

Online Radio & Electronics Course

Reading 1

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BASIC ELECTRICITY - PART 1

The objective of this and the following few readings is to introduce the beginner to the basic concepts of electricity and provide some revision for the more advanced reader. It is extremely important to have a thorough understanding of the fundamentals of electricity before any study of radio and communications. You may be surprised to know that many 'professionals' have a significant lack of understanding of the very basics of electricity. I think this is because you can actually get by without it; however this lack of basics makes understanding of more complex theory difficult and uninteresting.

ELECTRICITY

The complicated electronic systems involved in modern-day communication, satellites, nuclear power plants, radio, and television, and even up-to-date automobiles, **does not** really require technicians to understand the functioning of electric and electronic circuits. Modern day electronics is very modular. A remove and replace, or substitution of the suspected 'faulty module' is generally the approach to modern electronics servicing. This, in itself is not a bad thing, as in the real world, getting an electronic device up and going is the most important thing. However, to have a true understanding, requires a strong foundation in the basics of electricity.

The term "electronic" infers circuits ranging from the first electronic device the electron tube to the newer solid-state devices such as diodes and transistors, as well as integrated circuits (IC's). The term "electric" or "electrical" is usually applied to systems or circuits in which electrons flow through wires but which involve no vacuum tubes or solid-state devices. Actually, many modern electrical systems are now using electronic devices to control the electric current that flows in them.

WHAT IS ELECTRIC CURRENT?

What makes such a simple thing as an electric lamp glow? It is easy to pass the problem off with the statement, "The switch connects the light to the power lines and it glows" or something to that effect. But what does connecting the light to the power lines do? How does energy travel through solid copper wires? What makes a motor turn, a radio play? What is behind the dial that allows you to pick out one radio station from thousands of others operating at the same time? How fast is electricity really?

There are no simple single answers to any of these questions. Each question requires the understanding of many basic principles. By adding one basic idea to another, it is possible to answer, eventually, most of the questions that may be asked about the intriguing subjects of electricity, electronics, and radio. When the

light switch is turned on at one point in a room and the light suddenly glows, energy has found a path through the switch to the light. The path used is usually along copper wires, and the tiny particles that do the moving and carry the energy are called **electrons**. These electrons are important to anyone studying electronics and radio, since they are usually the only particles that are considered to move in electric circuits. To explain what is meant by an electron, it will be necessary to investigate more closely the makeup of all **matter**.

The word "matter" means, in a general sense, anything that can be touched. It includes substances such as rubber, salt, wood, water, glass, copper, and air. The whole world is made of different kinds of matter.

The ancient Greek philosophers were always trying to find the 'stuff' that the universe was made of. Even before Greeks, the Alchemists were trying to find the basic building blocks that all matter was made from, though most of the time their driving force was not so much science but the pursuit of wealth. They figured that if they could isolate the building blocks of matter then they would be able to 'create' matter themselves. One of their pursuits was the creation of the precious metal gold.

Water is one of the most common forms of 'stuff' that we call matter. If a drop of water is divided in two and then divided again and again until it can be divided no longer and still be water, then we have arrived at the smallest possible piece of water. We have a water molecule. The ancient Greeks would have called the smallest droplet of water an atom (atomos). The word atom means indivisible. We know today that substances such as water can be divided into more fundamental bits.

The water molecule can be broken down into still smaller particles, but these new particles will not be water. Physicists have found that there are three smaller particles making up a molecule of water: two atoms of hydrogen (H) and one atom of oxygen (O) as shown at right.

