YOUR INTRODUCTION TO RADIO'S FIRST PRINCIPLES

Lesson No. ND-1

SPRAYBERRY ACADEMY of RADIO

ESTABLISHED 1932

PUEBLO, COLORADO

This is one of a series of lessons in radio and television for home study, training you to become an

ELECTRONICIAN*

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*Trademark.

Portable field transmitter-receiver in operation. Soldier at right turns crank of a hand generator, used to charge batteries supplying current to the set. Courtesy U. S. Signal Corps.

YOUR INTRODUCTION TO RADIO'S FIRST PRINCIPLES

Lesson No. ND-1

The radio industry of today and tomorrow offers radio men with knowledge and experience almost limitless horizons of opportunity. Both in civilian and military fields the demand for well-trained radio experts of all types is constantly increasing. New discoveries and advances in radio, electronics and television are opening up thousands of good-paying jobs. **The man who, like yourself, has the forethought to realize this fact and prepare himself accordingly will be assured of a bright future.**

Just two things are required to produce a successful radio man—a thorough, competent, well-planned course of training, and the unswerving application of the individual student to that course. Your choice of the former is one you'll never regret, for you have selected one of the finest home study radio courses available today—one which is proved and time-tested. You'll thank yourself many times in the days to come for deciding to let SAR (Sprayberry Academy of Radio) train you for Success in Radio. You'll develop the confidence you need in yourself and the SAR course as you go along from lesson to lesson, so just keep in mind the latter requirement — application — and you can't miss.

Right at the start we shall tell you why our training plan takes the form it does. There is a reason for it, and that reason may be summed up in one word: **experience.** Each part of this course is included because experience through years of turning out successful radio men has taught us that the method we have adopted is the best one.

As mentioned before, the most important obligation **you** have in preparing for a career in radio with the SAR course is to yourself. You must firmly resolve to give this course of training your best efforts, and then keep this promise religiously. Experience with other students has shown that if you do this, you will progress rapidly and be successful sooner than you'd believe possible right now. It goes without saying that the more time you give to the study of a subject, the more you will know about it.

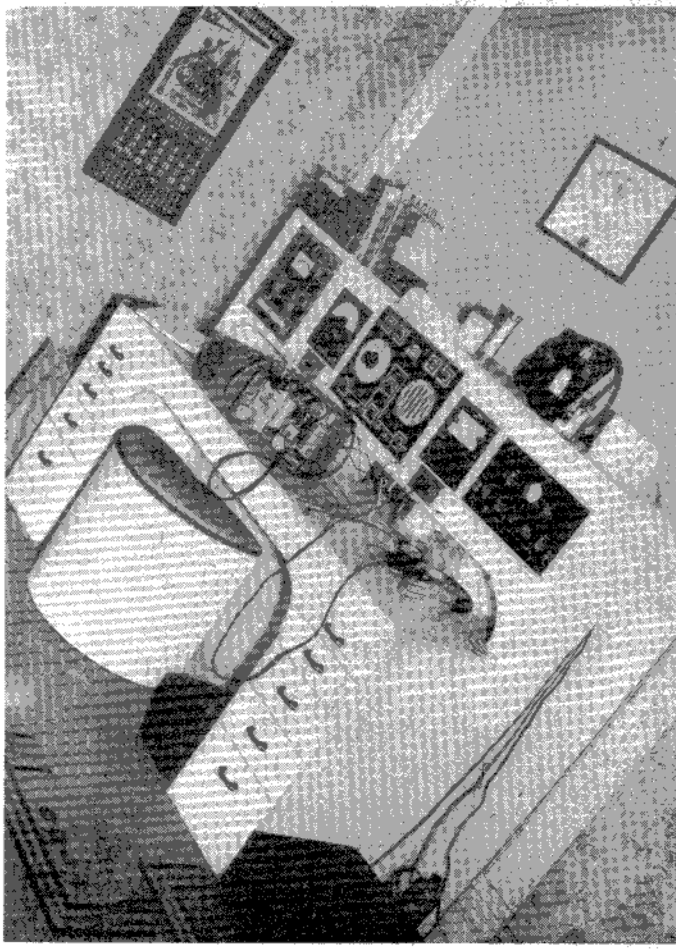
Naturally, you must do most, or all, of your study at home, probably in the evenings or on your day off. Our course is geared to this necessity. You won't be taught by ordinary classroom methods, but rather by a method which we know to be best under your special study conditions. There will be no unnecessary and confusing jumping around from subject to subject, in an attempt to give you a broad outline of radio in general. Don't expect the SAR course to push you right into radio technicalities, without preliminaries. Before a good, substantial house can be built, its foundation must be solidly placed. Then it must be built up, brick by brick, until it is completed. We are going to build up your radio knowledge on the same principle, and it is for this reason that we place emphasis on the time element.

Arrange your spare time **now** so you can give the study of your SAR course the attention it requires. You alone can decide the amount of time you'll devote to it, but here's a hint that may help you measure the study time needed for each lesson: study every lesson until you can answer the questions at the end of the text **without reference to the lesson itself.** Make that your first rule of study. If you comply with this rule faithfully, you'll make steady and lasting progress. If you can answer the questions after studying the lesson through only once, well and good. But if it takes more **studying** and more **thinking,** don't hesitate to put in that extra concentration.

There are several advantages in home study. You can select your study periods to suit your own conveniences. You are not held to the routine of a class of other students. You can go slowly or fast, depending on your ability to assimilate new subjects. You can do review work at your own leisure. Remember, you are a one-man class in this work, so be sure to get your full measure of the opportunities which **home study** offers to the ambitious individual.

Now let's discuss for a few moments the path over which **you're** going to travel in your study of the SAR course. We reiterate the necessity of a good foundation. This doesn't mean that the SAR course is going to be difficult for you to follow. If you heed the study instructions, you'll sail along without any trouble at all. A few students in the past have written that they didn't want to be bothered with **study of basic laws and funda-**

At right is the service bench of a typical Sprayberry student. On this bench, with its complete equipment, the future radio man learns the art of his trade, with the aid of experiments and actual radio construction work. Note Sprayberry Diploma on wall over bench. Possession of this means that the owner has learned Radio from A to Z.

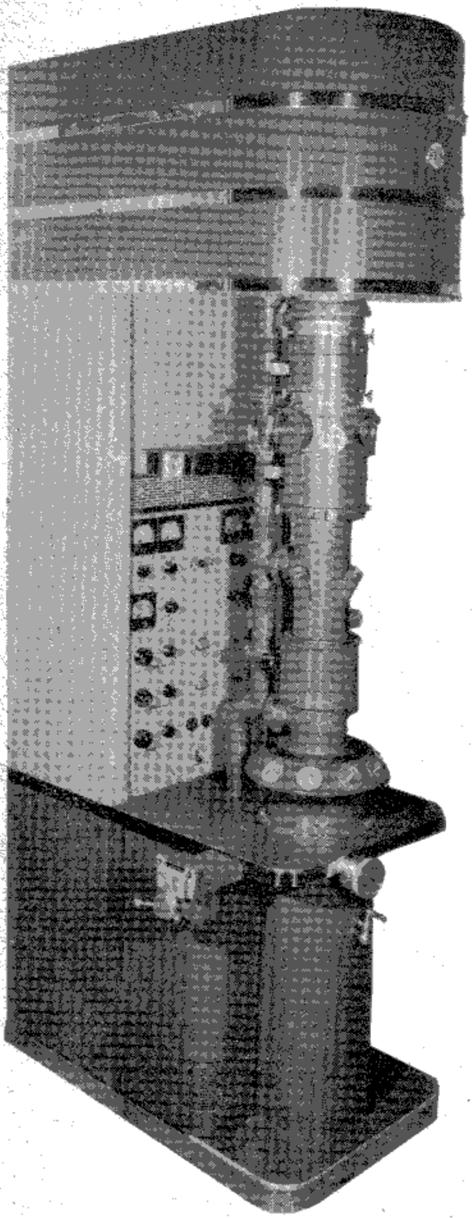


mentals of electricity. Some have said that they just wanted to learn to service and repair radio sets, or do some other specialized job without absorbing any of the basic study.

This would be the same as asking a music teacher to show you how successfully to play a musical instrument without practice, the learning of musical notes, etc. **Of course, the answer is that it just can't be done.** This is mentioned only to impress upon you the importance of each successive lesson and the necessity for its particular position in the whole training program.

No one has yet discovered how to teach a technical subject like radio without going into the basic laws and fundamentals which control it. This is just as true in home study as it is in the classroom. So if at first you seem to be getting into fields which are apparently far removed from radio, remember that such study is absolutely necessary.

We are not going to require you to learn anything that is not essential, but we **are** going to keep our promise to train you thoroughly in radio principles and practice. We know it will result in your being a credit to yourself, to SAR, and perhaps to your country as a properly trained radio man. As you begin to study these fundamental subjects, be patient and bear in mind that this is the groundwork of **tested teaching methods.**



The RCA electron microscope. With this latest wonder of science magnifications of 100,000 diameters can be obtained. This instrument uses electrons instead of light rays, and electrostatic fields in place of glass lenses. Courtesy of R.C.A.

WHY RADIO AND TELEVISION ARE POSSIBLE

As a simple statement of fact it may be said that **electricity** makes radio and television possible. This is the foundation on which all of man's knowledge of radio and television is built. And from this basic concept the possibilities for expansion into new and untried fields are almost limitless. It appears from what is known now that the world of the future is going to be more and more electronically controlled in every phase of our lives. Since this is so certain, you can well afford to take the time to look into the existing store of knowledge on the underlying base of radio and television—**electricity.**

If you were to ask, "What is electricity?" no one could give you a definite answer and be able to prove it beyond doubt. So it is admitted right at the start that it is not known what electricity is made from. From this a start will be made to more definite fields of which we do have concrete knowledge.

