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UNITED ELECTRONICS LABORATORIES

LOUISVILLE KENTUCKY

REVISED 1967

AN INTRODUCTION TO ELECTRICITY AND THE ELECTRON THEORY

ASSIGNMENT 5

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AN INTRODUCTION TO ELECTRICITY AND THE ELECTRON THEORY

No one can learn a great deal about the theory and practice of electronics who does not also know a few of the fundamental facts about electricity and magnetism. All electronics theory is built around these basic facts, and every circuit depends upon electricity for its operation.

Science's understanding of electricity is still not complete, and what is known has been discovered over a period of many years. A list of names of persons who have helped to develop the science of electricity would sound like a roll call in a league of nations. From Italy we have Luigi Galvani, and Alexandro Volta, the men who developed the voltaic cell. We honor Volta, when we use the term **volt** as the unit of electrical pressure. Everyone knows the name Guglielmo Marconi, who built up the transmission of radio signals and made over-seas radio communication possible.

Georg Simon Ohm was a German physicist who gave us one of the fundamental laws of electricity. In his honor we call the unit of electrical resistance the **ohm.** One of the later Germans, Heinrich Hertz, was the discoverer of Hertzian waves, or radio waves. His countryman, Wilhelm Conrad Roentgen, learned how to use electricity to produce X-rays.

From France we have Andre Ampere, for whom the unit of current strength is named; and also Charles de Coulomb, who did a great deal of research in electricity and magnetism, and took part in the development of the metric system. The unit of quantity of electricity, the **Coulomb,** is named in his honor.

Hans Christian Oersted, a Danish physicist, paved the way for the later researches of Michael Faraday; and his discoveries showed the close relationship between magnetism and electricity.

Crossing the English Channel to Scotland, we find such names as James Clerk Maxwell, the physicist, whose work on magnetism is still the foundation upon which our magnetic theory is built. England contributed J. J. Thompson, the man who proposed the electron theory, and Michael Faraday. Without Faraday's work we might still be depending upon batteries for our commercial electricity.

In the United States, our own Benjamin Franklin proved that lightning was a form of electricity. Joseph Henry was a pioneer on self-induction, and was a leader in the practical development of the electromagnet. In his honor, the unit of measure of the electrical size of coils is called the **henry**.

We could go on and on mentioning the names of the men who have been instrumental in the development of electricity. In the practical field, we have Thomas A. Edison, inventor of the phonograph, the incandescent electric lamp and a storage battery. He was also a pioneer in the introduction of dynamo-electric machinery. Cyrus Field was an American who laid the first submarine Atlantic cable. In the field of communication, we find such names as Samuel Morse, Lee De Forest and Alexander Graham Bell. This list is by no means complete. It gives us only a glimpse of the many men who have helped to develop a field that can hardly be surpassed in interest or usefulness.

Electricity is certainly not a new discovery. As long ago as the year 600 B.C., the Greek philosopher Thales is said to have discovered that a piece of a substance called amber, which had been rubbed with flannel, would attract small pieces of paper. Nothing of value came from his discovery, however, and it seems to have been about 2200 years later that it was discovered that **many** substances have this same property.

About 1600 A.D., William Gilbert made the discovery that different kinds of material can be excited by means of friction just as amber can. He gave the name electricity (from the Greek word for amber, "electron") to the phenomenon produced in this manner. He showed, too, that electricity and magnetism are not identical, although they have some properties in common.

In 1672, Otto Von Guericke constructed a crude electrical machine for producing static (or "at rest") electricity. This machine consisted of a ball of sulphur mounted on an axis. When the ball was turned, a hand held against its surface was electrified. An improved form of static electricity generator, as used in laboratories and for demonstration purposes, is shown in Figure 1.

In 1752, Benjamin Franklin performed his well-known experiment of flying a kite in a thunderstorm. He proved for us that lightning and electricity are identical, and that lightning is caused by atmospheric electricity. He also introduced the names of **positive** and **negative** for the two kinds of electricity.

(Incidentally, Franklin was a very lucky man in performing his experiments. Recent experiments, from the top of the Empire State Building, have shown that the current in a single bolt of lightning will range from one hundred thousand to two hundred thousand amperes.)

Some Experiments with Electricity

No doubt, you have noticed the crackling sound produced by rubbing a cat's back in dry, cold weather. In winter, a person sliding across a car seat can develop enough electricity by friction to get quite a shock when he touches the door handle. If your hair is dry, it flies out in all directions when you use a rubber comb, and the electrified comb will pick up bits of paper. All of these phenomena are due to "static electricity".

