INTRODUCING YOU TO RADIO

1FR-3

NATIONAL RADIO INSTITUTE
ESTABLISHED 1914
WASHINGTON, D. C.

STUDY SCHEDULE NO. 1

By dividing your study into the steps given below, you can get the most out of this part of your N. R. I. Course in the shortest possible time. Check off each step when you finish it.

☐ 1. **How To Study**......................See "How To Study" FOLDER
This folder will show you how to make every minute count when studying at home, so that you can complete your N. R. I. Course in the shortest possible time. It also contains helpful instructions for answering the test questions. After reading this entire folder carefully once, follow its suggestion and read the stimulating message on the back cover of this first lesson.

☐ 2. **Your Future in Radio**..........................Pages 1-7 of this lesson
Read these pages without making any special effort to study them. Let this first reading give you a general idea of what is in the first section of the lesson.

☐ 3. **Radio Maps Will Guide You**..............................Pages 3-7
Read these sections over again now slowly, one paragraph at a time. When you are confident you understand all important ideas, answer Lesson Questions 1 and 2 on page 29.

☐ 4. **Electricity and Magnetism**................................Pages 7-18
Go through this section the first time just as if it were a fascinating magazine article, without trying to study it. If this first reading makes you realize how important a knowledge of electricity and magnetism is to a radio man, you have accomplished the purpose of this step.

☐ 5. **What Electricity Is**...Pages 7-12
Re-read this section slowly once or perhaps two or three times. When you feel that you have a clear understanding of how electrons give us electricity, answer Lesson Questions 3, 4 and 5.

☐ 6. **Radio Uses for Magnetism**..............................Pages 12-18
Read these sections over again slowly and carefully, re-reading whenever necessary to give you the feeling that you have mastered each new idea. When you feel that you understand these highly practical explanations of magnetism, answer Lesson Question 6.

☐ 7. **Radio Tubes**..Pages 19-26
Read this short but highly important section through the first time without thinking about studying it, just to get a general idea of what a radio tube is like. Next, read the section through slowly, mastering one paragraph at a time. Finally, answer Lesson Questions 7 and 8.

☐ 8. **Transformers**... Pages 26-28
Read this interesting section in an ordinary way the first time, just to get a general idea of what iron-core transformers are like. Next, start over again, and read slowly and carefully so as to master this subject. Now answer Lesson Questions 9 and 10.

☐ 9. **Mail Your Answers for Lesson 1FR-3 to N. R. I. for Grading.**

☐ 10. **Practical Job Sheet No. 1**..........................Separate Job Sheet
Read this job sheet carefully, then keep it for future reference. These job sheets give practical information on radio servicing. You'll put this informations to use just as soon as you start servicing receivers. A review of the job sheets at that time will be very important—helping you get off to a successful start by showing you just what to do.