WHAT WE KNOW ABOUT ELECTRICITY

Although man cannot see electricity, he really does know a great deal about it. Scientists over a period of many years have discovered much about electricity. In fact, it has been studied so intensively that certain rules or laws have been evolved which, when followed, permit man to make electricity do almost any task. As you progress with your studies, you will learn more and more about these laws and will soon be able to work with and control electricity.

Modern radio and television are based upon a **certain few electrical laws.** It follows then that your study must begin with the fundamental principles of electricity. Perhaps you have previously studied electricity and feel that you need not study more about fundamental electrical laws. You may know a great deal about electricity; nevertheless we urge you to study carefully this and the following lessons, because we want your training to be complete, and we don't want you to overlook a thing which may later keep you from understanding important principles.

Throughout your study of the SAR course you will find that use is often made of an **analogy.** First you should understand the word "analogy." The dictionary states that an analogy is "reasoning in which from certain observed and known relations or resemblances others are inferred." A good example of an analogy is a comparison between the wind and electricity. You know that both exist, yet you have never seen either. You may, however, see the effects of both. For instance, you have seen the **effect** of wind bending a tree while it was blowing. (See Fig. 1.) Also, you have observed an electric fan turn (see Fig. 2) or an electric bulb give off light (see Fig. 3) due to the **effect** of electricity. In neither case have you been able to see the wind or electricity—only their effects.

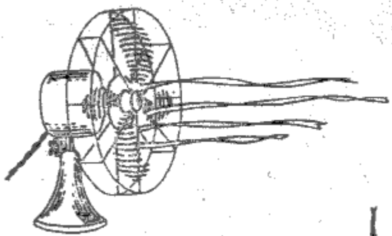


FIG. 2

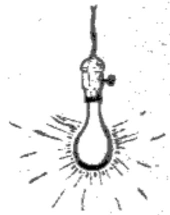


FIG. 3

Two common household accessories which show the effects of electricity are the fan and the light bulb. You cannot see the electricity itself — only its work.

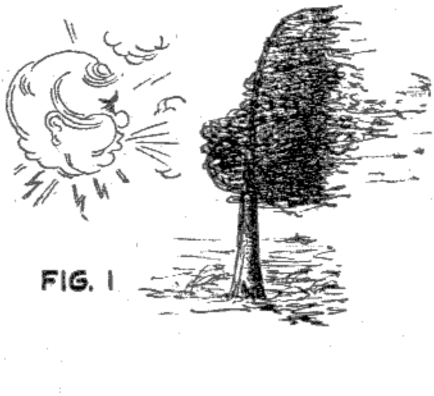


FIG. 1

Here is an example of an analogy of the effects of wind and electricity. As you progress in your study of radio, other analogies will be used to help explain new subjects. In other words, **well known** principles will be compared—those with which you are familiar—with new principles—those with which you may not be so familiar. This will make it easy for you to understand the new subjects as they are introduced.

There are two forms of electricity—**static** and **dynamic.** Static electricity is electricity **not in motion,** for example, not moving along a wire or performing some other useful purpose under force. Dynamic electricity is electricity **that is moving,** for example, along a copper wire circuit, its motion the result of force produced by an electrical generator operated by a gas, steam, or other mechanical engine. Dynamic electricity may also be set in motion by a chemical action taking place within a storage or "dry" battery. In addition, **dynamic** electricity may be set in motion by heat and by certain photo sensitive surfaces, as you will learn later on.

NATURE OF MATTER

Scientists who have spent the greater portion of their working lives investigating the structure of matter tell us that everything in

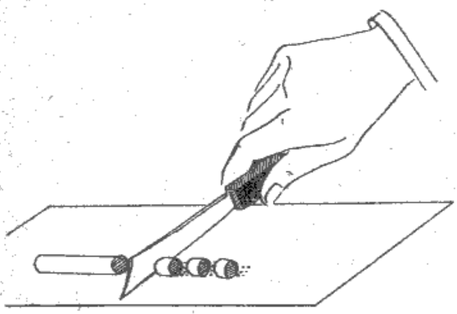


FIG. 4

the entire world consists of **small particles of static electricity.** These small particles have been given the name of **electrons and protons.** The name electron or proton may not mean very much to you at the moment. However, they will be mentioned many times in your study of succeeding lessons, and it is best to get a general idea of them right now. In doing this, it is necessary to mention briefly the fundamental structure of all matter.

In school you probably studied about matter, molecules, atoms, elements, and electrons. These will be correlated and each one explained. This will help you to obtain a clear understanding of **why** the electron is so important in the study of radio.

Matter is the technical name for everything for which there is tangible evidence—everything which has weight and occupies space is called matter.

Molecules in different combinations make up the substance of matter. It follows then that there are as many **different kinds** of molecules as there are substances —an unknown number. You have no doubt read of copper, oxygen, salt, or other types of molecules. Perhaps you did not clearly understand just what this meant. It simply means the smallest particle (division) of a substance which it is possible to obtain and still have the particle **retain** the **original characteristics** of the substance.

Suppose you had a powerful microscope which was strong enough to magnify a very small piece of chalk (about the size of a pin point) to many, many million times its actual size. Assume that this would allow you to observe any physical change in the chalk. Then suppose it was possible for you to start slicing the piece of chalk into small particles with a knife. (See Fig. 4.) As you continued this process, the chalk would be divided into smaller and smaller pieces. There is a limit to the size into which the chalk might be subdivided and **still remain chalk.** The fact is that the smallest particle of chalk you could obtain, would be called a chalk molecule. Any further breaking up of this minute particle of chalk would so change its characteristics that it would no longer be chalk. (The same would be true in principle for any other substance.) Instead, the very small particle would now be called an **atom.** (It is physically impossible to see a molecule even with the most powerful microscope. A microscope was mentioned simply to aid you in understanding how a molecule might be isolated.)

It has been shown how a piece of chalk might be divided and subdivided until one of its divisions would finally result in a chalk molecule. Too, you have learned that any further division of the molecule would result in an atom. Molecules and atoms are so small that it is a physical impossibility to see them, let alone divide them by mechanical means, as with a knife. Such division is possible, however, by electrical or chemical methods. **The most important thing for you to remember is that the molecule is made up of one or more atoms.**

THE ELECTRON THEORY

Perhaps you are wondering just what all of this has to do with radio and electricity. We are coming to that very shortly. A knowledge of molecules and atoms is very necessary before you can follow and understand **the electron theory.** There is nothing difficult about it. Just keep in mind what has been said about the relative size of the molecule and atom.

When a molecule is broken or divided into atoms, the atom becomes a pure particle, representing one of several types of **elements.** For instance, tin, zinc, tungsten, hydrogen, oxygen, sulphur, silver, gold, etc., are examples of elements. It is easy to see, then, that not all atoms are alike. Scientists have discovered about ninety-two of these elements.

A general knowledge of the 92 atomic elements is important to the radio man if for no other reason than the fact that it helps him get a mental grasp of the nature of electricity. The elements are not equally distributed in our universe. It is known that as few as 20 of them make up by weight 99.5% of the earth's crust. The remaining 72 elements represent ½ of 1 per cent of the earth's crust. A table (page 8) lists the 92 elements. The atomic number of each element is given, plus its chemical symbol. The atomic weight of most of the elements is also given. A question mark opposite elements 43, 61, 85 and 87 shows that the weight of these elements is still unknown. Thus there is still much to be discovered about the elements. Man's knowledge of them is still in the elementary stage.

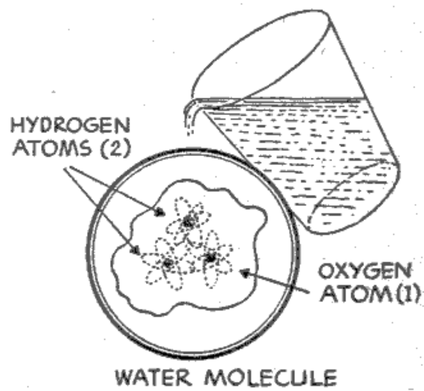


FIG. 5

Now you do not need to make a detail study of the 92 elements. But, you should understand that different combinations of atoms make up different types of molecules, and these in turn make up the different substances of matter.

For instance, consider water. A water molecule consists of two atoms of hydrogen, and one atom of oxygen. A drinking glass of water then consists of many, many millions of billions of water molecules. (Fig.5.)

