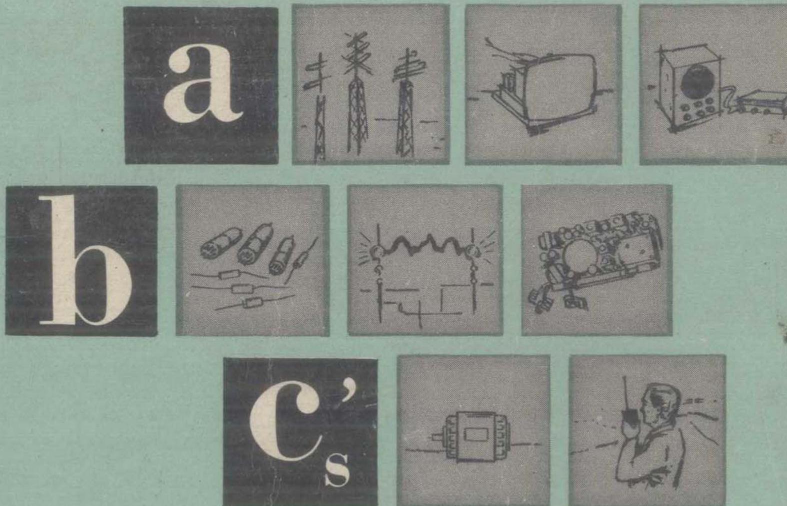

abc's of Electronics

by FARL J. WATERS

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Preface

This book is just what the name implies—a simple, easy-to-follow text devoted entirely to the fundamentals of electronics. Completely avoiding unnecessary complex technical concepts and highly mathematical terms, the subject is presented in simple language, using analogies which are familiar to everyone.

Included in this text are discussions of electron currents and the part they play in electricity, the electric and magnetic forces responsible for causing electron currents to flow, the various forms of opposition encountered by electron flow, and the effects of different components on these electrons. Later chapters cover the much needed basic theory concerning radio waves and how they are produced, and the construction and operating principles of vacuum tubes and transistors, and how these components function in typical circuits. An appendix packed with useful reference data such as electronic standards, formulas, and color codes, is also included and will prove helpful.

Included at the end of each chapter are a number of review questions. The answers to these questions have purposely been omitted to provide you with a means of determining whether or not you have learned the more important electronic principles. If you are unable to answer these questions, or if you are not sure your answers are correct, it will pay you to review the chapter before going on to the next. Upon request, you may obtain an answer sheet from the publisher.

If, after finishing this book, you have an understanding of the basic electronic principles, or for that matter only a desire to learn more about the subject, then this book will have served its purpose.

FARL J. WATERS

To my father, and to the memory of my mother.

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CHAPTER 1

THE ELECTRON

A Very Small Workman

"Which came first, the chicken or the egg?", is the popular question for social debate. It is another "which came first" question that accounts for the fact that there is no definition of *electricity*. While there are a number of reasons why electricity cannot be properly defined, probably the biggest reason is whether or not electricity or electronics is the originating point.

The word electricity began with application of the Greek term *elektron* by Dr. William Gilbert, M.D. (English 1540-1603). From the Greek word elektron, meaning amber, came the term electrics. In 640 B.C., a Greek by the name of Thales, found that static electricity could be produced by briskly rubbing a rod of amber. Later, the American, Benjamin Franklin (1706-1790), proved lightning to be electricity. Both the scientist and the layman considered this unseen thing a fluid.

It was not until the late 1890's that the English scientist, Sir Joseph John Thomson, and others ushered in the Electronic Age by explaining atomic structure. The *electron theory* that evolved from that discovery defined electricity as the movement or the accumulation of electrons. Thus, the common conception of electronics being a part of electricity has been falsely acquired by both layman and scientist. The term electronics is commonly assigned to that portion of the science making use of the electron tube (the radio tube) or the new semi-conductor elements known as *transistors*. The term electric is generally used with regard to the development of power, light, heat and similar applications. However, since electronics is a descriptive term for all electron behavior and of all the apparatus making use of that electron behavior, it follows that this term would also apply to electricity.