☐ 11. **Start Studying the Next Lesson.**

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INTRODUCING YOU TO RADIO

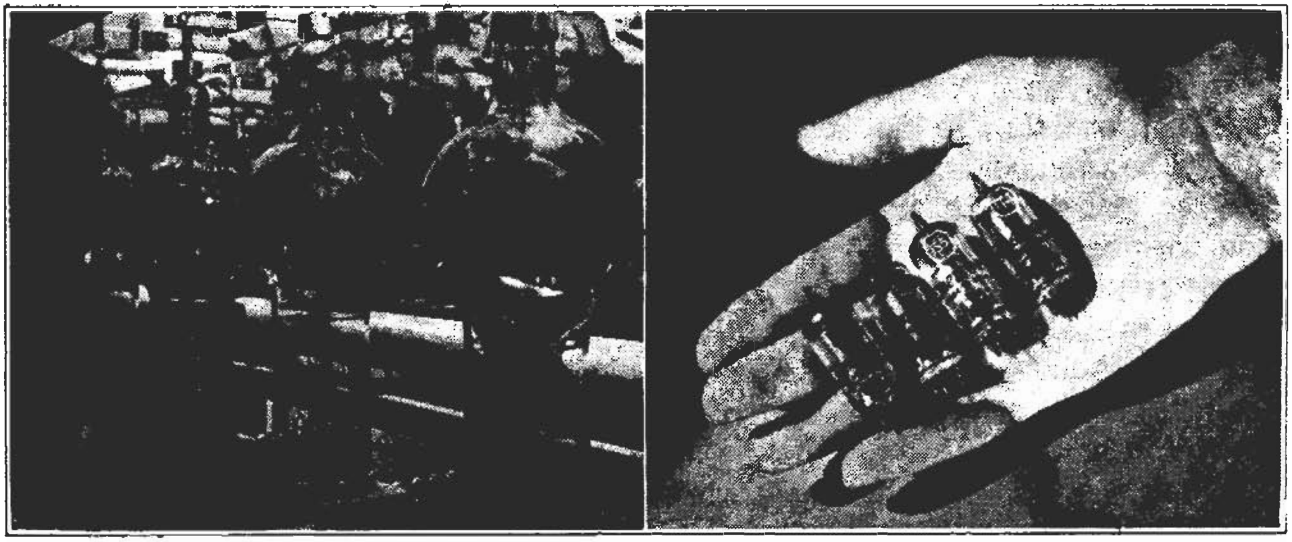
Your Future in Radio

DECIDING to study the N.R.I. Radio Course is one of the wisest decisions of your life. Why? Because this radio Course has been planned and written from beginning to end *especially for men who must do their studying at home,* usually after their regular day's work. You will learn radio with the aid of short-cut teaching techniques—not ordinary classroom methods, but specially-developed, thoroughly tested home-study methods. You will obtain a complete basic radio training without wasting your time in the study of unnecessary material.

You're going to get real results from this Course *sooner than you expect.* The fundamental radio ideas and basic testing methods which you master one after another are almost immediately usable, because in the very first lessons you begin preparing for practical everyday radio jobs.

The amount of education you now have is of less importance than an unswerving ambition to succeed. The first lesson starts *right at the beginning* of radio knowledge, and prepares you for the more advanced second lesson. Each new technical or special radio word, each symbol, and each abbreviation is explained the first time it appears.

Each lesson is full of dollars-and-cents information which is vital to real mastery of radio. By the time you finish the last lesson, you just can't help but be worth a whole lot more money to the world than you are today.



Courtesy Westinghouse Elec. & Mfg. Co. *Courtesy Emerson Radio & Phonograph Corp.*

In this very first lesson of your N.R.I. Course, you will learn the fundamental manner in which all radio tubes operate. This means that after mastering this first lesson, you will know how electrons flow through the giant high-voltage radio tubes (at the left) of station KDKA's transmitter, and you will be just as familiar with the behavior of electrons in the four tiny radio receiver tubes shown at the right.

The surest way not to fail is to determine to succeed. Make a sincere vow right now that you are going to follow up your hunch about radio—*that you are going to finish the N.R.I. Course and succeed in radio.* Give this world-famous Course just a fifty-fifty chance, and it'll help you just as it has helped so many thousands of other men. Stick to your vow, and you won't have to worry any more about your future.

If you have faith in yourself, if you sincerely believe that you have the ability to master radio, *and never waver from that belief,* your battle is half won already! The N.R.I. Course will do the rest if you give it a chance to work for you. We have actual records to prove that it has brought real success to thousands of other men who had the will-power to finish it. Surely you consider yourself just as good in every respect as these men. In fact, you are probably a lot more ambitious, a lot more in earnest than some of them. If you are as good as these men, *you can succeed, too.*

About a hundred years ago, Abraham Lincoln said: *"I will study and prepare myself, and some day I know my chance will come."* These words are even more true today than they were in Lincoln's time, because there are more opportunities now and they come much faster.

In radio, for instance, there are hundreds of different job opportunities in just that one branch known as entertainment broadcasting, which deals with the sending and receiving of programs through space. You will learn about some of these jobs in the very next section of this lesson.

As an N.R.I. graduate, you will be in a position to *choose* your opportunity, instead of waiting for it to come to you. You can decide for yourself whether you want an operating job, whether you want to do radio receiver servicing, or whether you want to play a part in building the great transmitting stations or the millions of receivers which serve this fast-growing broadcasting industry.