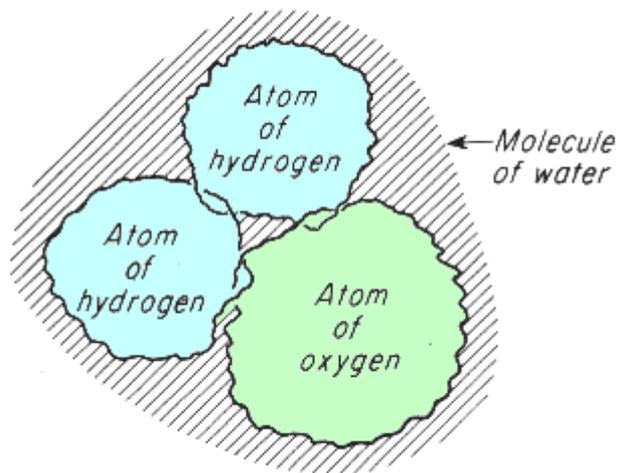


Fig.1 – Water molecule

The symbols 'H' and 'O' are universal symbols used to represent Hydrogen and Oxygen. Oxygen, at normal temperatures, is one of several gases that constitute the air we breathe. Hydrogen is also a gas in its natural state; it is found in everyday use as part of the gas used for heating or cooking. If a gaseous mixture containing 2 parts of hydrogen and 1 part of oxygen is ignited, a chemical reaction in the form of an explosion takes place. The residue of the explosion will be water (H₂O) droplets.

As a child, (much to my mothers dismay) one of the experiments I enjoyed the most was mixing Hydrogen and Oxygen gases in a ratio of 2 to 1 in a jar and placing the

jar in sunlight. A violent explosion would occur as the sunlight triggered a combining of the gases to produce water and release a significant amount of excess energy in the process. This is not an experiment that I would recommend. I still have all my fingers, however this is just the result of being lucky more than anything else.

So, water is made up from two atoms, hydrogen and oxygen. Water is a molecule. A molecule is a substance that is made up of groups of atoms.

If you divided a droplet of water down to its smallest possible size you will have a single molecule of water. If you had the means to divide the water molecule further, you will no longer have water; you will have the atoms (hydrogen and oxygen) that make up water. The chemical name of water then is Di-Hydrogen Oxide.

It has been found that atoms are also divisible. An atom, being made up of at least two types of particles: **protons** and **electrons**, and a third particle called a **neutron**. Don't let these names concern you too much. For our purposes the most important particle is the electron, at this time. Electrons and protons are called **electrical particles**, and neither one is divisible (in normal environments). All the **molecules** that make up all matter of the universe are composed of these electrical proton-electron pairs.

ELECTRONS AND PROTONS

Electrons are the **smallest** and **lightest** of the fundamental particles. They are said to have a **negative** charge, meaning that they are surrounded by some kind of an **invisible field of force** that will react in an electrically negative manner with other matter. Protons are said to have a positive charge and they are surrounded by an invisible force field that causes them to react in an electrically positive manner.

The words **negative** and **positive** are **just names** to describe the so-called charge of electrons and protons, and their charge describes how they interact with each other. We could just as easily call the charge of the electron the **white charge** and the charge of the proton the **black charge**. My point is, 'charge' is an electric behaviour and since there are two types of charge we need to name them so that when we talk about them we will know which behaviour we are speaking off: either the positive charge behaviour, or the negative charge behaviour.