To detect the presence of a charge of electricity, we may use a pith-ball "electroscope". It consists of a ball of pith suspended from a support by means of a silk thread. If we electrify a glass rod by rubbing it with silk and hold this electrified rod near the pith-ball, we find that the pith-ball is first attracted to the rod and then repelled. This is illustrated in Figure 2. This same effect is produced if we rub a rod of hard rubber with flannel or cat fur and then hold it near the electroscope. It is interesting, too, to find that the silk, flannel, and cat fur also show signs of electrification when tested with the electroscope.

Let us charge a glass rod by rubbing it with silk and then suspend it by a silk thread, as shown in Figure 3. **If we bring it near a second glass rod charged in the same manner, the rods repel each other.** If we bring near the suspended glass rod a piece of hard rubber which has been electrified by rubbing it with cat fur, we find that the two rods are attracted to each other. By the same method, it can be shown that a charged rubber rod, suspended in the same manner, is repelled by a similarly charged rubber rod, but attracted by a glass rod electrified by rubbing it with silk. Thus, it seems obvious that there are two kinds of electricity.

An electric charge produced on a glass rod by rubbing the rod with silk is called a **positive charge,** and that kind of an electric charge produced on a hard rubber rod by rubbing it with a piece of cat fur is called a **negative charge.** Sometimes they are called **plus** and **minus charges.** These experiments have also demonstrated a basic law of electricity which can be stated as follows: **Like electrical charges repel; unlike electrical charges attract.**

We saw that when a charged rod is brought near a pith-ball electroscope, the pith-ball is first attracted to the rod, and then repelled. What happens is that the charged rod first attracts the pith ball, and the ball swings toward, and touches the rod. Then, the charge from the rod spreads out over the pith ball until both are charged equally with electricity of the same sign. Then repulsion occurs.

A more sensitive electroscope is shown in Figure 4. It consists of a brass rod terminating at one end in a brass ball or disc. The rod is thrust through a rubber stopper and suspended in a glass flask. To the lower end of the rod two strips of gold leaf, or aluminum foil, are attached. An electric charge applied to the ball, or disc, spreads down over the rod to the leaves, or foil, and since both leaves are thus charged with electricity of the same polarity, they repel each other. An efficient electroscope may be used to detect the presence of an electric charge, to determine its sign, or to measure its intensity.

The Field of Force

It was pointed out in several of the examples, that the effect of the electric charge was felt **before the charged object came in contact with the uncharged object.** For example, if a charged rod is held near, but not touching, bits of paper, the bits of paper will be attracted and will jump to the charged rod. We see that the electric charge is exerting a force on these bits of paper, in spite of the fact that they are not touching. This force must be exerted through the air. The charged particle is said to be surrounded by a **field of force.**

This **field of force** is called an electric field of force, or more commonly an **electric field.** The term electric field merely means the region surrounding a charged body, wherein the charged body exerts force on other objects. If two bodies carrying the same charge are brought close together, their electric fields repel, and if two bodies with unlike charges are brought close together, their electric fields attract.

There are other fields of force besides the electric field. Gravity is an example of a field of force. When an object is dropped, it falls to the earth. This is because a field of gravitational force surrounds the earth. This field of gravitational force draws objects to the earth. Another field of force is the field of magnetic force that surrounds a magnet. This field will be studied in a later assignment.

Each of these **fields,** gravity, electric and magnetic, are different types of fields. **They are not the same things.** The only thing in common between them is the fact that they all exert force through the air. There is much that the scientists do not know about how these three fields are able to exert force through air. Einstein spent much of his life studying this problem and was unable to solve it completely.

Let us support the ball B, of Figure 5, by a silk thread and then join the ball to the knob of an electroscope by means of a copper wire. If the ball B is then charged electrically, the charge is conducted or led along the copper wire to the electroscope, whose leaves diverge. If we were to repeat the experiment, but connect the ball to the knob of the electroscope by means of a silk thread, any charge applied to the ball B does not travel to the electroscope, and there is no divergence of its leaves.

Materials which readily transmit an electric charge are called **conductors.**

Materials which do not readily conduct an electric charge are called **insulators.**

The Theory of Electricity

This force which we call electricity has caused many philosophers to wonder. We know electricity best by the effects which it can produce. It supplies us with light, it rings bells, it sweeps our rugs, it can be used for cooking and heating, and it even helps us to keep time. Electricity runs our industrial plants, and even does our thinking!

In his theory of electricity, Benjamin Franklin assumed that electricity is a fluid. He assumed that any object which is positively charged has an excess of this electrical fluid; if an object has less electrical fluid than normal, he considered it as negatively charged. Just as heat is believed to flow from objects of high temperature to those of a lower temperature, so Franklin assumed that electricity flows from positive (plus) to negative (minus). Although Franklin's theory is out-of-date and certainly incorrect, yet it was used so long that a large number of books and texts still use diagrams that represent electric current as flowing from the positive to the negative terminal. We know now that the electric current consists of a stream of electrons, instead of a fluid as Franklin supposed, and that it flows from the negative terminal to the positive.