Furthermore, as the recently-developed frequency modulation system of broadcasting spreads throughout the country, the existing job opportunities will increase correspondingly in number. In addition to all this, commercial television is now a reality, and will be seeking trained men in increasingly greater numbers each year. Truly, the career of radio offers a promising future to men like you!

But a still more amazing fact about a radio career is that there is an even greater variety of opportunities for you outside of the entertainment broadcasting field. In short-wave radiotelephone and radiotelegraph communication systems on land, on the sea, and in the air are thousands of fascinating good-pay jobs for men who have the complete basic radio training that you are now obtaining.

In addition to all this, there are still more job opportunities for you in fields beyond the sending and receiving of messages or programs by radio.

You may some day find yourself in a theater, installing, adjusting and repairing the electric eyes and amplifier systems which make modern movies talk.

You may go to ball parks and conventions, to take charge of public address equipment which boosts man's feeble voice as much as a million times.

You may hike through canyons and foothills, using modern radio and electrical prospecting equipment to locate new oil fields and new deposits of precious minerals.

Wherever there is equipment which uses radio tubes, radio parts, radio principles and radio servicing methods, there also are opportunities for men with the thorough radio training you will soon have.

You are going to see great things happen in radio. You are going to see breath-taking new developments which far outshadow even the recent miracles of color television and noise-free broadcasting. You will be prepared for the today undreamed-of jobs which are created by new developments, because your N.R.I. training is built upon a sound foundation of fundamental radio and electrical facts.

In a way, you are to be envied, because as a graduate of this N.R.I. Course you will *start* your career in radio with knowledge which it has taken others almost a lifetime to acquire. Yes, one of the great things about the N.R.I. method of home training is that it gives you in a very few months even more up-to-date knowledge and information than many "old timers" have when they retire from radio!

Now you're ready to GO—ready to start your study of radio.

Radio Maps Will Guide You

At regular intervals in the N.R.I. Course, you will be given an outline of what comes next. Each outline is really a *"radio map"* of part of the Course, because it shows how each of the study subjects fits into your complete radio training. You will use these outlines as guides for getting your radio training as **fast as possible**, just as you would use a road map to guide you to a distant town over the shortest possible route.

Map of a Radio System. In this lesson, you start right in to learn about electricity, magnetism, radio tubes, and transformers—things you will work with on radio jobs every day. These subjects are so important that they deserve a *radio map* all their own, just for this lesson.

This first radio map takes you on a quick imaginary trip through the complete broadcasting system pictured in Fig. *1*. You find out where radio tubes and transformers are used in a modern radio system, and discover that electricity and magnetism have highly important effects in each one of the six parts of the system. Also, you will begin learning about important good-pay radio jobs for which you prepare yourself.

Once you have become familiar with the practical uses for electricity, magnetism, tubes and transformers, you will be eager to tackle the rest of this lesson and learn more about each one of these subjects.

1. Microphone in Studio. Our flying trip through a radio system starts in the broadcasting studio, where the sounds which make up a radio program are produced. Sounds are mighty important to a radio man, because he has to make sure that the sounds which come out of loudspeakers in homes are as nearly as possible like the sounds which enter the microphone at the studio.

Without the aid of radio, ordinary sound waves can travel only a few hundred feet at the most. But radio changes feet into miles, and allows you to hear sounds which are hundreds or even thousands of miles away without using wires. Not many years ago this would have been called magic, but today people think nothing about hearing sounds which are halfway around the world. All this is possible simply because radio men know how to put electricity and magnetism to work!

The microphone is really the doorway of our broadcasting system. Sound waves enter it through a wire screen, and make a thin piece of metal move back and forth or *vibrate.* In the wires of this microphone are millions and millions of tiny particles called *electrons.* Magnetism gets into action and makes these electrons move back and forth in step with the vibrations of the thin metal piece.

Thus, the microphone converts sound waves into a varying electron movement. This electrical signal is called an audio signal and is actually *sound in an electrical form.* In other words, audio signals are *electrical equivalents of sounds.* (The word "audio" comes from a Latin word meaning "to hear," and is used by radio men to describe an electrical signal having characteristics of sound.)