Another example is common ta-

ATOMIC TABLE OF THE NINETY-TWO CHEMICAL ELEMENTS

At. No.	Element	Symbol	Atomic Weight	At. No.	Element	Symbol	Atomic Weight
1	Hydrogen	H	1.0078	47	Silver	Ag	107.880
2	Helium	He	4.002	48	Cadmium	Cd	112.41
3	Lithium	Li	6.940	49	Indium	In	114.8
4	Beryllium	Be	9.02	50	Tin	Sn	118.70
5	Boron	B	10.82	51	Antimony	Sb	121.76
6	Carbon	C	12.00	52	Tellurium	Te	127.5
7	Nitrogen	N	14.008	53	Iodine	I	126.92
8	Oxygen	O	16.0000	54	Xenon	Xe	131.3
9	Fluorine	F	19.00	55	Cesium	Cs	132.81
10	Neon	Ne	20.183	56	Barium	Ba	137.36
11	Sodium	Na	22.997	57	Lanthanum	La	138.92
12	Magnesium	Mg	24.32	58	Cerium	Ce	140.13
13	Aluminum	Al	26.97	59	Praseodymium	Pr	140.92
14	Silicon	Si	28.06	60	Neodymium	Nd	144.27
15	Phosphorus	P	31.02	61	Illinium	Il	*146.0
16	Sulfur	S	32.06	62	Samarium	Sm	150.43
17	Chlorine	Cl	35.457	63	Europium	Eu	152.0
18	Argon	A	39.944	64	Gadolinium	Gd	157.3
19	Potassium	K	39.10	65	Terbium	Tb	159.2
20	Calcium	Ca	40.08	66	Dysprosium	Dy	162.46
21	Scandium	Sc	45.10	67	Holmium	Ho	163.5
22	Titanium	Ti	47.90	68	Erbium	Er	167.64
23	Vanadium	V	50.95	69	Thulium	Tm	169.4
24	Chromium	Cr	52.01	70	Ytterbium	Yb	173.5
25	Manganese	Mn	54.93	71	Lutecium	Lu	175.0
26	Iron	Fe	55.84	72	Hafnium	Hf	178.6
27	Cobalt	Co	58.94	73	Tantalum	Ta	181.4
28	Nickel	Ni	58.69	74	Tungsten	W	184.0
29	Copper	Cu	63.57	75	Rhenium	Re	186.31
30	Zinc	Zn	65.38	76	Osmium	Os	190.8
31	Gallium	Ga	69.72	77	Iridium	Ir	193.1
32	Germanium	Ge	72.60	78	Platinum	Pt	195.23
33	Arsenic	As	74.93	79	Gold	Au	197.2
34	Selenium	Se	79.2	80	Mercury	Hg	200.61
35	Bromine	Br	79.916	81	Thallium	Tl	204.39
36	Krypton	Kr	83.7	82	Lead	Pb	207.22
37	Rubidium	Rb	85.44	83	Bismuth	Bi	209.00
38	Strontium	Sr	87.63	84	Polonium	Po	210.0
39	Yttrium	Y	88.92	85	Alabamine	Ab	*221.0
40	Zirconium	Zr	91.22	86	Radon	Rn	222.
41	Columbium	Cb	93.3	87	Virginium	Vi	*224.0
42	Molybdenum	Mo	96.0	88	Radium	Ra	225.97
43	Masurium	Ma	?	89	Actinium	Ac	227.0
44	Ruthenium	Ru	101.7	90	Thorium	Th	232.12
45	Rhodium	Rh	102.91	91	Protoactinium	Pa	231.04
46	Palladium	Pd	106.7	92	Uranium	U	238.14

*Estimated

ble salt. A molecule of salt consists of one atom of chlorine gas and one atom of sodium metal. Place many, many million molecules of salt in a container and there results a mass of salt. (Fig. 6.) Another interesting point may be brought out at this time. The only difference between the mass of salt, and its container (whatever substance it may be) is in the **kind, number,** and **arrangements** of the atoms. The same is true of **all** matter. The only reason that an automobile and a potato are not alike is because their atoms are composed of different elements, which are arranged differently.

Years ago when the atom was first discovered, scientists thought that they had at last found the smallest particle of matter, and by further research, these particles were classified into distinct groups, representing the elements, which have already been mentioned. But man is never satisfied. Research during the past few years has enlightened scientists even more. They have discovered more and more about the atom and have learned that it may be divided further. As a result of this research, they have discovered the **electron**—the **very foundation of modern electricity** and **radio.**

So far in your study, you have learned that all matter is made up of different substances; that these substances may be broken down into molecules; that the molecule may be further broken down and isolated into atoms of the essential ninety-two elements (the stuff of which all creation is made), and that the atom may be said to consist of electrons—the smallest particles of matter known to man—minute particles of **electricity.**

You are confronted, then, with the fact (as far as is known), that all of creation — every possible thing that you can think of is in reality made up of these tiny particles of electricity—**electrons.**

Since you now have some idea of an electron, you can begin to study some of the laws which scientists believe govern and control the actions of electrons. Notice that stressed is the word **believe.** This is done because scientists themselves—those in the best position to

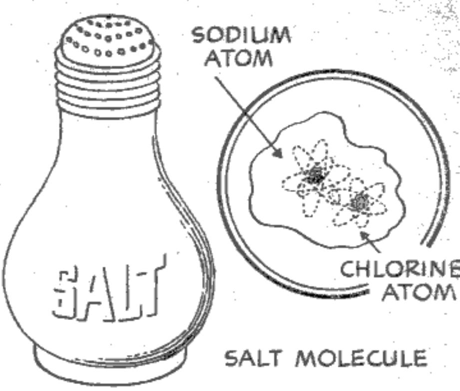


FIG. 6

know—are not absolutely sure about some of the things which they **suppose** to exist. They have a theory — the **electron theory** — which they have every reason to believe is correct. No one has proved they are wrong, nor has anyone given a better and more convincing theory about electricity than the one which you are now studying. (When a **theory** is known to hold true in every instance of its application, it is called a **law.**)

As you study further in this lesson you will have to use your imagination and rely on analogies a great deal. For example, as a part of the electron study, you will consider the **positive nucleus** of the atom. No one knows for sure the exact nature of the positive nucleus. It is not thoroughly understood even by scientists. It is a deep problem—one that closely approaches **life** itself. But don't let it worry or bother you—allow the scientists that privilege. Fortunately, it is not absolutely necessary for you to know what the electron is made of nor is it necessary for you to understand the nature of the positive nucleus. You can easily learn radio without these **unknown quantities.**

All that you should understand

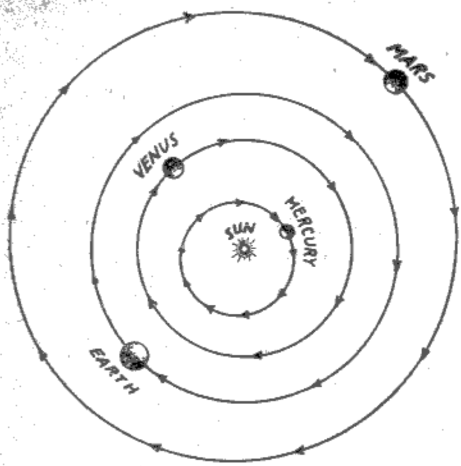


FIG. 7

about this is that the electrons and the positive nucleus are in **actual existence.** Accept that as fact, and concentrate on the study of the laws which govern their actions.

HOW ELECTRONS WORK

You will now begin to study electrons in more detail. Once again resort will be made to an analogy. This time, an example of astronomy (a study of heavenly bodies—the stars, moon, etc.) will be used. This will represent the known action, and it will be compared to the theory of electrons and the positive nucleus of an atom.

It is not necessary for you to have a detailed knowledge of astronomy in order to understand the analogy that will be used. Astronomers have, since ancient Greek times, studied the sun, moon, earth, planets, etc. It follows then that they have had ample time to accumulate evidence to prove the motion of the planets. Therefore, you can accept their explanations **as facts.**

Astronomers tell us that **mercury, venus, earth,** and **mars** rotate about the **sun,** as in Fig. 7. These travel around the sun in the paths or orbits indicated by the four circles. Thus you will see that **mercury** is nearest the **sun** and is indicated by a globe. The other planets are likewise indicated by globes.

From your own observation you know that the earth is in constant motion—you know this from the fact that the sun apparently rises and sets each day. That is, on your side of the earth you know there are a certain number of hours of daylight and a certain number of hours of darkness. When your side of the earth is towards the sun, there is daylight, and as the earth revolves it gradually turns away from the sun, so that it gets dark. This constant, common motion is **therefore proved to you.** Astronomers have, by mathematics and observation, also proved that the other planets revolve about the sun in much the same way. **Thus there is positive evidence of this motion.**

From a study of Fig. 7, it is easy to see that the sun exerts an attracting force towards the other planets—**what it is,** no one knows, but it is known that **this force exists.** There is reason to believe that a **repelling force** exists between the planets themselves. That is, it seems that a force is present that **keeps them apart** and in their respective paths of **travel.**

Study this action for a moment, and you will readily see that this must be a **delicately balanced force.** Whatever it is, it is strong enough, and so balanced, as to prevent the planets from bumping into one another. This force is constant, **and** continues steadily day in and day out.

Astronomers call the planet arrangement just described a **solar system.** Scientists believe that the action which is constantly going on within the structure of an atom, is very similar to the action described for the solar system. For a comparison, let the sun represent the positive nucleus and let the other planets represent the electrons. If this is done, then it is possible to get a concrete picture of the action that is thought takes place in an atom.

The electrons actually revolve about the positive nucleus, and are for the most part in **constant motion.** As already stated, scientists are not sure about the positive nucleus. They do know, however, that it exerts an attractive force which most certainly **does** hold the electrons in and around an atom. For the want of a better name they have called this force a **positive charge** of electricity. The electrons are therefore called **negative charges** of electricity because they are **opposite** in electrical charge with reference to the nucleus.

Electrons have been isolated or separated from their atoms in various ways and at a number of different times. However, no one has succeeded in isolating and studying the positive nucleus. It is known that it exists, just as surely as it is known that the sun exists. What it is made of, no one knows. Those who have given the matter a serious lifetime study, think that the nucleus is made up of a **closely packed** arrangement of positive and negative particles. The positive particles are called **protons** and the negative particles **electrons.**

As near as can be determined from its behavior, a greatly enlarged view of an imaginary atom with its nucleus and electrons would appear somewhat as in Fig. 8.