The electron theory has superseded Franklin's theory and has come to be considered as the correct theory. To understand the electron theory, we must know something of the nature of matter.

Suppose that a piece of some solid object—a piece of copper wire, for instance—is examined beneath a very powerful microscope. It will be seen that the copper appears to be composed of small particles or grains held together in some mysterious manner. These grains are called "crystals" of copper, and through the use of an electrically controlled instrument, the Electron microscope, a single crystal can be made to appear quite large.

It is well known that ordinary light will not pass through a metal, but a beam of X-rays will penetrate thin sheets of metal very easily. X-rays are fundamentally of the same nature as visible light, but their frequency is much higher and they contain much more energy. If a beam of X-rays were directed on one of these single crystals of a metal, the X-rays will pass through it, coming out on the other side. By photographically studying the directions from which these rays emerge, it can be determined that the crystal of the metal is composed of rows upon rows of small particles arranged in the form of a lattice structure. An example of this is shown in Figure 6. Each of these little submicroscopic particles is thought to be an **atom** of the metal.

In the crystals of the copper, the atoms are considered to be held in fixed positions within the crystal. However, in a gas, the atoms are not fixed in position, but move about freely within the container holding the gas. But whether in a solid or a gas, the individual atoms themselves are made up in a very definite way.

Until the intensive research on the construction of the atom which took place during the war, it was believed that there were 92 separate and distinct types of atoms. The research since that time has revealed at least eleven more types of atoms. Each type of atom accounts for a different **element.** An element is defined as a substance which cannot be separated into substances different than itself by ordinary chemical means. Examples of elements are: oxygen, tin, gold, copper, etc.

Atoms are made up of three principal kinds of particles. These three particles or "atomic building blocks" are:

1. The **electron** which has a **negative** charge.

2. The **proton** which has a **positive** charge. Its charge is just equal in magnitude to the charge of the electron, but of course, opposite in polarity.

3. The **neutron** which has mass, or weight, but no charge.

The proton and neutron are equal in weight, being 1849 times as heavy as an electron.

Except for hydrogen, all known atoms are composed of these "building blocks". The thing that determines the characteristics of the different elements, iron and oxygen for example, is the number of each of these "atomic building blocks" in each atom and the arrangement of these particles. An atom of hydrogen contains only one proton, one electron and no neutrons. This atom is the lightest in weight of all atoms. An atom of helium contains two protons, two electrons, and two neutrons. An atom of helium is shown in Figure 7.

All electrons are identical regardless of what element they are in. For example, the electrons in an atom of tin are the same as the electrons in an atom of helium. Also, all protons are identical regardless of the element, in which they are located. This is also true of the neutrons.

All atoms, in their normal state, are neutral. That is, they have no charge. This is because they contain an equal number of electrons and protons.

The electrons, protons and neutrons are not uniformly distributed throughout the space occupied by an atom. The protons and neutrons are grouped together in the center of the atom, as shown in Figure 7. This center portion, consisting of the protons and the neutrons, is called the nucleus, the net charge of the nucleus is positive. Circulating around the nucleus in orbits are the negatively charged electrons. This rotation of the electrons around the nucleus is very similar to the rotation of the planets about the sun in the solar system. The negatively charged electrons are attracted to the nucleus due to the fact that unlike charges attract. Why these electrons do not go directly into the nucleus is as difficult to explain as why the earth doesn't go directly to the sun.

This theory of the construction of matter is called the electron theory, and was proposed by the English scientist, J. J. Thompson.

While the neutrons are fundamental "atomic building blocks", they contain no electrical charge; so we can neglect them in our discussion of the action of an atom as far as the electrical charges are concerned.

Applying this electron theory to the glass rod of our earlier experiments, we see that the glass rod would be made up entirely of electrons, protons and neutrons. The protons are believed to be fixed in the atoms, but the electrons are loosely held and are transferable. When the number of protons and electrons are equal, the rod has no electrical charge. But when we rubbed the glass rod with a piece of silk, some of the electrons were brushed off the glass and became a part of the silk. This caused the glass to have a **deficiency** of electrons, or to put it another way, an **excess** of protons, giving it a resultant net charge which was positive. This was shown by the electroscope. The silk had an excess of electrons, giving it a **negative** charge, and this could also be shown on the electroscope. Therefore we can conclude, that to have electrification, there must be either an **excess of electrons** or a **deficiency of electrons**. An **excess of electrons** produces a negative charge, and a **deficiency of electrons** produces a positive charge.