The microphone feeds its audio signal into a *cable,* which consists of two insulated wires surrounded by braided metal which is covered with rubber.

2. Control Room. The audio signal which is produced by the microphone travels through the microphone cable to an *audio amplifier* in the control room. This audio amplifier consists of radio tubes, transformers and other parts mounted inside a cabinet and connected together in such a way that when a weak signal is fed in, the amplifier produces a new signal which is much stronger but still has *the same characteristics* as the weak signal.

An audio amplifier is thus a signal-booster which takes in the weak audio signal of the microphone, and puts out a new signal which is hundreds of times stronger—strong enough for the long trip over telephone lines to the transmitter.

To be technically correct, however, we must point out that signal-boosting is accomplished by radio tubes which are capable of making *more electrons* move in step with the original sound. Furthermore, it is *magnetism* which does the work of transferring the signal from one tube to the next through transformers.

The man who adjusts the knobs at the front of the audio amplifier while watching the radio artists through a large plate-glass window and listening to their program with headphones is the *monitor operator.* Chatting with him for a few minutes, we learn that some announcers talk too loud for radio purposes, while others barely speak above a whisper. All speakers must sound just about the same in loudness to radio listeners in homes, so this monitor operator turns up the volume (makes the audio amplifier do more boosting) for a weak-voiced speaker, and cuts down the volume when any one starts shouting in front of the microphone.

Excessively loud sounds can overload a transmitter and cause it to go "off the air" for a few moments. To avoid this the monitor operator must turn down his volume control *before* a loud musical passage, a cough, or any other loud sound. Some operators become so skilled at figuring out when loud sounds will occur that they are jokingly called mind-readers!

3. Transmitter. Leaving the control room, we follow our radio program (now in the form of a strengthened audio signal) over a telephone line to the transmitter building which is usually located a few miles outside the city.