All matter is composed of small units called *molecules*. The molecule is so small that it is difficult to give a comparison for its size except to note that the smallest particle of matter one can imagine may contain many thousands of molecules. In turn the even smaller atom is subdivision of the molecule. The number of atoms, their arrangement and the type or types of atoms which compose the molecule determine its character. The character of the molecules within a material identifies that material. For instance, rubber and paraffin both contain carbon and hydrogen atoms; however, the rubber molecule has many thousands of carbon atoms as compared with the paraffin molecule which has 25 to 30 atoms of carbon. Chloroform molecules have the shape of a three-sided pyramid constructed of five atoms (Fig. 1-1),— one of hydrogen, one of carbon, and three of chlorine. As another example, atoms of copper combine with other atoms of copper into molecules to form the metal which is recognized by its distinctive color as being copper.

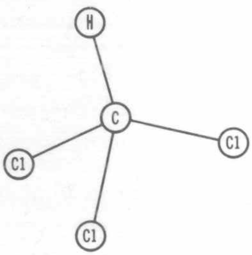
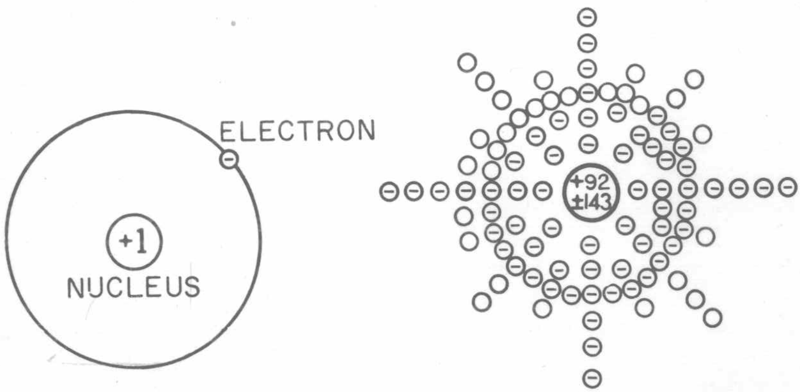


Fig. 1-1. Relationship between the 5 atoms of a chloroform molecule.

Fundamentally all matter is composed from combinations of 92 different atoms or elements. In addition to these 92 elements, atomic research has produced a number of elements that revert with time to the original element of uranium and therefore cannot be considered basic elements. As might be expected, each element has atoms of differing character. Within the atom is a nucleus made up primarily of *protons* and *neutrons* surrounded by electrons revolving in a number of orbits. Fig. 1-2 shows the complexity of the uranium atom as compared with that of a hydrogen atom. The latter has only one proton circled by one electron while the uranium atom has 92 protons, 143 neutrons, and 92 electrons.

Within the nucleus of the atom the neutrons and protons are bound together by the most powerful force known. Even though this nuclear force binding the protons and neutrons together is now being used for many purposes, including the powering of U.S. Navy submarines, very little is known of its true nature. It is said that these nuclear forces are a million times stronger than those holding the oxygen atoms and the hydrogen atoms together within a molecule of water.



(A) Hydrogen atom. (B) Uranium atom.

Fig. 1-2. Comparison between atoms.

Extending the experiments of Thales the Greek, Benjamin Franklin found that rubbing a glass rod produced a form of electricity differing from that produced by rubbing a rubber rod. It was also noted that when a charge developed on the glass rod was transferred to two light weight pith balls, it caused them to repel each other. However, the two pith balls were attracted when one was charged from the glass rod and the other from the one made of hard rubber. Since the two forms of electricity appeared to be opposite, Franklin labelled one as positive and the other as negative. Actually the assignment of positive or negative to either of the two forms of electricity was a matter of choice. At that particular time Franklin may have supposed the positive electricity nearest his goal.

Later it was discovered that negative electricity is associated with an excess of electrons and the definition of a negatively charged particle was assigned to the electron. Conversely, positive electricity is then a deficiency of electrons or an excess of positively charged protons. Within the normal atom, the number of electrons is equal to the number of protons, hence a neutral charge condition exists. Since the protons are so tightly bound within the nucleus, only the electrons are free to create the excess or deficient condition referred to as electricity. Thus, in the study of electronics we are interested in the activity of the electrons.