The Electric Current

In many ways, the action of electricity can be compared to water. Water at rest is not doing any work. Similarly, electricity at rest (**static** electricity) does no work. When water flows from one point to another, it can be used to do work—turn dynamos, mill wheels, etc. When an electrical charge moves from one point to another, it, too, can do work—turn a motor, heat a toaster, etc. The movement of an electric charge along a conductor is called an **electric current.**

Thus, static electricity is produced by electrons at rest, and current electricity is electrons in motion. Electrons streaming along a conductor form an electric current, but we cannot have an electric current unless we **build up a difference in potential between two points on a conductor, or in a circuit.** Then we shall have an excess of electrons in one part of the circuit and a deficiency in another part. If the difference of potential is maintained, a **continuous current will flow through the circuit.**

To compare these statements to an easily understood example let us assume that we have two vertical cylinders connected near the bottom with a pipe in which there is a stopcock. Such an arrangement is illustrated in Figure 8. Cylinder A is filled with water to the line C, and cylinder B is filled to the line D. If we open the stopcock, water will flow from A to B, but the flow will stop as soon as the water level is the same in both cylinders. The current stops flowing when there is no longer a difference of pressure. It is possible to put a pump into the circuit and keep pumping water from B into A, just fast enough to maintain the same difference of pressure as we had in the beginning. As long as a constant difference in pressure is maintained by the pump, a constant amount of current will flow from cylinder A to cylinder B.

Suppose that we have two bodies connected by a copper wire such as shown in Figure 9. One of these bodies is positively charged (that is, has too few electrons), the other is negatively charged (an excess of electrons), and the two are connected by a copper wire which has a free interchange of electrons.

At the instant the two bodies are connected, the positive body will attract electrons associated with the atoms at the end of the copper wire, and will pull some of them out. This will provide the positive body with the electrons it needs, and this body will become neutral, or have an equal number of positive and negative charges. Pulling electrons from the end of the copper wire will however tend to leave this section of the wire positive and it will attract electrons from the next section of the wire. This portion of the copper wire will, therefore, pull electrons from the next section, and so on until the distant end is reached. Here this last portion of the wire can take electrons from the negative body since the negative body has an excess of them. Through this action, which occurs very rapidly, the two charged bodies become neutral; that is they each now contain equal numbers of positive and negative charges.

A review of this action shows this: At the instant the copper wire was attached between the two unequally charged bodies (and probably for a brief instant afterwards) **electrons moved within the copper wire.** The direction of their motion was from the negative body to the positive body. Also, it was seen that the motion of electrons soon ceased, because when the charges on the bodies became equalized, there was no attracting force left to cause the electrons to flow. This flow of electrons is considered **an electric current.** Thus, **an electric current may be defined as a progressive flow of electrons.**

In an ordinary piece of copper wire the electrons are moving about in a haphazard fashion at the rate of about 35 miles per second. If there is a difference of electrical potential between the two ends of the wire, or in other words, if the ends of the wire are connected to a battery, in addition to this to and fro motion, there is a comparatively slow drift of electrons from one end of the wire to the other. It is this slow drift of electrons in a given direction that we ordinarily call the electric current. Because each electron can carry an extremely small quantity of electricity, it is only movement of large numbers of them in which we are interested. It has been estimated that it would take all the inhabitants of the earth, counting night and day at the highest rate of speed possible, two years to count the number of electrons which pass through an ordinary 40 watt electric lamp bulb in a second. This is about the same number of electrons necessary to operate an ac-dc table model radio.

At this point it will be well to clear up one misunderstanding which has existed for some time. This is the matter of the direction of current flow. It was pointed out in the explanation of the electron theory, that the current flows from the negatively charged body to the positively charged body. This has been definitely proved to be true. Prior to the electron theory, Benjamin Franklin's "fluid" theory was used and current was assumed to flow from positive to negative. A great number of books have been written employing this incorrect idea. These books are still in existence. Also some modern texts are still being written using this idea of current flow. This is particularly true of books for "power men" rather than electronics men. For this reason you may find other texts which will state that current flows from positive to negative, but do not let this confuse you. **Current,** which is a slow drift of electrons, **flows from negative to positive.** In this training program the flow of current will always be assumed to flow from the negatively charged body to the positively charged body.

The unit which is used to measure the amount of electricity flowing in a circuit, is the "ampere". When 6,280,000,000,000,000,000 electrons are flowing past a point in one second, one ampere of current is flowing. This term ampere, and fractions of it, will be encountered very often in electronics, so remember, **it is a measure of the current flowing in a circuit.** The abbreviation used to represent ampere is A (sometimes, a). Thus, 3A means 3 amperes, and 10A means 10 amperes.

Of course, we can't **count** the electrons flowing in a circuit, to find out how much current is flowing. Instead, the amount of current flowing in a circuit is **measured** with a meter called an **ammeter**.