So far the picture of an atom consists of the center, or nucleus (closely packed protons and electrons), around which other electrons constantly revolve. Those electrons, located in the nucleus and directly associated with the protons, are called **fixed electrons,** and so far as is known have never been removed from the nucleus. The electrons which **revolve about** the nucleus are called outer or **free electrons,** because, as will be shown later, **is is possible to make them jump from one atom to another.**

THE BUILDING BLOCKS OF ELECTRICITY

From what you have studied so far, it is easy to see that a force

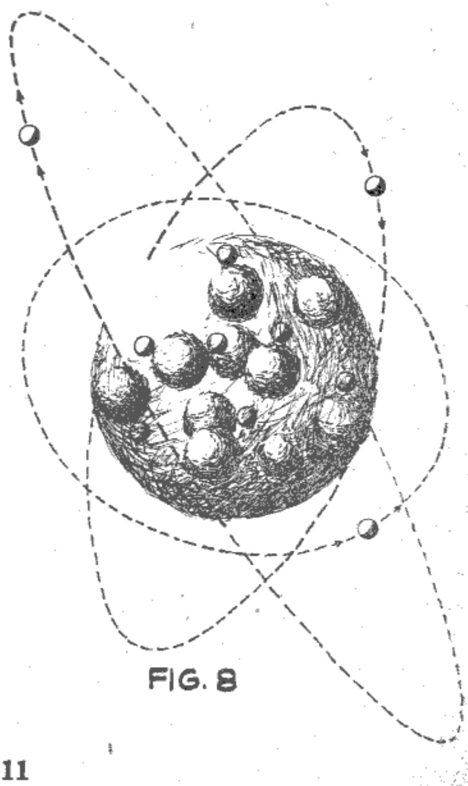
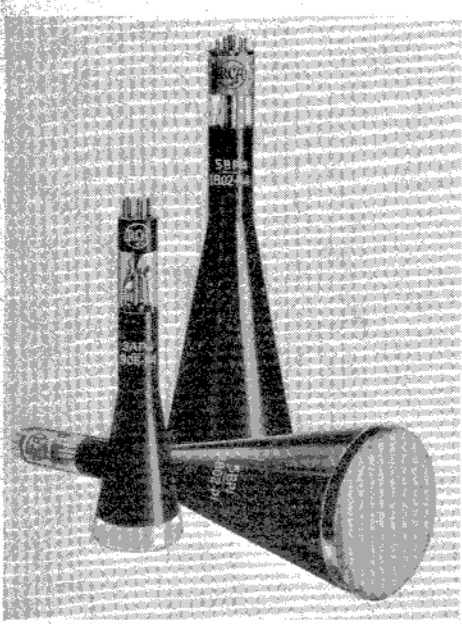


FIG. 8



Besides radio, the wonders of television are made possible by man's harnessing of the electron. Above are three types of cathode ray tubes, used in television. Courtesy of R.C.A.

exists between the nucleus and the free electrons. Just what this force is, no one knows—but it is called **energy or electricity.** Whatever it is, there is a strong **attraction** between the two. But, by studying this force, scientists have also learned that electrons **repel one another.** They have also learned that protons **repel one another.** From this, two most important electrical laws are obtained.

(1) **Like charges of electricity repel each other.**

(2) **Unlike charges of electricity attract each other.**

Be sure to remember these laws. As progress is made in your study it will be necessary to keep this in mind in order to understand some of the actions which will be described in other lessons.

You will remember it was stated that the electrons of the atom were in constant motion. This relates to electrons moving around within their own particular orbits in and about the atom. **This motion should not be confused with the action of** electrons moving from atom to atom. Where this happens there is a dynamic flow of electricity under force, as from a generator. What is particularly referred to here is the motion of electrons in and around the atom much as the planets revolve around the sun. This represents the **normal condition** of the atom when it is not under the stress of some external force. In other words, this condition represents **static electricity.**

Keeping this in mind, you will now study another important point. You have seen how the electrons revolve about the nucleus. The fact that they constantly revolve, indicates that there is **space** between them—just as there is space between the sun and the planets. But in the case of atoms, you have to **reduce in size** your concept of this space. It is difficult, for example, to think of a piece of metal as being made up of groups of atoms with empty space (ether) between the electrons and protons which compose the atoms, when to human eyesight the metal appears to be absolutely solid. That is a physical concept which seems to be almost beyond human imagination. Yet when you realize the very tiny smallness of atoms, electrons, protons, etc., you can begin to appreciate the probability of this theory being true. It follows, then, that you have to try to think of these things in purely imaginary terms, because what actually takes place is far beyond the limit of human eyesight.

It is necessary, therefore, to assume that space of some kind or other does actually exist between the electrons and protons which make up the mass of the atom. To this imaginary space scientists have given the name of **ether** (from the Greek, meaning space between the heavenly bodies). This space is not thought of as the air or as the atmosphere, because these, too, are known to be made up of gas molecules and atoms. Ether is that space, or something equivalent to space, that is present between the free electrons and the nucleus of the atom. Ether is thought of as being present in all matter and is believed to be absolutely continuous and without end. Scientists believe that the ether is the medium through which radio waves travel—something which you will study in another lesson of the SAR course. Just because the ether is something intangible, don't let a lack of complete understanding of it worry you. All that you should remember about it is the fact that ether is supposed to provide the medium through which electrons travel. You don't have to know the secrets of the ether in order to understand radio or television actions.

ELECTRICAL BALANCE IN THE ATOM

In a normally charged atom, the amount of negative charge of the electrons just equals the amount of positive charge of the protons. **Hence the atom does not show external evidence of being dynamically charged with electricity.** Rather, this is an example of static electricity mentioned earlier in this lesson. This action is better understood if you consider two pressures exerting their force against each other, as in Fig. 9.

To get a mental picture of this, note that in Fig. 9 there are two **screw type** jacks located between **two immovable blocks of concrete.** A coil spring is placed between each jack and its corresponding block of concrete—this allows the jacks to give in case of **unbalanced** pressure. The two jacks are pushing against a wood block. An arrowhead is used as a reference point. The jacks are adjusted to give five pounds of pressure. It is easy to see that if both jacks exert a pressure of five pounds, the wood block will remain at the center, or reference point. In other words, if the

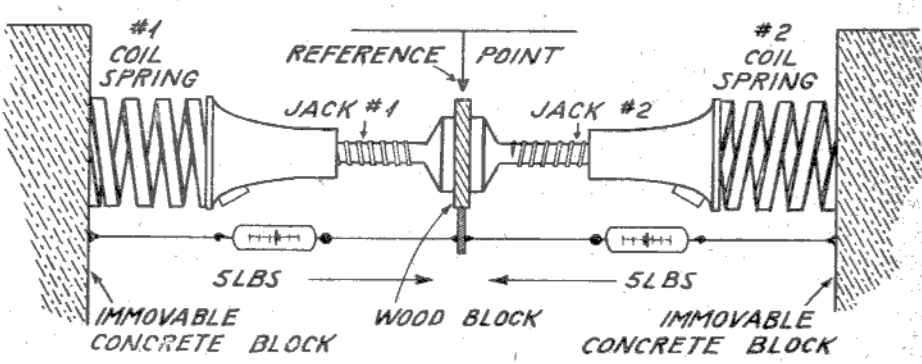


FIG. 9

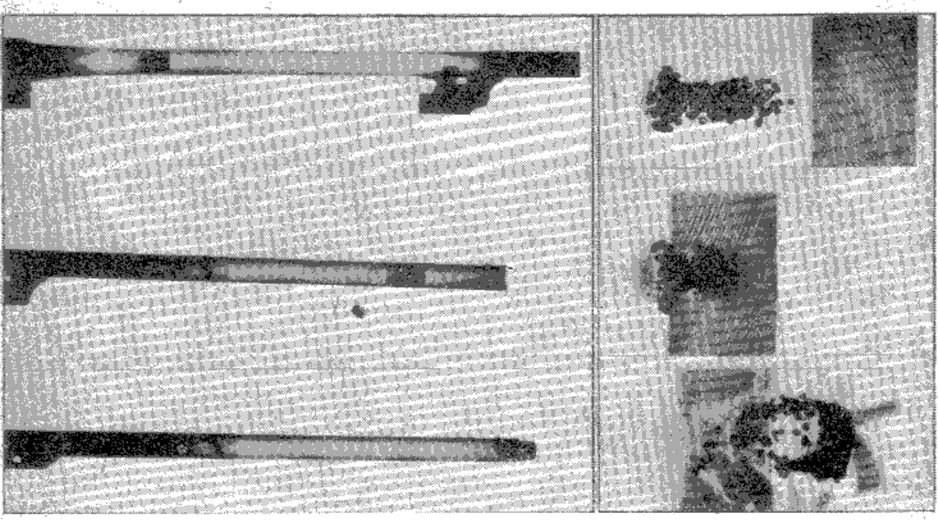


FIG. 10: Another miracle of the electron is dramatically demonstrated by these photos, made with the aid of an electron (X-ray) tube, of a charge traveling through the barrel of a shotgun (left), and penetrating a thick wooden plank (right).

effect is the same as if **no pressure were present.** The pressures are balanced, or neutralized. But, what would happen if the pressure of jack No. 1 is increased to six pounds? Naturally the pressure of jack No. 1 would overcome that of No. 2 and the wood block would be forced to move to the right, to a distance corresponding to one pound of pressure—the difference between five and six pounds of pressure. Similarly other amounts of **unequal** pressure of the jacks would cause a movement of the wood block **indicating an unbalanced condition.**

The foregoing is a mechanical illustration of balanced and unbalanced conditions by means of changing pressures. This is roughly analogous to the electrical changes which it is believed take place in an atom. Normally, the negative pressure is equal to the positive pressure—and as a result, the positive and negative charges are neutralized, just as the mechanical pressures are equalized in Fig. 9.

In electrical terms, **electrical pressure or voltage** is sometimes called **electromotive force,** and is abbreviated **emf.** You see, therefore, that within an atom, **electrical energy is present**—but there is no external evidence to indicate the presence of dynamic electricity unless the charges within the atom become **unequal. Remember this, because it is important.**

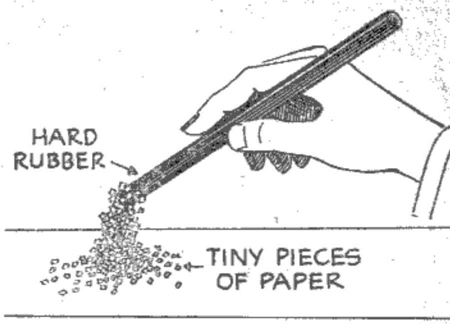
You now have the picture of an atom, consisting of negative and positive particles of electricity, which are neutralized. Therefore, the atom, under normal conditions, retains its own negative free electrons due to the attractive force between the negative electrons and the positive nucleus.

