for producing electric charge
hydroelectric power = electricity produced by falling water
law of charge conservation = amount of charge in the cosmos is constant
static electricity = stationary electrons
transformer = device for processing alternating current