Insulators and Conductors

It is common knowledge that current does not flow through the nonmetallic parts of electrical equipment and that it does flow through metallic parts (wires etc.) We see the wires on the power line poles supported by insulators. We may wonder why some materials will carry an electric current and others will not. The answer to this is found in the electron theory of matter.

In the materials which are good conductors, some of the electrons are not held tightly in their orbits. When these atoms are subjected to a difference in potential, these loosely-held electrons are free to move from one atom to another. These electrons, which are free to move from one atom to another, are called "free electrons". This movement of free electrons is the flow of current which we have been discussing. In the materials which are called insulators, all of the electrons are held tightly in their orbits. When these atoms are subjected to a difference in potential, very few free electrons are present, so only a **very, very small** current flows. Some good **insulators** are glass, rubber, porcelain, quartz, silk and dry air.

The best electrical **conductor** is silver. It is seldom used due to its expense. Copper is the next best conductor and is widely used. Aluminum is the next best commonly used conductor. There is no such thing as a perfect insulator or a perfect conductor. The best insulators will have a **few** free electrons and will allow a small electric current to flow if subjected to a difference in potential. Also, even the best conductor, silver, offers some opposition to the flow of an electric current.

Between these two extremes (insulators and conductors) will be found a large number of materials which are neither good insulators nor good conductors. Some of these materials are called semi-conductors and others are called resistors. **A resistor is a material which opposes the flow of an electric current.** The unit of electrical resistance is the "ohm". Some commonly used resistance materials are carbon and iron.

The unit of resistance, the "ohm", was named in honor of George Simon Ohm. It is defined by international agreement, as the resistance of a column of mercury weighing 14.4521 grams, having a uniform cross section, and a height of 106.3 centimeters at 0° centigrade. The "ohm" will become a more practical term when you consider the fact that a 9.35 foot length of number 30 copper wire will have one ohm resistance. There is approximately one ohm of resistance in 1000 feet of number 10 copper wire. In electronics circuits, resistors will be found in the range from a few ohms to about 10 million ohms. The Greek symbol omega (Ω) is often used to indicate ohms.

The property of a resistor, that of **opposing** the flow of an electric current, is called resistance. This property is just the opposite of the property of a conductor. The property of a conductor is to **allow** the flow of an electric current. This property is called conductance. The unit of conductance is just the opposite of the unit of resistance, that is, it is the same word spelled backwards. The unit of conductance is the "mho".

Potential Difference

We have seen that an instantaneous electric current composed of electrons flows from one electrically charged body to another if their electric charges were different. Now, instead of always speaking of differences in electric charges, we commonly call it a **difference of potential.** The word "potential" has several meanings, but the best one to use here is "inherent ability". Thus, when two bodies have unequal charges—as we have been considering—they have a difference of potential; that is, they have the **inherent electrical ability** to cause a current to flow through the copper wire. In other words, **a potential difference may be defined as the electrical condition, or force, that causes or tends to cause an electric current to flow**.

In measuring altitudes, sea level is usually used as a reference, and certain localities are referred to as being above or below sea level. Similarly, in electrical and electronic work, a body (such as the earth or the metal chassis) may be taken as a reference and electrically charged bodies may be specified as being so many volts above or below this zero potential.

Electromotive Force

We have seen that an electric current would flow through a conductor such as a copper wire if the two ends of the wire were at a difference of potential. In the circuit of Figure 9, the potential difference was provided by two unequally charged bodies, and as soon as the unequal charges were neutralized, the current ceased to flow. Of course, this was because after neutralization no difference of potential was present to force the electrons along the wire.

Let us add a third element to Figure 9, making it appear as Figure 10. This new element has been connected to the positive and negative bodies, and since this new element has the property of maintaining these bodies positive and negative, a **constant** difference of potential will exist and a continuous current will flow.

When a device such as shown in Figure 10 maintains one body positive and another negative, it is the common practice to say that the two bodies are maintained at a difference of potential because of the "electromotive force" that the device generates. In electronics, we often abbreviate the words "electromotive force" as "emf". **An electromotive force may be defined as the electric force generated by a device (such as a battery or generator) that causes a difference of potential to exist between the terminals of the device.** Thus, the emf that is produced by batteries and electric generators is the force that pushes or forces an electric current through the external circuit connected to the battery or generator, and it does this by establishing a difference of potential between its terminals.

The emf is measured in Volts. Thus, if we have a 45 volt battery, this means that the battery will maintain a difference of potential of 45 volts between its terminals. You will find the terms **voltage, difference in potential, potential difference,** and **emf** all used interchangeably. The abbreviation used to represent voltage is V. Thus, 45 V means 45 Volts. Voltage is measured by a meter called a Voltmeter.