You should also understand that the electrons are **moving** around the nucleus, due to the natural energy of the atom, just as the planets revolve about the sun (Fig. 7). In other words, in an atom nature has provided a wonderful source of energy, which, if directed and controlled properly, can be made to do **work.**

The energy within an atom (static electricity) is self-contained, as you can easily understand when you consider the neutralized forces which are present. Man's problem, then, is to **liberate this force**—which is exactly what is done when a **flow of electric current** is present in a circuit (dynamic electricity). Before you learn exactly how this is done, you must devote a little more study to the atom. You must first learn how the free electrons are liberated from the atom, causing an **unbalance**—and therefore a movement from atom to atom. This corresponds roughly to the movement obtained when the forces of the two jacks were unbalanced as in Fig. 9.

STATIC ELECTRICITY

An experiment will now be described which satisfactorily proves the electron theory. (You are not required to conduct this experiment, but it is suggested that you do so for the satisfaction of demonstrating the evident truth of the theory.) To carry out this experiment, tear a small piece of paper into very fine bits (the smaller the better) and arrange these bits of paper into a closely packed group, on a table in front of you. Next rub a piece of hard rubber (such as a comb or the end of a fountain pen) vigorously against your coat sleeve or trouser-leg. Quickly place the piece of hard rubber among the bits of torn paper



SHOWING HOW BITS OF PAPER ARE ATTRACTED TO HARD RUBBER

FIG. 11

and withdraw it. What has happened? You will find that the bits of paper are sticking to the end of the hard rubber. (See Fig. 11.) Repeat this experiment again, but this time **do not touch the rubber to the paper.** Instead, gradually bring the end of the hard rubber near the bits of paper. If this is done, you will find that at a certain distance the bits of paper will jump up and attach themselves to the rubber. Hence an electrical **field of force** makes its presence known. What does this indicate to you? First of all, it indicates that there is a **very strong attraction** between the rubber and paper. It will now be determined why this attraction was developed—it **did not exist** in the normal condition of either the paper or the rubber.

Before the hard rubber was rubbed against the wool, both were electrically in **balance**—that is, the **negative** charge in each just balanced the **positive** charge in each. However, the rubbing action by **friction** causes some of the free electrons of the atoms of the wool to be dislodged and become temporarily attached to the hard rubber. Since the hard rubber has acquired extra electrons, the **elec-**

trical balance of it has been upset. As a consequence, the hard rubber has been placed in a state which causes it to repel electrons. It is now in a negatively charged condition, because it has an excess of electrons.

It is easy to see, therefore, that **theoretically** when two **unlike** substances are rubbed together, **two** distinct types of electrical charges develop—a **positive** charge and a **negative** charge. In the case under consideration, the cloth on which you rub the hard rubber becomes positively charged and the hard rubber becomes negatively charged. It should be understood that it is **impossible** to **produce** a charge of one kind without **producing another charge of the opposite kind.** The hard rubber, being negatively charged, picks up the paper because the **excess** electrons on the rubber attract the positively charged nuclei (plural for nucleus) of the paper. Since the rubber has an **excess** of electrons it forces the free electrons in the paper atoms to move to the opposite side of the nuclei. Since the hard rubber does not move physically, the paper must move to the hard rubber.

If you make this test, you will notice that when the pieces of paper have clung to the rubber for just a few seconds, some of them almost jump away (they are repelled due to the law of like charges repelling one another) from the rubber while others cling to it for a time and then drop off. All of this simply means that the electrical balance has been restored. The free electrons of the paper and hard rubber gradually assume their normal static positions.

You perhaps wonder about the positively charged cloth. When it was last mentioned, it was said that it had assumed a positive charge, which means that its electrical balance was also upset. You will remember, too, that the electrical unbalance of the hard rubber was restored by causing it to come in contact with the bits of paper. How is the unbalance of the cloth restored?

This is explained by the theory that electrons are present **everywhere** and in **everything.** There are a certain number of free electrons revolving or moving around atoms in all matter. When an **unbalance** is created, there is simply a **readjustment** of the surrounding electrons, tending to restore the balance immediately after the force moving the electrons is removed.

All of this leads to the rather startling fact that the number of electrons in the entire universe is constant and absolutely unvarying. This means that electrons can be neither **destroyed** nor **created.** Or, stated another way, electricity can be neither destroyed nor created. It is a fact, however, that electrons (electricity) can be set in motion by various means, as you will find out a little later. It is this **movement of free electrons** which constitutes a flow of electricity. All you need to do to get this flow of electricity is to produce a force which will move the free electrons which are present in varying degrees in all matter.

In the cloth-hard-rubber-paper experiment, the force was **friction** caused by the vigorous **movement** of the hand rubbing the hard rubber against the cloth. This is just a crude way of causing a movement of free electrons—there are other more convenient methods which will permit a flow of dynamic electricity, as you will soon learn.

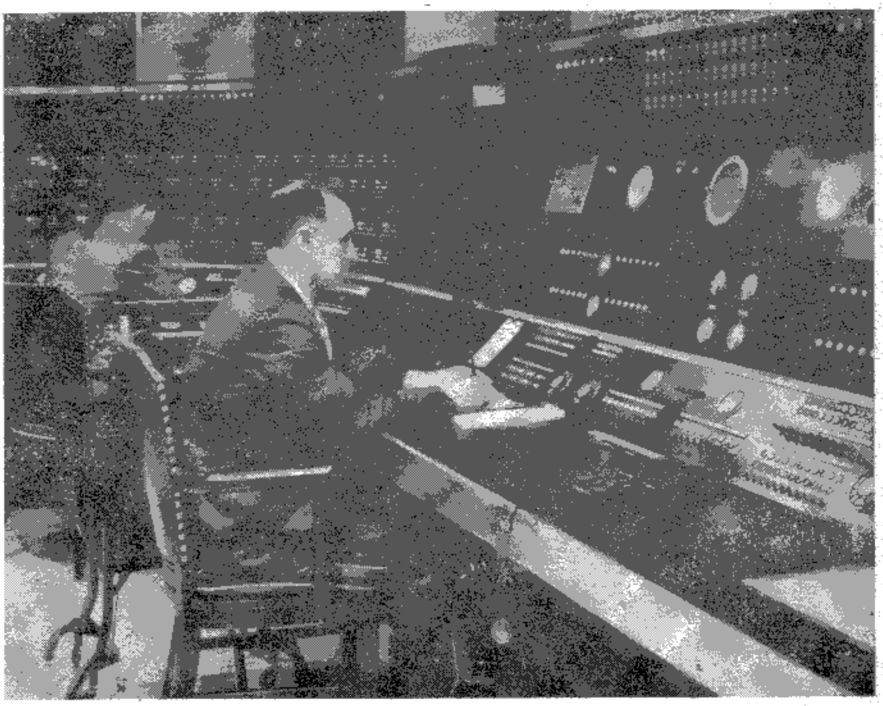
SUMMING UP THE EXPERIMENT

The foregoing description may appear to you as a rather complex set of circumstances, but as a practical radio man you do not need to go into it too deeply.

There are only a few principles that you need to remember about this fundamental concept of electricity. The most important thing for you to remember is that the atom has an inherent electrical characteristic. Furthermore, each electron making up the atom has an inherent electrical charge (negative) which is inseparable from it and in comparison to the size of the electron is extremely large. Likewise, the protons making up the nucleus of the atom have their corresponding electrical charge which is called positive.

Each atom when in an electrically balanced condition, which by the way is its normal state, is surrounded by a space or zone of influence which is called an electric field. Since it is associated with electrons at rest, this charged field is often called an **electrostatic** field or **static** field because static means at rest or not in motion.

The static field is charged with energy or force extending out from the electron in all directions and is



Greatly expanded peacetime radio, electronics and television industries will provide many fine opportunities for the radio man who trains himself now. Above is the master control panel of the National Broadcasting Company headquarters in New York. Through this exchange the various studios are connected with nationwide networks. The panel has 3,700 lamps and keys. Courtesy of NBC.

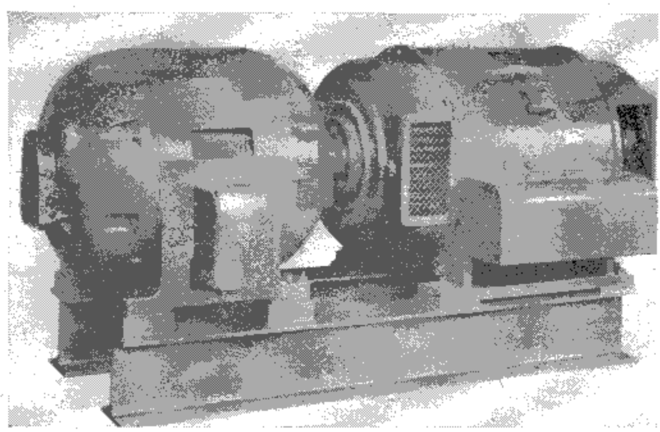
capable of exerting force and pressure on another field at a considerable distance away. There is no definite proof of just why this field is able to exert force at a distance through empty space. Regardless of that, there is definite proof of its existence, and that is the important part for the practical radio man.

DYNAMIC ELECTRICITY

When the atom and its electrons are in an electrical unbalanced state, conditions suitable for the flow of dynamic electricity are present. As already explained, electricity or current will flow through a circuit when the electrons start to move from atom to atom. Hence there is a flow of free electrons along a suitable circuit. When these free electrons flow from atom to atom along a circuit, another and totally different field of force (which can act at a distance through space) is brought into being. This is called the **magnetic field** and is the most useful of the two fields of force already mentioned. The magnetic field will be taken up in detail in another lesson later on in your studies. It is sufficient just at present to remember that when free electrons jump or flow from atom to atom that a current of dynamic electricity flows.

It has already been stated that electricity cannot be destroyed or created. It is true, of course, that you often hear or read of electricity being **generated** by a generator or dynamo. Also, you know that it is a common thing to say that a person is going to have the storage battery in the auto charged. These terms, while not strictly true, are in common usage and are therefore accepted for convenience and to avoid confusion. What is really meant when these terms are used is that the generator or battery forces the electricity (that is already in existence) to move.