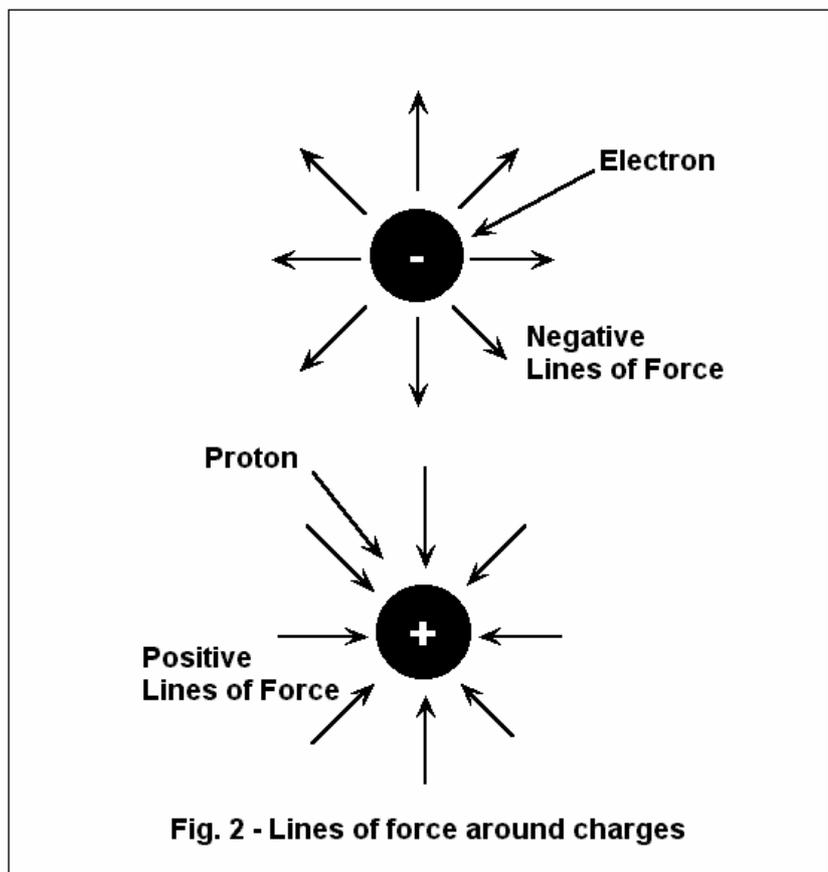


Fig. 2 - Lines of force around charges

AN EXPERIMENT WITH CHARGE

You may have already done this, if you have please try it again. Tear up some tiny strips of paper and place them on the table in front of you. Make sure no one is watching! Now run a hair comb through your hair briskly several times and place the comb close to the bits of paper. Before, the comb touches the paper, a bit of paper will leap off the table and move through the air and cling to the comb. This happens because you have produced a charge on the comb, which will physically interact with matter around it (in our case the bit of paper). The charge on the comb was created by friction between the comb and your hair.

Protons are about **eighteen hundred** times as massive as electrons and have a positive electric field surrounding them. The proton is exactly as positive as the electron is negative; each has a unit electric charge.

When an electron and a proton are far apart, only a few of their lines of force (the invisible field around them) join and pull together. The attracting pull between the two charges is therefore small. When brought closer together, the electron and proton are able to link more of their lines of force and will pull together with greater force.

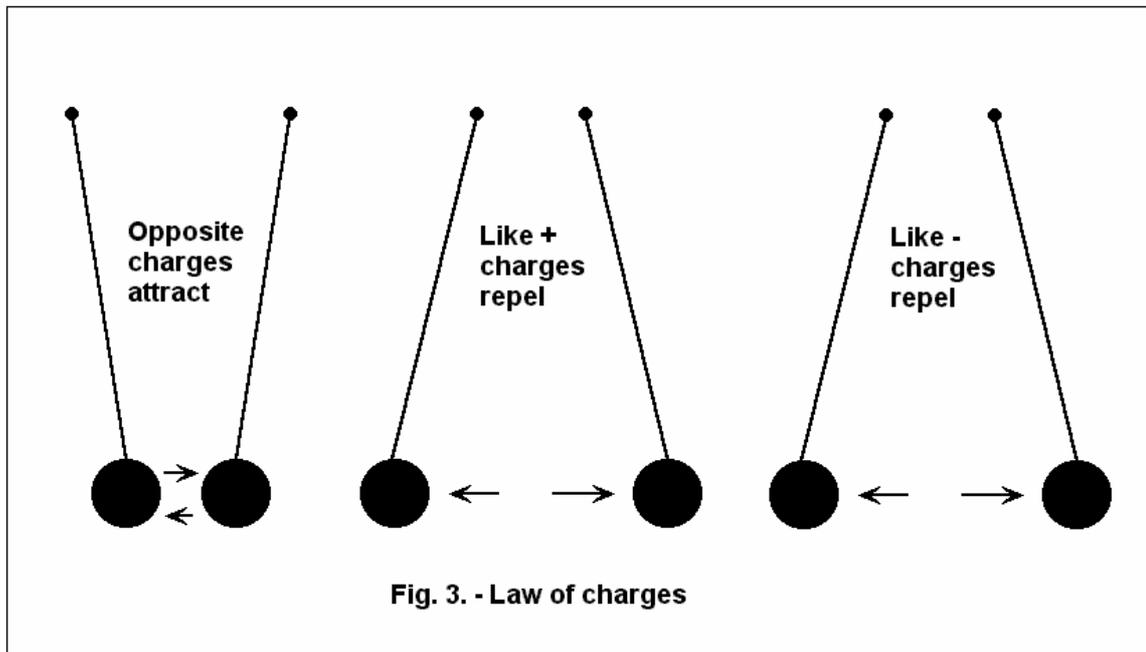
If close enough, all the lines of force from the electron are joined to all the lines of force of the proton and there is no external field, and they attract each other strongly. Together, a positive charge proton and the negative charge of an electron cancel out and they form a neutral, or uncharged, group. The neutral atomic particle, known as a **neutron**, exists in the nucleus of all atoms heavier than hydrogen.