Types of Current

The type of current which flows in a circuit when a constant difference in potential, such as that produced by a battery, is maintained is called a **direct current.** This current is always flowing in the same direction through the conductor and is constant in magnitude. Thus, if there is one ampere of current flowing at one instant, there will still be one ampere of current flowing at some later instant.

Later in the training we shall encounter other types of current. One of these types is called **pulsating direct current.** This is a current which is always flowing in one direction, but varies in magnitude. Thus, if there is one ampere at one instant, at some later instant there may be 5 amperes or 1/10 ampere of current flowing in the circuit.

Still another type of current is the **alternating current.** This type of current is periodically changing in direction, and always changing in magnitude. This is the type of current supplied to the house lighting circuits of most communities. We will study this type of current in detail in future assignments.

Units of Current, Voltage and Resistance

The fundamental units used to measure current, voltage and resistance are sometimes rather unwieldy to use when discussing electronics circuits. For example, it is very common to find currents in the neighborhood of one one-thousandth of an ampere flowing in an electronics circuit. We will also encounter resistances of several million ohms. To eliminate the use of these large numbers and fractions, a number of sub-units or multiple units are used. The table below lists some of these units. The last column gives the abbreviation used for these units.

Unit	Stands For		Abbreviation
	Fraction	Decimal	
Milli	$\frac{1}{1000}$	.001	m
Micro	$\frac{1}{1,000,000}$	.000001	μ (Greek letter mu)
Pico (Micro-Micro)	$\frac{1}{1,000,000,000,000}$	.000,000,000,001	p (sometimes $\mu\mu$)
Kilo	1,000		k
Meg	1,000,000		Meg or M

Let us see how we would use these units to represent the one-one thousandth of an ampere mentioned previously. Looking at the table we find that milli stands for one-one thousandth, so this value of current is commonly called one milliampere, and is abbreviated 1 mA. To represent a value of 10 million ohms we would use 10 megohms. To represent one millionth part of a unit we would use the term micro. For example, the current flowing in the "picture tube" in a television receiver might be 1 microampere. This would be written, 1 μA. Some television receivers use voltages of 15 thousand volts. This would be indicated by 15 kV.

Let us re-emphasize these facts. Current is the **flow of electrons** in a conductor. Voltage is a measure of the **force** that causes the current to flow. Resistance is the **opposition** offered to the flow of an electric current.

Summary

Atoms are composed of electrons, protons and neutrons.

Electrons have a negative charge.

Protons have a positive charge.

Neutrons have no charge.

Protons and neutrons form the nucleus of the atom.

Electrons revolve around the nucleus in fixed orbits.

The normal atom is "balanced" electrically; that is, it has an equal number of electrons and protons.

Some materials, called conductors, have "free electrons"; that is, electrons which are not tightly held in their orbits.

Insulators have all of their electrons tightly held in their orbits.

An electric current is the flow of free electrons along a conductor. An electric current will flow through a conductor if a difference in potential exists across that conductor.

An electric current is measured in amperes. (Abbreviated A)

Difference in potential is measured in volts. (Abbreviated V)

Resistance is the opposition offered to the flow of electric current. It is measured in ohms.

Current flows from the negative terminal of a battery, through the circuit to the positive terminal.

We saw earlier how the electrons making up the current are driven through the wires and other elements making up a circuit by a force which is known as an electromotive force. The unit of this force is known as the "volt". A volt is the electrical force that will cause 1 ampere of current to flow through a wire which has 1 ohm of resistance.

Thus, it is possible to know three things about every circuit carrying a current. These are: (1) the strength of the current, (2) the voltage in or across the circuit and, (3) the resistance in the circuit. In a future assignment we will learn how to find the third of these when any two of the three are known.

From this assignment you should attempt to get a clear picture in your mind of what the construction of an atom is like. Then remember these facts:

(1) The positively charged protons **do not move** from atom to atom.

(2) Some atoms do not hold their negatively charged electrons very tightly. These loosely held, or free electrons, may move

from one atom to another. The movement of these free electrons in some definite direction is the flow of an **electric current**. Electric current is measured in amperes.

(3) If any body has more than its normal amount of electrons, that body will have a **negative charge.**

(4) If a body has fewer electrons than normal, that body will have a **positive charge.**

(5) The difference in electrical charge of bodies is called the difference in potential.

(6) Difference in potential is measured in volts.

These statements have been repeated for but one purpose. That is, to enable you to understand the difference between voltage and current. Remember, **voltage is the electrical pressure,** and **current is the movement of electrons** which result when electrical pressure is applied.

"HOW TO PRONOUNCE . . ."