Once inside the transmitter, we find that our audio signal gets another

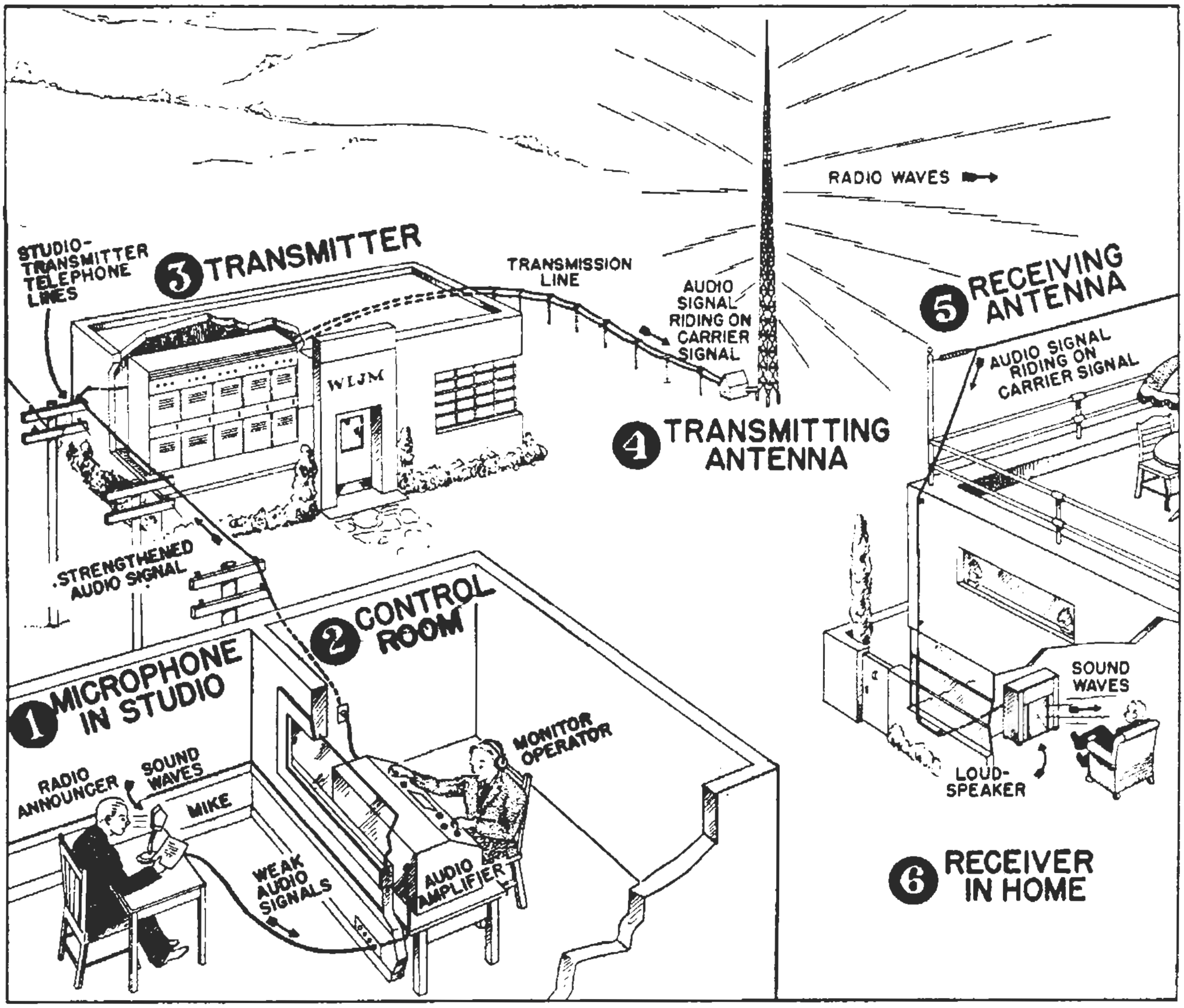


FIG. 1. This first radio map shows the six important sections of a radio broadcasting system. Start with the studio microphone at 1 and trace the signals until you reach the receiver loudspeaker at 6.

tremendous boost in strength from tubes and transformers. But no matter how much we boosted this audio signal, we wouldn't be able to make it travel more than a few hundred feet through space at the most.

We have to carry our audio signal through space on another signal known as the *carrier signal.* This carrier signal is the true *radio* signal.

Each station is assigned a carrier signal of its own by the Government. The carrier signal is produced by more radio tube circuits, and is combined with the audio signal in a radio tube circuit designed especially for "mixing" purposes.

The audio signal, riding on its own radio carrier, is given a final boost in strength by huge power tubes, and is then fed to the transmission line which serves the transmitting antenna. There's plenty of power behind our signal now—enough to fry to a crisp any unlucky mouse or grasshopper who gets across the high-voltage tube terminals.

The radio operator on duty at the transmitter must see to it that the radio signal which the transmitter is sending out into space has the same form at all times as the original sounds in the studio.

In addition, the operator must check meter readings in the transmitter regularly and try to anticipate possible breakdowns of tubes and parts. He can then replace weakened parts after the station shuts down for the day.

The goal of an operator is to keep his station on the air every second of the scheduled operating time. This is not as difficult a job as it seems, for an operator who fully understands the simple fundamental characteristics of each radio part and circuit in the transmitter rapidly acquires an uncanny ability to tell when a particular part is failing and in need of attention or replacement.

4. Transmitting Antenna. Coming out of the transmitter building, we hike along the transmission line to a little house just under the transmitting antenna tower. Technically speaking, we should call this the *tuning house,* but since you plan to be a practical radio man, you might as well get accustomed to hearing it called the "*dog house.*" Every transmitter has its dog house in the shadow of the antenna tower, and nearly every radio operator has at one time wisecracked about "leading a dog's life" when he had to go out to the dog house in stormy weather to read the meters.

The dog house contains radio parts which can be adjusted so as to "tune" the tower to the assigned carrier signal of the station. The antenna then gets all the signal power which the transmitter can feed to it through the transmission line. The meters in the dog house tell "how the station's doin'," and must be read at regular intervals each day.