The fact that electrons repel other electrons, protons repel other protons, but electrons and protons attract each other gives us the basic law of charges:

Like charges repel, unlike charges attract.

Because the proton is about 1,800 times heavier than the electron, it seems reasonable to assume that when an electron and a proton attract each other, it will be the **tiny electron** that will do most of the actual **moving**. Such is the case. It is the electron that moves in electricity. If the proton was the smaller particle we would probably have called what we know today as 'electr'icity, something like 'proton'icity.

Regardless of the difference in apparent size and weight, the negative field of an electron is just as strong negatively as the positive field of a proton is positive. Though physically small, the field near the electron is quite strong.



If the field strength (field strength = the strength of the invisible field) around an electron at a distance of one-millionth of a metre is a certain amount, at two-millionths of a metre it will be one-quarter as much; at four-millionths of a metre it will be one-sixteenth as much; and so on. If the field decreases as distance increases, the field is said to vary inversely with distance. Actually, it varies inversely with the distance squared.

Note: a millionth of a metre has a name; it is called a 'micron'.

When an increase in something produces an increase in something else, the two things are said to vary directly rather than inversely. Two million electrons on an object produce twice as much negative charge as one million electrons would. The charge is directly proportional to the number of **electrons**.

The invisible fields surrounding electrons and protons are known as electrostatic fields. The word 'static' means, in this case, "stationary", or "not caused by movement". When electrons are made to move, the result is **dynamic electricity**. The word "dynamic" indicates that motion is involved.

To produce a movement of an electron, it will be necessary to have either, a negatively charged field to push it, or positively charged field to pull it. Normally in an electric circuit, both a negative and a positive charge are used (a pushing and pulling pair of forces).

THE ATOM AND ITS FREE ELECTRONS

There are more than 100 different kinds of atoms, or elements, from which the millions of different forms of matter found in the universe, are composed. The heaviest elements are always radioactive and unstable, decomposing into lower atomic-weight atoms spontaneously.

Let me elaborate on the last paragraph. There are about 100 different atoms occurring in nature. A lot more can be manufactured by scientists using such devices as particle accelerators (atom smashers).

The heavy atoms, those containing a large number of protons, electrons and neutrons, like uranium and radium are unstable. They throw off energy (they are radioactive) and they decompose to eventually form stable non-radioactive atoms.

A material, which is only made from one type of atom, is called an **element**. Water is not an element because it contains two types of atoms, hydrogen and oxygen. Water is therefore a molecule. Copper contains **only** copper atoms, so copper is an element. There are many other common elements.

The simplest and lightest atom (or element) is hydrogen. An atom of hydrogen consists of one electron and one proton, as shown in figure 4. In one respect the hydrogen atom is similar to all others: the electron whirls (orbits) around the proton, or **nucleus**, of the atom, much as planets **rotate** around the sun. Electrons whirling around the nucleus are termed planetary, or orbital, electrons.