(Note: the accent falls on the part shown in CAPITAL letters.)

ampere	(AMM-peer)
coulomb	(COOL-omm)
induction	(inn-DUCK-shun)
incandescent	(inn-kann-DESS-ent)
micro	(MIKE-row)
neutron	(NEW-tronn)
nucleus	(NEW-clee-uss)
ohm	(OME)
pico	(PEE-coe)
proton	(PRO-tonn)

Test Questions

Be sure to number your Answer Sheet Assignment 5.
Place your Name and Associate Number on **every** Answer Sheet.
Send in your answers for this assignment immediately after you finish them. This will give you the greatest possible benefit from our personal grading service.

1. State the basic law for electrical charges.
   LIKE REPEAL UNLIKE ATTRACT
2. What is the main difference between a conductor and an insulator?
   NO. OF FREE ELECTRONS
3. In the electron theory, does an electric current flow from **positive to negative** or from **negative to positive?**
4. What is an electron?
   NEG. PART OF ATOM AROUND NUCULUS
5. What is an electric current?
   SLOW PROGRESSION OF ELECTRONS ALONG A CONDUCTOR
6. (a) How many ohms are there in a megohm? 1,000,000
   (b) How many milliamperes are there in an ampere? 1,000
7. What is the unit of resistance? ohm
8. (a) List three good conductors. silver, copper, aluminum.
   (b) List three good insulators. dry air - rubber, glass
9. What is the name of the force which causes electrons to move in a circuit? E.M.F VOLTAGE ELECTROMOTIVE FORCE
10. Is current measured with an **ammeter** or a **voltmeter?**

STATIC ELECTRICITY GENERATOR

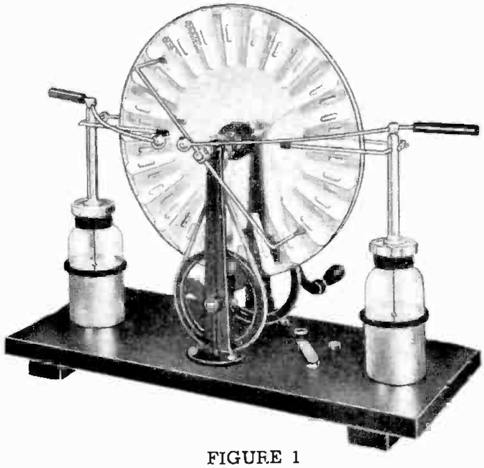
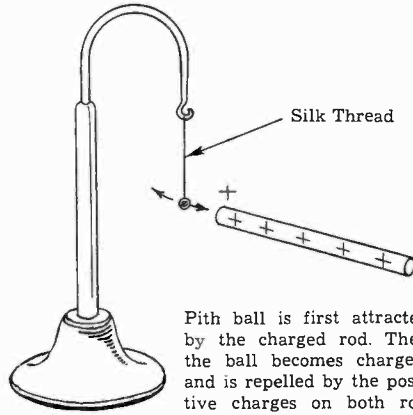


FIGURE 1

PITH BALL ELECTROSCOPE



Pith ball is first attracted by the charged rod. Then the ball becomes charged, and is repelled by the positive charges on both rod and ball.