Normally the movement of electrons is in the form of orbits around the nucleus of the atom. Within the hydrogen atom, one electron moves about the nucleus in a single orbit or shell. But seven orbits are required for the 92 electrons in the uranium atom. Since each orbit must be spaced away from the adjacent orbit, the force exerted by the protons to hold the electron within an orbit varies with each orbit. Consequently, those electrons beyond the second orbit are more or less free to move from one orbit to another orbit or from atom to atom. Accordingly, the copper atom has 19 free electrons that can move from an original orbit to another orbit or from the original atom to another.

Theory states that a small amount of this electron movement occurs continually in all matter. But if this movement can be concentrated so that 6,280,000,000,000,000,000 electrons pass a given point in one second, it can produce enough heat to raise the temperature of 0.00093 pound of water by 1°F. At first this might seem to be an enormous number of moving electrons required to accomplish such a small feat. However, within a one inch length of No. 14 B & S copper wire there are approximately 70,000,000,000,000,000,000,000 free electrons (about 12,000 times the number of electrons considered above). Heat created by movement of electrons is the result of the friction between those electrons as they jostle about from one atom to the next.

An electron is somewhat analogous to a drop of water. Alone, neither the drop of water nor the electron can exert much force. But in years past many drops of water turned the giant mill wheel and today the same milling operation is performed by the proper channeling of many millions of electrons. In the same sense that the water of the stream has to be brought to bear its force on the mill wheel, the flow of electrons must follow the windings of the motor before the wheat can be ground into flour.

Thus, by knowing that either the drop of water or the electron will seek its neutral level through the path of least resistance, man can make both work for him. It is easy to see how a drop of water makes its way through the soil, ditches, streams, and rivers to the sea—its point of neutral level. But it is a different world—a world of smallness, extreme complexity and to some extent abstraction—through which the electron may travel to enter the neutral level of an atom. Of course, the atom is only neutral when its number of electrons equals that of its protons. Any unbalance (electric charge) is neutralized only when free electrons seeking to produce this neutral condition unite with that atom lacking its normal number of electrons.

REVIEW QUESTIONS

1. Who was Thales and what did he discover?
2. What is the Greek word meaning amber?

3. What is the movement or the accumulation of electrons?
4. Name the small units of which all matter is composed and its smaller subdivision?
5. How do differing atoms exist in natural form?
6. What kind of atoms are found in copper? In rubber? In chloroform?
7. Name the three particles found within the atom.
8. What happens to the pith balls when charged with like charges? When charged with unlike charges?
9. Is the electron a positively or negatively charged particle?
10. What are free electrons?

CHAPTER 2

ELECTRICITY and MAGNETISM

Partners in Electronics

It is an old vaudeville gag that the cow does not give her milk, you have to take it from her. In the same sense, the atom does not give up its electrons, but force must be used to take the electron from its neutral position within the atom.

STATIC ELECTRICITY

Static electricity (electricity at rest) is the storage of positive or negative charges on a body. When a rubber rod is rubbed with a piece of fur, electrons taken from the fur are deposited on the rod. The rubber rod then has a negative charge—a charge that can be transferred to another object by touch. If the object to which the charge is transferred is quite large or not separated from other material by an *insulator,* the excess electrons will become scattered and lose their effectiveness. The insulator referred to is any material having an atomic construction that does not readily allow electron movement. Of the opposite characteristic is the conductor—any material that passes electrons easily. There is neither an absolute insulator nor an absolute conductor.

The electricity produced on the rubber rod is a matter of friction. Electricity produced by friction is commonly a static form used primarily in laboratories for research. In more common occurrences of static electricity, it is a nuisance and often damaging rather than useful. The printing industry uses extreme precaution to reduce the static electricity which accumulates on paper rolling through the printing press. Common manifestations of frictional static electricity are when hair is attracted to a comb, lint to clothing, or when a spark jumps from one person to another.