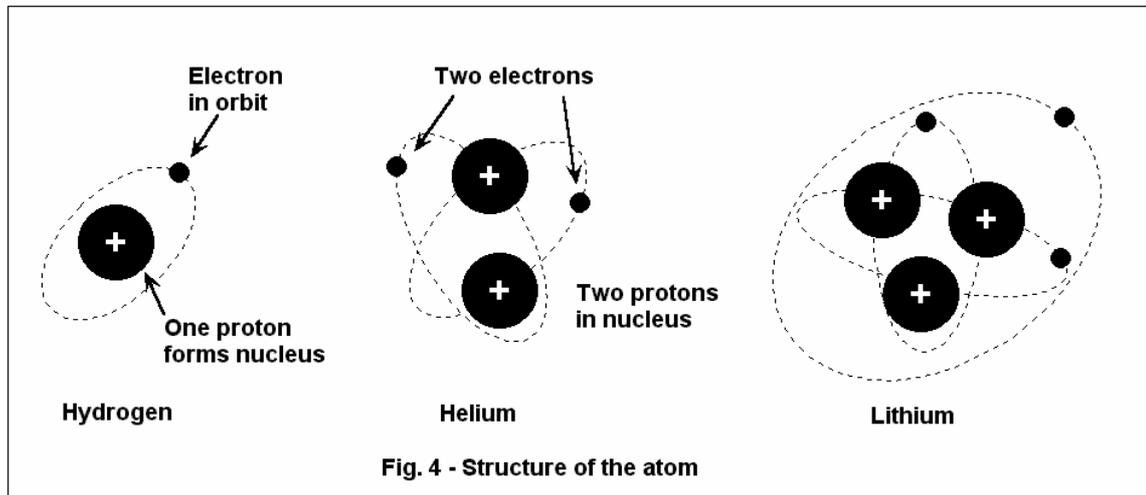
The nucleus is just the name given to the 'centre' of the atom.

The next atom in terms of weight is helium, having two protons and two electrons. The third atom is lithium, with three electrons and three protons, and so on. Some well-known atoms (elements) in order of their atomic numbers are:

1 Hydrogen (H)	28 Nickel (Ni)
2 Helium (He)	29 Copper (Cu)
3. Lithium (Li)	30 Zinc (Zn)
6. Carbon (C)	32 Germanium (Ge)
8. Oxygen (O)	79 Gold (Au)
13 Aluminium (Al)	82 Lead (Pb)
14 Silicon (Si)	88 Radium (Ra)
26 Iron (Fe)	92 Uranium (U)

Most atoms have a nucleus (centre) consisting of all the protons of the atom and also one or more neutrons. The electrons (always equal in number to the number of nuclear protons) are whirling (orbiting) around the nucleus in various **layers**. The first layer of electrons outside the nucleus can accommodate only two electrons. If the atom has three electrons, two will be in the first layer and the third will be in the next layer. The second layer is completely filled when eight electrons are whirling around in it. The third is filled when it has eighteen electrons.

Some of the electrons in the outer orbit, or shell, of the atoms of many materials such as copper or silver exist in a higher "conduction level" and can be dislodged easily. These electrons travel out into the wide-open spaces between the atoms and molecules and may be termed **free electrons**. Other electrons in the outer orbit will resist dislodgment and are called **bound** or valence electrons. Materials consisting of atoms (or molecules) having many free electrons will allow an easy interchange of their outer-shell electrons, while atoms with only bound electrons will hinder any electron exchange.



Copper for example has one electron in its outer orbit or layer. This lonely little outer electron of the copper atom is very easy to 'steal' from the copper atom and made to move. The outer electron is called a free electron. It is not really free, but loosely bound to the atom and easy to encourage away and made to move, so we call it a free electron.

Copper does not resist strongly the movement of its outer electrons, or in other words, it does not offer much resistance to us if we try to get its outer electrons to move. We will talk about how we get them to move later. A material, which does not have free electrons, is said to have a high resistance. All metals have free electrons.

Most common metals when heated cause greater energy to be developed in their free electrons. The more energy they have, the more the electrons resist orderly movement through the material. The material is said to have an increased resistance to the movement of electrons through it.

THE ELECTROSCOPE

An example of electrons and electric charges acting on one another is demonstrated by the action of an electroscope. An electroscope consists of two very thin gold or aluminium leaves attached to the bottom of a metal rod. To prevent air currents from damaging the delicate metal-foil leaves, the rod and leaves are encased in a glass bottle, the rod projecting from the top through a rubber cork.

To understand the operation of the electroscope, it is necessary to recall these facts:

1. Normally an object has a neutral charge.
2. Like charges repel; unlike charges attract.
3. Electrons are negative.
4. Metals have free electrons.

Normally the metal rod of the electroscope has a neutral charge, and the leaves hang downward parallel to each other, as shown in figure 5. The leaves are shown in two positions in figure 5. The normal position is the inner one showing the leaves hanging vertically down from the rod.