FIGURE 2

A SIMPLE EXPERIMENT

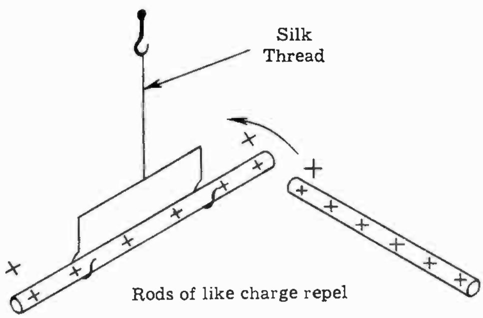


FIGURE 3

A SENSITIVE ELECTROSCOPE

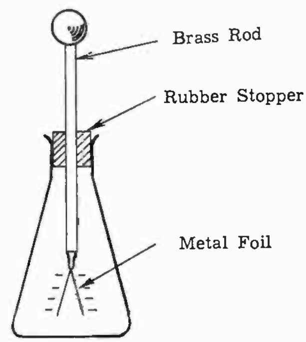


FIGURE 4

HOW ELECTRICITY MAY BE CONDUCTED

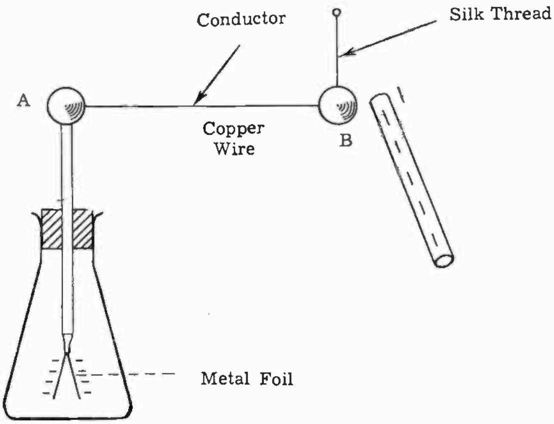


FIGURE 5

CONSTRUCTION OF
A CRYSTAL

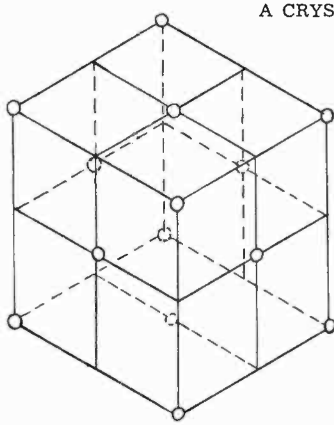


FIGURE 6

AN ATOM OF HELIUM

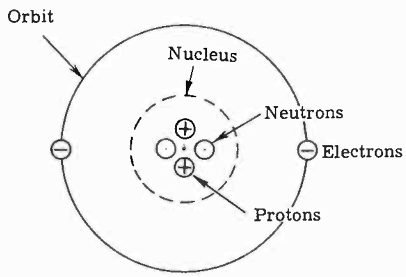


FIGURE 7

HOW DIFFERENCE OF PRESSURE CAUSES CURRENT FLOW

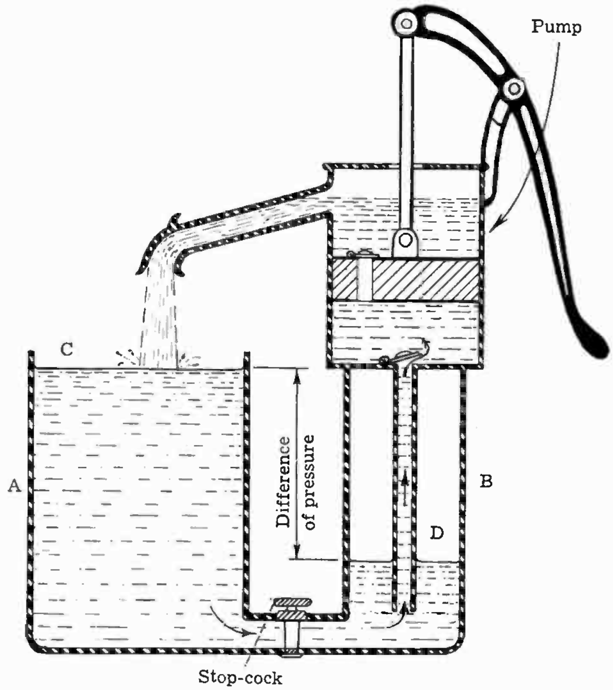


FIGURE 8

DIFFERENCE OF ELECTRICAL PRESSURE CAUSES CURRENT FLOW

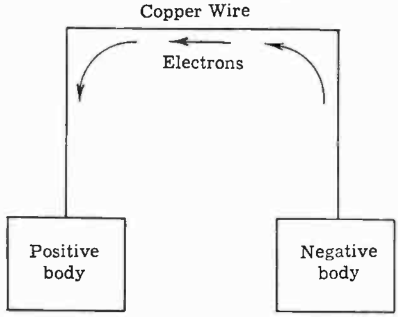


FIGURE 9

HOW A DIRECT CURRENT FLOW IS ESTABLISHED

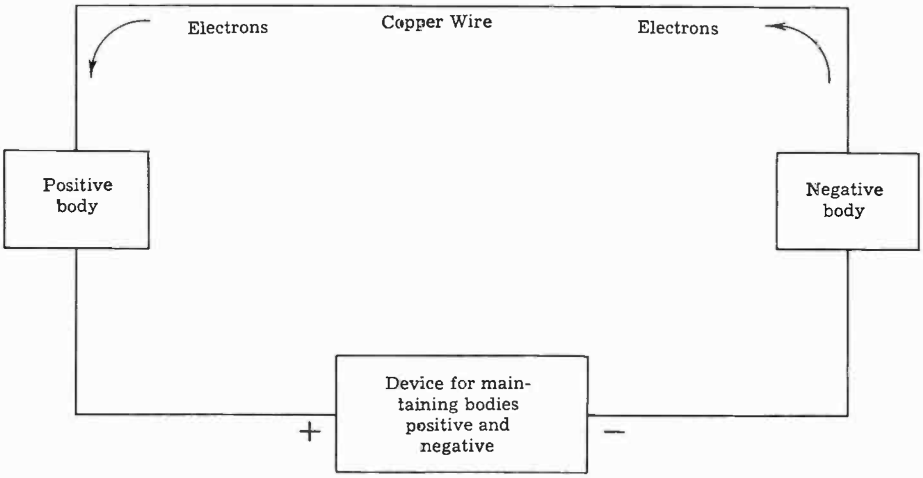


FIGURE 10