Lightning is one form of static electricity that cannot be entirely attributed to friction. Usually during warm weather, clouds acquire a static charge that moves from cloud to cloud or from cloud to earth creating the spectacular flash we know as lightning. This visible flash with its accompanying thunder is the result of a great number of electrons forcing their way through the atmosphere, which is normally an insulator and does not allow electrons to flow through it.

DYNAMIC ELECTRICITY

Of greater importance and usefulness than static electricity is that form of electricity which has a continuous source of free electrons that can be drawn off, or discharged, at a chosen rate. This form of electricity is referred to as *dynamic* electricity.

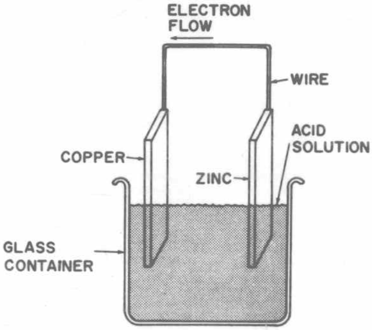


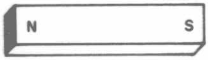
Fig. 2-1. The voltaic cell.

One method of producing dynamic electricity is provided through chemistry. In 1800, the Italian, Count Alessandro Volta placed zinc and copper strips in an acid solution. When the two metal strips were connected by a conductor, as in Fig. 2-1, gas bubbles formed about the copper. Volta also observed that the zinc strip was being eaten away. The sulfuric acid solution he used contained positive hydrogen ions and negative sulfate ions. The *ion* is an atom or group of atoms having gained or lost electrons by combining with another atom or group of atoms. In forming sulfuric acid, two hydrogen atoms give up their two electrons to the sulfate group. The sulfate group thus becomes a negative ion that tends to combine with and lose its excess of electrons to the zinc strip. The electrons freed at the zinc strip then travel through the conductor to the copper strip where they are attracted to the positive hydrogen ion. As the hydrogen ion regains its electron, it is again a free atom of hydrogen which can escape into the air. If Volta had had Edison's electric lamp connected between the copper strip and the zinc strip, the flow of electrons would have lighted the lamp.

This cell of Volta—the Voltaic Cell—was limited in its usage by the fact that the sulfate ions, the hydrogen ions, and the zinc are consumed in the process. However, it was this principle that led to our present dry cell (flashlight battery) and to the lead-acid battery used in our automobiles.

MAGNETIC ENERGY

The English physicist, Michael Faraday (1791-1867) spent most of his life attempting to find a link between magnetism and electricity. As yet, that link has not been firmly established. However, we do have a theory that gives us a means of studying the magnetic induction which causes electron movement. Loadstone or magnetite, a form of iron ore discovered near the city of Magnesia in Asia Minor about 585 B.C., was found to have the ability to attract pieces of iron and some other metals. These



(A) Bar.

(B) Horseshoe.

Fig. 2-2. Permanent magnets.

pieces of loadstone, or magnetite, are now referred to as magnets. Modern magnets are made of steel which has been treated to acquire the properties of a magnet. They are formed into a bar (Fig. 2-2A) or a horseshoe (Fig. 2-2B).

When freely suspended in a horizontal position, the bar magnet will tend to swing until one end points in a northerly direction. It is then convenient to refer to that end, or pole, of the magnet pointing North as the North or N pole. It follows that the other end of the magnet is the South or S pole. Much like the positive and negative charges of electricity, like magnetic poles (N or S) repel each other. Conversely, unlike poles attract each other. Thus it appears that near the geographic North pole there is an area having the characteristics of the S magnetic pole. Because of this a light-weight freely-moving magnet can be used as a compass for guidance along unmarked trails.