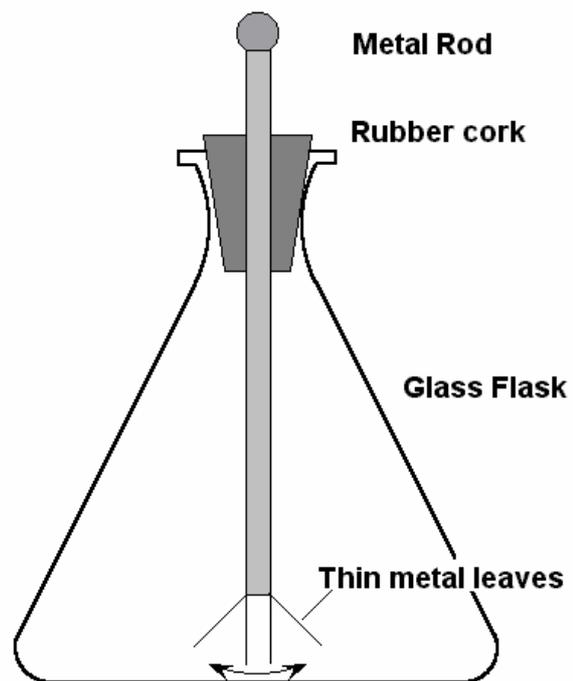


Fig. 5 - The Electroscope

Rubbing a piece of hard rubber with wool causes the wool to **lose electrons** to the rubber, the **excess electrons** on the rubber charging the rubber **negatively**. When such a negatively charged object is brought near the top of the rod, some of the free electrons at the top are repelled and travel down the rod, away from the negatively charged object. Some of these electrons force themselves onto one of the leaves, and some onto the other. Now the two leaves are no longer neutral but **are slightly negative and repel each other**, moving outward from the vertical position as shown. When the charged object is removed, electrons return up the rod to their original areas. The leaves again have a neutral charge and hang down parallel to each other.

Since the charged object **did not touch** the electroscope, it neither placed electrons on the rod nor took electrons from it. When electrons were driven to the bottom, making the leaves negative, these same electrons leaving the top of the rod left the top positive. The overall charge of the rod remained neutral. When the charged object was withdrawn, the positive charge at the top of the rod pulled the displaced electrons up to it. All parts of the rod were then neutral again.

If a positively charged object, such as a glass rod vigorously rubbed with a piece of silk, is brought near the top of the electroscope rod, some of the free electrons in the leaves and rod will be attracted upward toward the positive object. This charges the top of the rod negatively because of the excess of free electrons there. Both leaves are left with a deficiency of free electrons which means they are positively charged. Since both leaves are similarly charged again, they repel each other and move outward a second time.

Note: a deficiency of electrons on an object leaves the object with a positive charge. An excess of electrons gives it a negative charge.

If a negatively charged object is **touched** to the metal rod, a number of excess electrons will be deposited on the rod and will be immediately distributed throughout the electroscope. The leaves spread apart. When the object is taken

away, an excess of electrons remains on the rod and the leaves. **The leaves stay spread apart.** If the negatively charged electroscope is touched to a large body that can accept the excess free electrons, such as a person, a large metal object, or an earth (the ground), the excess electrons will have a path to leave the electroscope and the leaves will collapse as the charge returns to neutral. The electroscope has been discharged.

If a positively charged object is **touched** to the top of the metal rod, the rod will lose electrons to it and the leaves will separate. When the object is taken away, the rod and leaves still lack free electrons, and are therefore positively charged, and the leaves will remain apart. A large neutral body touched to the rod will drain some of its free electrons to the electroscope, discharging it, and the leaves will hang down once more. The electroscope demonstrates the free movement of electrons that can take place through metallic objects or conductors when **electric pressures**, or charges, are exerted on the free electrons.

End of Reading 1.

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The model of the atom shown in this section with electrons circling the nucleus is called the Bohr Model. This model is adequate for the purposes of describing the electrical properties of the atom. The 'quantum model' is more precise in describing all of the characteristics of the atom. There is no need to go into the Quantum model of the atom for exam purposes. You will find a brief description of the Quantum model in the 'supplementary downloads' section of this website. This is **not** required reading.