This brings up another important law. In general, dynamic electricity (electrons moving from atom to



Two common sources of electricity (direct current) are the motor generator, shown above, and the battery, in this case a dry cell. Generator sets electricity in motion by mechanical action, while battery, either dry or storage (wet) depends on chemical agents. Courtesy of G. E.

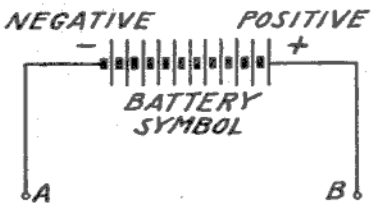


FIG. 12

atom) is caused to come into effect by mechanical or chemical means.

The mechanical method is exemplified by the rubber-paper test, or more practically by the revolving armature of the generator or dynamo.

A movement of free electrons may also be caused by mixing certain chemicals and causing them to act on metals, as in the battery.

Both the mechanical and chemical methods of producing electricity (making free electrons move) are indeed long and complicated subjects, requiring an immense amount of study for proper understanding. You, of course, are not attempting to learn to be an electrical engineer, and it is not necessary for you to spend months of time studying the production and generation of electricity in order to learn radio. Instead, we want to give you the main and most useful fundamentals of radio, so that you may go right ahead with your studies without loss of time. Since you want to learn radio, you want to study the laws of how electricity **acts,** rather than how electricity is made to move.

GENERATORS AND BATTERIES

All you need to know about the production of electricity is the basic fact that a **force** causes electrons to move from atom to atom, and that this constitutes a **flow of electricity.** The forces that move electricity are usually batteries or generators. The electrical symbol for a battery is shown in Fig. 12. Fig. 13 shows the symbol for a D. C. (direct current) generator (later on you will study all of the electrical and radio symbols).

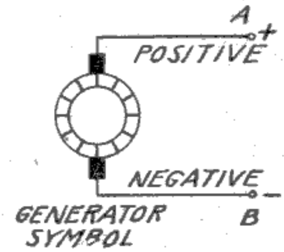


FIG. 13

There is one important thing that you should remember about the flow of electricity—**that is, it must have a complete electrical path,** or circuit. Each battery or generator has at least two terminals between which the electricity will flow. Note A and B of Figs. 12 and 13. That is, you cannot connect one end of a **single wire** to a battery or generator, and expect electricity to flow over the wire. It is absolutely necessary to have a return path back to the generator or battery before the circuit is complete and electricity will flow. Fig. 14 shows how a small light bulb might be connected to a battery to produce light. Note there is a complete continuous path over which the electricity may flow.

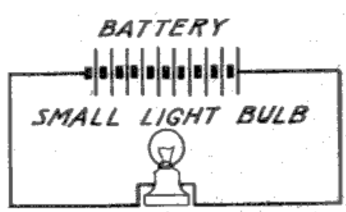


FIG. 14

It has been mentioned that electricity will flow along a copper wire under proper conditions. There is a reason for this. It has been found that electricity flows through some substances better than others. Copper wire is generally used, because it provides an **economical conductor.** Its free electrons move more easily from atom to atom than those of most material; iron, aluminum and zinc are examples of other conductors, less efficient than copper. Fig. 15 shows an enlarged imaginary view of a copper wire with electron current flowing. This particular subject is associated with another electrical term—conductivity—but you will study more about that later. At this time you should understand that a copper wire is usually used to carry or conduct electricity, because it is the best and most economical electron **pipeline** found to date.

You should now understand that you can employ batteries or generators to move electrons, and that at least two wires are necessary in order to provide a path over which the electrons can move from, and back to, the generator or battery.

The generator or battery is usually spoken of as the **source** of electricity. Of course, exactly that is not meant. What is meant is that the generator or battery is the source of the **force which moves the electrons.** However, it is common practice to call the battery or generator the **source** of electricity, and in the remainder of this lesson and in succeeding lessons, we will likewise refer to the battery or generator as being the source of electricity. This will cause no confusion if you will remember the above explanation.

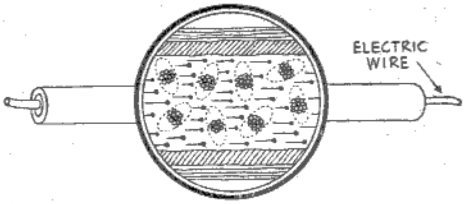


FIG. 15

FLOW OF ELECTRONS

When it is said that electrons move along a wire, it does not mean that they always move along the length of the entire wire all at once—it takes time for them to reach their destination.

To get a better understanding of the way in which electrons travel, consider for a moment the water that flows in iron pipes. You know that in most towns and cities running water is available, in the buildings by means of iron pipes. A large pumping station (operated by machinery) provides the **force** by which the water is forced along through the iron pipes to the buildings.

When the pumping station forces water into the input of the pipes, you don't get the **same water** immediately. Instead, the water at the **input** of the pipes has to force the water **already in the pipes ahead of it.** It is the same with electricity. (See Fig. 16.) When the force at the **source** of electricity pushes against the electrons, it causes an instantaneous movement of electrons **all along the wire.** Thus, while there is a flow of electrons along a wire, those electrons against which the force is exerted, may not actually do the work to be done.

For instance, where electricity is available to provide light, etc., for our homes, the generator itself may be located many miles away from us. Yet the force exerted at the generator causes a movement of electrons in the wires located in our homes, in much the same way that the pumping station causes a movement of water in the iron pipes in our homes (due to pressure). It should be understood that this movement is practically instantaneous, and that the force or effect of electricity travels at the same speed as light, 186,000 miles per second.

Electricity for operating most radio receivers is obtained by simply inserting the plug from the receiver into an electrical outlet, located along the wall of the room. (There are other systems in use, as for instance, batteries for auto receivers, etc. However, this will be taken up in detail in other lessons.) Therefore, the subject of how electricity is produced—how it moves, etc., will be left now and you may simply assume that it is available at the common electrical outlet or socket—objects with which you are familiar.

Your knowledge of electricity has now been built up to the point where you should have a satisfactory explanation of how electricity may be made to move along a circuit. You know that it is a powerful source of energy instantly available at the common electrical outlet. You know too that electricity is dangerous. By reputation you know it can cause serious injury as well as death. So it should be a cardinal principle in your mind to treat it with respect and due caution at all times and never take anything for granted.

Electricity can be just as safe as any other force with which you have to deal if it is properly understood and handled accordingly. So an important part of your radio and electrical education should include at least the rudiments of the practical aspects of handling electrical energy. It is for this reason that the following general principles should always be remembered when working with any electrical device.

CONDUCTORS AND INSULATORS

In this discussion all technical details will be omitted and the dis-

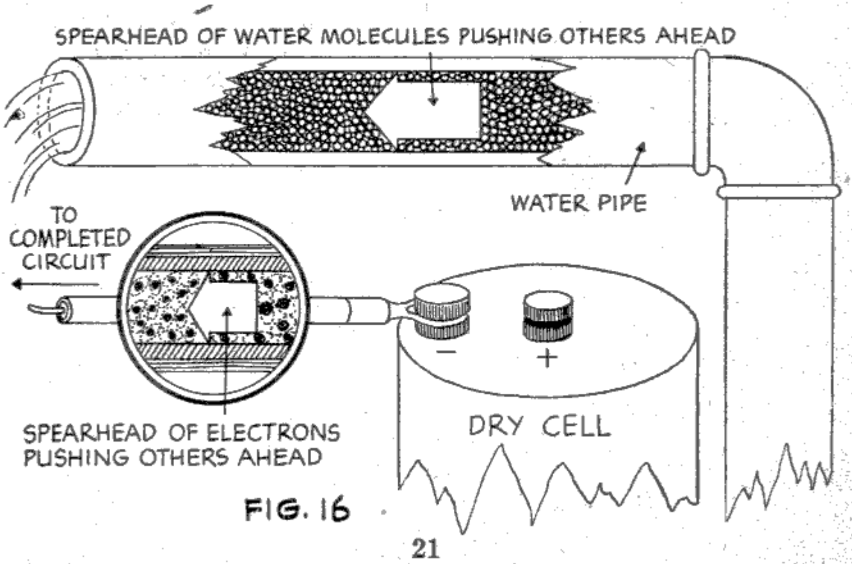


FIG. 16

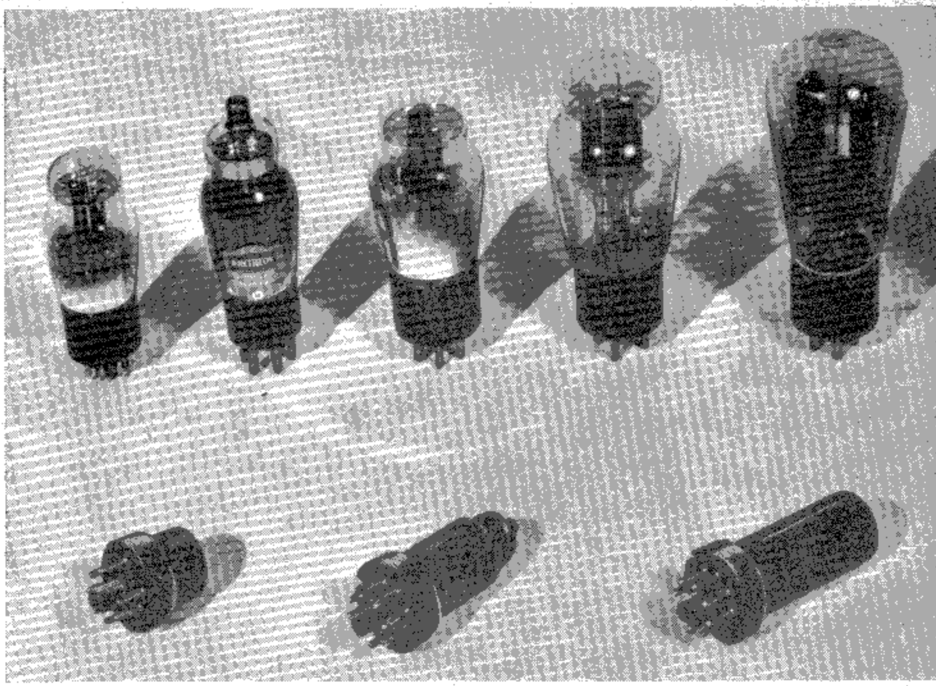
cussion confined to general terms. As you will learn in later lessons, electricity will flow through all materials. In some of these materials it flows with great ease, and in others with great difficulty. This suggests two broad classifications of all materials from an electrical viewpoint. These are conductors and insulators. Those materials through which current flows with relative ease are called conductors. From a practical viewpoint, this broad classification would include the following materials, their order of listing indicating the relative ease with which they permit the flow of current with silver leading the list.