To study some characteristics of the magnet, place a bar magnet beneath a glass plate, and sprinkle iron filings on top of the glass. You will notice that the iron filings fall into definite

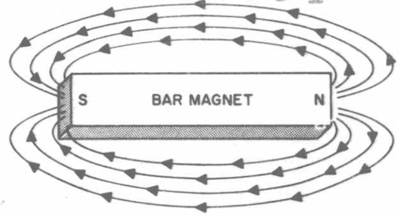


Fig. 2-3. Magnetic lines of force around a permanent magnet.

lines about the magnet. These lines which are referred to as *magnetic lines of force,* extend from one pole to the opposite pole, as seen in Fig. 2-3. The bunching of the iron filings indicates that the energy of the magnet exists in these magnetic lines of force. By pushing a piece of copper wire (which is nonmagnetic) under the glass plate into the magnetic lines of force, it is seen that the iron filings alter their position (Fig. 2-4).

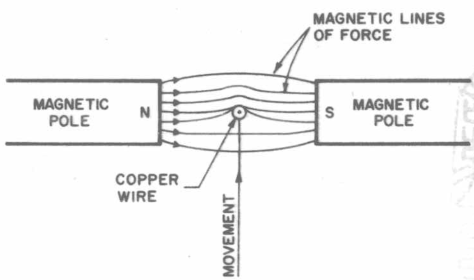
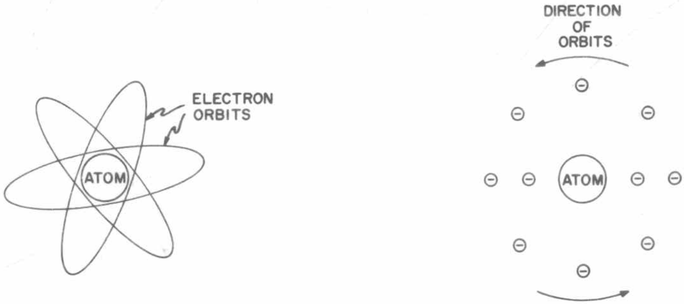


Fig. 2-4. Effect on the magnetic lines of force when a nonmagnetic conductor is passed through a magnetic field.

Much like the rubber band, these lines tend to give against the movement of the copper wire and are therefore elastic. This elasticity is limited, however, and there is a point at which the line will be broken or cut by the nonmagnetic material. After the limit of elasticity has been exceeded and a magnetic line of force cut, this line will reform to its original condition. But as the nonmagnetic material (the copper wire) moves, the lines bunch up ahead of the movement; thus, concentrating more lines of force at the leading side of the copper wire. If the movement stops, the lines of magnetic force will reform to give equal concentration on each side of the nonmagnetic conductor.

The orbits of the electrons around an atom are normally of many planes, as shown in Fig. 2-5A. However, the present theory is that an atom of iron having magnetic properties has electron orbits all lying in one plane. All electrons are moving in the same direction within those orbits (Fig. 2-5B). The magnetic atom is then like the blades of a fan whirling about its hub.



(A) Normal atom. (B) Atom with magnetic properties.

Fig. 2-5. Orbital paths of electrons around atoms.

The forces of repulsion existing between the electrons of adjacent atoms will cause other atoms to align in much the same manner. Across the pole face of a bar magnet, the atoms form a pattern similar to that shown in Fig. 2-6. The movement of electrons along the outer edge of the pole is in one direction, as indicated by the large arrow.

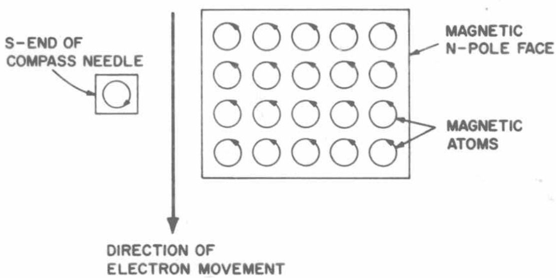


Fig. 2-6. Pattern formed by atoms across the N-pole face of a bar magnet.

A compass needle can be used to verify that the pole face shown in Fig. 2-6 is an N pole face. It would seem normal that an S-pole face would have an electron movement opposite that of the N pole, so that when the compass needle lines up with the large bar magnet the electron movement along adjacent edges would be in the same direction. Using the forefinger of your left hand to point in the direction of the magnetic lines of force, from N to S, note that the thumb indicates the direction of electron movement. Inversely, with the thumb of the left hand pointed in the direction of electron movement, the forefinger indicates the direction of the magnetic force.