(1) Silver, pure annealed
(2) Copper, annealed
(3) Copper, hand drawn
(4) Chromium
(5) Aluminum
(6) Tungsten
(7) Zinc
(8) Brass
(9) Phosphor Bronze
(10) German Silver
(11) Mercury
(12) Nichrome
(13) Gray Cast Iron
(14) Graphite
(15) Carbon
(16) Telurium

There is no sharp dividing line between insulators and conductors. However, those materials through which current flows with great difficulty are called insulators. This list would include a wide range of materials, but they are usually classified according to their composition. Thus there are **solids,** such as marble, slate, mica, glass, porcelain, paper, wood, etc. Under the plastic group there are the synthetic resins, known under such names as phenolic, vinyl, casein, bakelite, polystyrene, etc. In the liquid group there are oils of various kinds, varnishes, solvents, etc. Then there are various gases, the best known of which is air. So you see there is a wide range of materials which may be used for the **control of electricity.**

In later lessons you are going to learn much more about these things. For instance, you will learn that all materials in some degree obstruct the flow of electricity. This obstruction is called **resistance.** Thus it should be clear that good conductors have little resistance. Conversely conductors have high **conductance** and insulators have low conductance. From this explanation it should be clear that conductance and resistance have opposite meaning. In this connection you should remember that it is not our purpose to give you a complete explanation of all of these things in this first lesson. The details will be taken up in later lessons. All we want to accomplish in this first lesson is simply to give you an idea of electricity in general. In this way you can get a "bird's-eye-view" of what is to come in later lessons. Thus you can see the purpose of your studies—how they will lead you step-by-step to the more advanced subjects.

So far in this lesson you have learned that electrons are caused to move along a copper wire circuit and that this constitutes a flow of current or electricity. The mechanical force of the generator at the power house is changed into electrical force and this electrical force is maintained at our homes, offices and shops all the time. This electrical power is available to us over



Heart of the radio transmitter or receiver is the vacuum tube, within whose walls the electrons perform their task of changing sound to radio waves and back again. Above are different types of tubes used in ordinary radio receivers; glass and metal.

two wires, which is called a branch circuit. We merely connect to these two wires and from them we can obtain a tremendous amount of energy. With it we can cook our meals, preserve our food, heat our homes, wash our clothes, provide entertainment, etc. These are just samples of what can be accomplished by means of electricity.

All of this doesn't happen haphazardly. There are limits to what may be safely done. Since all of your study that is to follow is based on the use of electricity, it follows that before getting very far into this study you should know something about the limitations that govern and control electricity, and in that way you will have a more solid foundation on which to advance.

Consider for instance the two wires over which electricity is available for your use. Very definite limitations are placed upon them. Back of them is the tremendous power of the power house. This is so great and can actually cause such intense electron movement along the wires, resulting in so much heat generation that the copper wires will melt. All electrical conductors have definite current limits which cannot be safely exceeded. That is the reason house wiring is protected by fuses—if an overload occurs the fuses burn out instead of the wires. Manufacturers of electrical devices take this into consideration when designing the apparatus they make. They purposely limit the amount of electrical power which can be drawn from the line. On the other hand, if the two wires of the power line are touched together either accidentally or on purpose it constitutes a short circuit. When this happens either the fuse blows or the wires start to melt. It is for this reason that connection to an electrical power line must be made in a certain definite way. This is usually accomplished automatically by means of screw or prong type plugs. Thus connection to the line is a rather safe procedure even for the layman. Sometimes however, a novice will attempt to make direct connections to an electrical power line and without knowing what he is doing he may cause serious injury to himself, to others or to property. If for some reason you must make direct connection to an electrical power line, don't do it until you have opened the main switch or removed the fuses at the service entrance. For ordinary radio work you will probably never have need to connect directly to an electrical power line. On the other hand, we have known of beginner electrical and radio students trying this with harmful results. So always remember to open switches and remove fuses before making direct connections to any power line. This includes radio sets with exposed wiring. Until you become thoroughly experienced don't even inspect a radio set until its power plug has been removed from the electrical outlet.

TYPICAL HOME CIRCUIT

Every electrical power line is grounded, and in most communities **three feeder wires** are employed. This is called a three-wire system, and is shown symbolically in Fig. 17. The grounded wire of a three-wire system is called **neutral** on simply "ground." In Fig. 17 this would be wire number 2. This wire is permanently connected to the earth as a safety measure—connection usually being made to a metal rod driven several feet into the earth to insure good contact at all times.

Referring to Fig. 17 again, note there are three wires which make connection to the main wires leading back to the generator at the power house. For the usual power line in the United States there will be 115 volts available between wires 1 and 2 with the same value of voltage available between wires 2 and 3. Between wires 1 and 3, 230 volts will be available. Thus as you can see wire 2 really divides the available 230 volts into two circuits of 115 volts each with wire 2 being common to both circuits. For heavy duty work, such as cooking and for many industrial uses connections are usually made to wires 1 and 3 because if the electrical devices are arranged properly this makes for most economical operation.

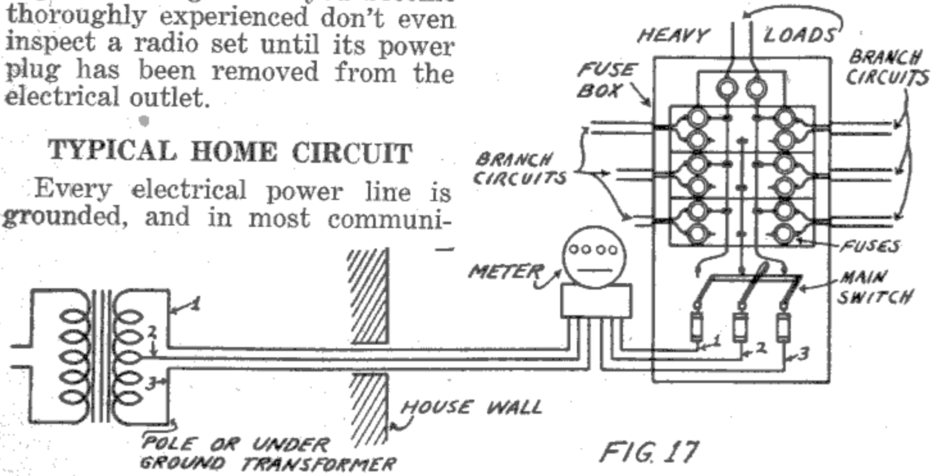


FIG. 17

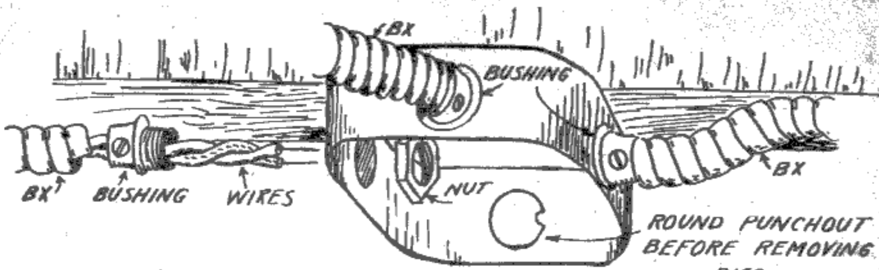


FIG. 18

For ordinary home or office use 115 volt branch circuits are connected to wires 1 and 2 and to wires 2 and 3. This divides the current load of a home or office for a given size of copper wire and again makes for economical operation besides adding the safety feature of having one wire grounded—the latter guarding against lightning and internal overloads—causing the excess current to go to ground where it can do no harm.

Due to the arrangement of the wiring in systems like Fig. 17, any grounded object which is a conductor will form a circuit between wire 1 and between wire 3 and ground. The human body is a good conductor of electricity. Thus if you stand on a damp cement floor or on the ground and touch either wire 1 or 3 it will be the same thing as connecting your body between wires 1 and 2 or between 2 and 3. In either case you will be severely shocked. The same thing would happen if you touched wire 1 or 3 and at the same time touched the metal covering of the wire or the metal box to which it connects. So be safe—never carelessly handle electrical wiring at any time. These precautions are given to you at this time right at the beginning of your training so you will know about these things in advance of any work you might decide to do on an electrical circuit, such as installing extra floor plugs, etc.

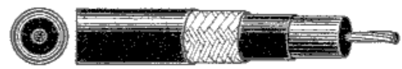
In all modern homes, offices and shops the electrical wiring is either enclosed in metal pipes called conduit or in a flexible metal sheath called BX cable. Regardless of whether conduit or BX cable is employed, it is grounded to the same common grounded point as wire 2 in Fig. 17. Thus the metal covering of the wires throughout the building is grounded. Whenever circuits come together for extension or for connection of outlets a metal box called a "knockout box" is used. Figure 18 shows a typical arrangement. All exposed metal (the BX cable and the box) is grounded and forms a common circuit. One of the two wires in the BX cable is also grounded (neutral) —it would correspond to wire 2 in Fig. 17. The other wire of the BX cable is not grounded and is known as the "hot wire" or "live wire." This would correspond to wire 1 or 3 in Fig. 17, depending on the branch circuit arrangement. Regardless of whether wire 1 or 3 is involved if either one touches any of the exposed metal in Fig. 18 or any other grounded object, a short circuit is caused to exist which means a fuse will blow or the wire will melt until an open circuit is formed which can come about by the wire no longer touching the metal.

In checking over Figs. 17 and 18 you will no doubt immediately see the value of insulation. From what you have already studied in this lesson you know you can not place two bare copper wires in metal conduit or BX cable as in Figs. 17 and 18. If this were done and the wires were connected to those leading back to the power house generator it would instantaneously form a short circuit and the wires would melt, with possible harm to the generator. Thus when conductors are placed close together in confined areas, protection must be provided for the wires in the form of insulation. From this you can see insulators are just as important and necessary as are conductors.

TYPES OF ELECTRIC WIRES

In a common power line circuit the wires must be covered with good durable insulation which will not melt or deteriorate even when under excessive heat and long continued use. Manufacturers of wire have developed excellent insulation for this purpose consisting of layers of rubber, paper, fabric, etc., all impregnated with wax or paraffin. Different combinations of these materials are formed for different types of current requirements.

In radio work all sizes of wire are employed, from about the size of a human hair on up to the size of an ordinary pencil, depending on the current requirements. These are covered and protected with different kinds of insulation for different types of radio apparatus. Since so much of your radio studies and work has to do with wires and insulation of varying sizes, a wire table is included in this lesson for your reference. It is shown on an accompanying page. This table may not mean so much to you now, but as your radio knowledge grows you will gradually appreciate its importance. It is included at this time in order that you may get a general idea of the types of wire in use in different radio and electrical applications.



Transmission wire: This wire has copper shield, cotton wrap, rubber sheath.

Transmission wire: Double wire, cellophane wrap, rubber cover, weatherproof.

Communication system wire: Double type for inside use; color-coded insulation.

Auto radio wire: This is a spark plug wire having tinned copper shielding.

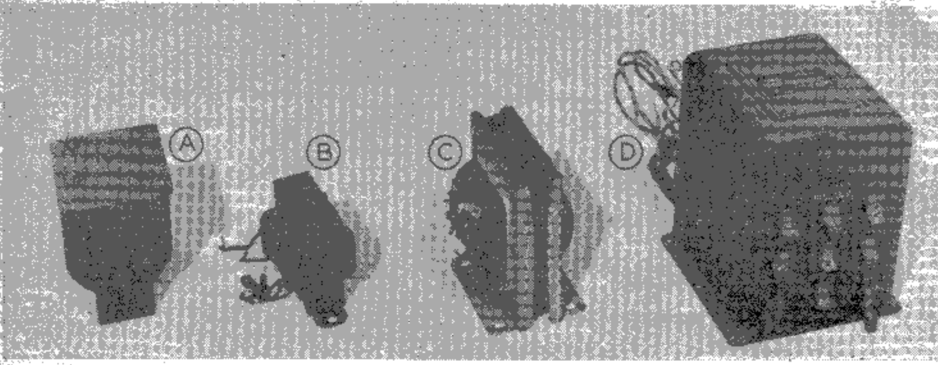
Courtesy of Belden Mfg. Co.

Numerous kinds of wire are used in radio, as designated by chart on opposite page and photo at right. This shows five grades of wire used around transmitters and receivers, plus a strand of all-rubber insulated lead-in wire at bottom. Courtesy of G. E.

COPPER WIRE TABLE

1 Gauge No. B. & S.	2 Diam. in Mils [1]	3 Circular Mil Area	Turns per Linear Inch				Feet per Lb.		10 Ohms per 1,000 ft. 25° C.	11 Current Carrying Capacity at 1500 C.M. per Amp. [2]
			4 Enamel	5 S.S.C.	6 D.S.C. or S.C.C.	7 D.C.C.	8 Bare	9 D. C. C.		
1	289.3	83690	—	—	—	—	3.947	—	.1264	55.7
2	257.6	66370	—	—	—	—	4.977	—	.1593	44.1
3	229.4	52640	—	—	—	—	6.276	—	.2009	35.0
4	204.3	41740	—	—	—	—	7.914	—	.2533	27.7
5	181.9	33100	—	—	—	—	9.980	—	.3195	22.0
6	162.0	26250	—	—	—	—	12.58	—	.4028	17.5
7	144.3	20820	—	—	—	—	15.87	—	.5080	13.8
8	128.5	16510	7.6	—	7.4	7.1	20.01	19.6	.6405	11.0
9	114.4	13090	8.6	—	8.2	7.8	25.23	24.6	.8077	8.7
10	101.9	10380	9.6	—	9.3	8.9	31.82	30.9	1.018	6.9
11	90.74	8234	10.7	—	10.3	9.8	40.12	38.8	1.284	5.5
12	80.81	6530	12.0	—	11.5	10.9	50.59	48.9	1.619	4.4
13	71.96	5178	13.5	—	12.8	12.0	63.80	61.5	2.042	3.5
14	64.08	4107	15.0	—	14.2	13.8	80.44	77.3	2.575	2.7
15	57.07	3257	16.8	—	15.8	14.7	101.4	97.3	3.247	2.2
16	50.82	2583	18.9	18.9	17.9	16.4	127.9	119	4.094	1.7
17	45.26	2048	21.2	21.2	19.9	18.1	161.3	150	5.163	1.3
18	40.30	1624	23.6	23.6	22.0	19.8	203.4	188	6.510	1.1
19	35.89	1288	26.4	26.4	24.4	21.8	256.5	237	8.210	.86
20	31.96	1022	29.4	29.4	27.0	23.8	323.4	298	10.35	.68
21	28.46	810.1	33.1	32.7	29.8	26.0	407.8	370	13.05	.54
22	25.35	642.4	37.0	36.5	34.1	30.0	514.2	461	16.46	.43
23	22.57	509.5	41.3	40.6	37.6	31.6	648.4	584	20.76	.34
24	20.10	404.0	46.3	35.3	41.5	35.6	817.7	745	26.17	.27
25	17.90	320.4	51.7	50.4	45.6	38.6	1031	903	33.00	.21
26	15.94	254.1	58.0	55.6	50.2	41.8	1300	1118	41.62	.17
27	14.20	201.5	64.9	61.5	55.0	45.0	1639	1422	52.48	.13
28	12.64	159.8	72.7	68.6	60.2	48.5	2067	1759	66.17	.11
29	11.26	126.7	81.6	74.8	65.4	51.8	2607	2207	83.44	.084
30	10.03	100.5	90.5	83.3	71.5	55.5	3287	2534	105.2	.067
31	8.928	79.70	101	92.0	77.5	59.2	4145	2768	132.7	.053
32	7.950	63.21	113	101	83.6	62.6	5227	3137	167.3	.042
33	7.080	50.13	127	110	90.3	66.3	6591	4697	211.0	.033
34	6.305	39.75	143	120	97.0	70.0	8310	6168	266.0	.026
35	5.615	31.52	158	132	104	73.5	10480	6737	335.0	.021
36	5.000	25.00	175	143	111	77.0	13210	7877	423.0	.017
37	4.453	19.83	198	154	118	80.3	16660	9309	533.4	.013
38	3.965	15.72	224	166	126	83.6	21010	10666	672.6	.010
39	3.531	12.47	248	181	133	86.6	26500	11907	848.1	.008
40	3.145	9.88	282	194	140	89.7	33410	14222	1069	.006

[1] A mil is 1/1000 (one thousandth) of an inch. [2] The current-carrying capacity at 1000 C. M. per ampere is equal to the circular-mil area (Column 3) divided by 1000.



Transformers and iron core chokes are used in radio sets. A is push-pull input or output transformer. B is an unshielded iron core choke coil. C is unshielded power transformer, used to supply high voltage to rectifier tube and low voltage to tube filaments in the radio set. D is large filament type transformer.

In the first column the size of the wire is given. The letters B and S represent the names Brown and Sharpe—the American standard gauge. Not all wire sizes are included in this table but enough are listed to give you a general idea of the wires used in radio work. Size 14 is generally found in ordinary house wiring, while sizes 18 and 20 are usually used to connect together the different parts of a radio set.

The second column is a measure of the diameter of the wire while the third column gives the circular area. The next four columns give numbers of turns per linear inch which may be wound on a coil form for different types of insulation on the wire. Thus the fourth column refers to the "baked on" enamel type of insulation. The letters S.S.C. for the fifth column refer to the Single Silk Covering, meaning one layer of silk thread for insulation. For the sixth column D.S.C. refers to Double Silk Covering, and S.C.C. refers to Single Cotton Covering. For the seventh column, D.C.C. refers to Double Cotton Covering—all of this of course referring to the type of insulation employed. The word single means one layer of insulation while double means two layers.

Columns eight and nine give the number of feet of wire per pound for the different sizes of wire. Column ten gives the resistance of the wire in ohms per 1000 feet at 25 degrees centigrade temperature. (Resistance and ohms are subjects which you will take up in later lessons.) Column eleven gives the safe current carrying capacity of the various sizes of wire.

If this current rate is greatly exceeded the wire will melt.

This wire table has introduced many new subjects which are not fully described in this lesson. However they will be taken up in detail in later lessons and you will be given complete information on them. The wire table will give you an idea of the interesting and informative studies which are ahead of you.

YOUR NEXT LESSON

In the next lesson you will learn more about electricity and will study some of the common electrical terms, such as **direction of current flow, voltage, current, power, resistance, conductors, etc.** These subjects will be easy for you, if you have studied this lesson thoroughly.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write our your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

Questions

No. 1 What are the two basic raw materials of all matter?

No. 2 Describe how electrons are associated with atoms and molecules.

No. 3 What is the smallest particle into which a substance can be divided without changing its characteristics?

No. 4 Compare the various parts of an atom with their equivalent in a solar system.

No. 5 What makes the electrons ordinarily stay near the nucleus of an atom?

No. 6 What are the laws of attraction and repulsion of electrical charges?

No. 7 What is the difference between a free electron and one intimately associated with the nucleus?

No. 8 Name two common sources of electricity.

No. 9 What is the difference between an insulator and a conductor?

No. 10 What actually makes up electrical current flow?