From the tuning house, our radio signal goes right up the giant antenna tower, to the very top. The signal still consists of electrons moving back and forth, back and forth, the entire length of the tower, and these electron movements through a tower in the sky produce the radio waves which travel off into space away from the tower. Our radio program is now being carried out through space in all directions by radio waves.

You will learn in the next lesson that a radio wave is just a combination of electric and magnetic effects, varying in strength from instant to instant just as the pressure of the original sound wave at the studio is varying.

5. Receiving Antenna. Through the sky we trace the radio waves to the receiving antenna at some far-off home. As these waves move past the receiving antenna wire, the millions of electrons which are *always* in a metal wire start moving back and forth in exactly the same way as did the electrons in the transmitting antenna tower. The receiving antenna thus changes our radio waves back into an audio signal riding on a carrier signal. It is like the signal we had at the output of the transmitter, except that the signal is millions of times weaker due to its trip through space.

6. Receiver in Home. We follow our signal down the antenna lead-in wire, and we arrive at the radio receiver in the home.

We find that the first few sections of the receiver build up the strength of this weak signal, step by step. The carrier signal, no longer needed, is next removed from the audio signal by a section called the *detector.* After this, the audio signal is boosted in strength by more radio tube circuits in the *audio amplifier* section. This section feeds our signal into the very last transformer in the receiver, called the *output transformer.*

Finally, we come to the all-important loudspeaker, which is connected to the output transformer. The loudspeaker uses both electricity and magnetism to change the greatly strengthened audio signal back into sounds.

Radio servicemen are highly important in connection with this last section of our broadcasting system, for these men are needed to keep the millions of receivers in this country in operating condition. They have to locate and replace defective parts, and make correct adjustments of receivers whenever necessary, so the sounds coming out of the loudspeakers will be as nearly as possible like the original sounds in the studio.

Electricity and Magnetism

Even in a brief study of a radio system, we cannot help but marvel at the important parts which electricity and magnetism play in the operation of practically every radio device. But what is electricity? What is magnetism? If you learn the answers to these two questions once and for all now, *you will have the foundation for everything else you will study and work with in your radio career.*

Our first question is about electricity. But don't expect to find a long and complicated explanation of electricity—don't even expect to find the rest of this lesson devoted to this one subject. This is a *practical* home study Course, so it gives you only those electrical facts *which practical radio men need to know.* Once you master these few facts about electricity—once you realize that all forms of electricity are due either to electrons in motion or electrons at rest—you'll be ready to make electricity work for you in radio equipment.

What Electricity Is

Everything on this earth is made up from tiny particles, so small they cannot be seen even with the most powerful microscope. These particles are attracted to each other with great force in the case of solid materials like iron or copper, with less force in the case of liquids like water or oil, and with the least force in the case of gases like oxygen or hydrogen.

Scientists have identified several different kinds of these particles, but the only one in which radio men are interested is the electron. It has been proved beyond all doubt that electrons exist everywhere—in the air, in water, in every single object in the world!

During normal conditions, each radio part, each wire, each object on the earth has its own definite number of electrons. The exact number runs way up into the billions even for small objects, but always depends upon the size and nature of the object. Whenever this normal condition exists for some object, that object has no electricity, and is said to be *neutral* or *uncharged.*

In metals like copper, silver or aluminum, some of the electrons are continually wandering around inside the metal itself. These electrons are known as *free electrons,* because they are free to move. The rest of the electrons always stay in the same locations; in fact, if we could discover how to move them, we would be able to change one metal to another—we would realize the age-old dream of changing lead into gold.

We can secure electricity either by taking some of these free electrons away from an object or by adding more free electrons to the object, because we then upset the normal balanced condition. This brings us to an important basic definition:

Whenever an object has more or fewer free electrons than normal, electricity exists in the object.

Sources of Electricity. But where can we get extra free electrons? This is an easy question to answer—get the extra free electrons from a battery, a power line, a generator, or any other device *which possesses the ability to supply free electrons.* Examples of a few common sources of electricity are pictured in Fig. 2.

Since radio men always work with free electrons (never with the fixed electrons), we can just say *electrons* from now on, when we mean *free electrons.* Remember—whenever you read about electrons in radio magazines or N.R.I. lessons, think of *free* electrons.

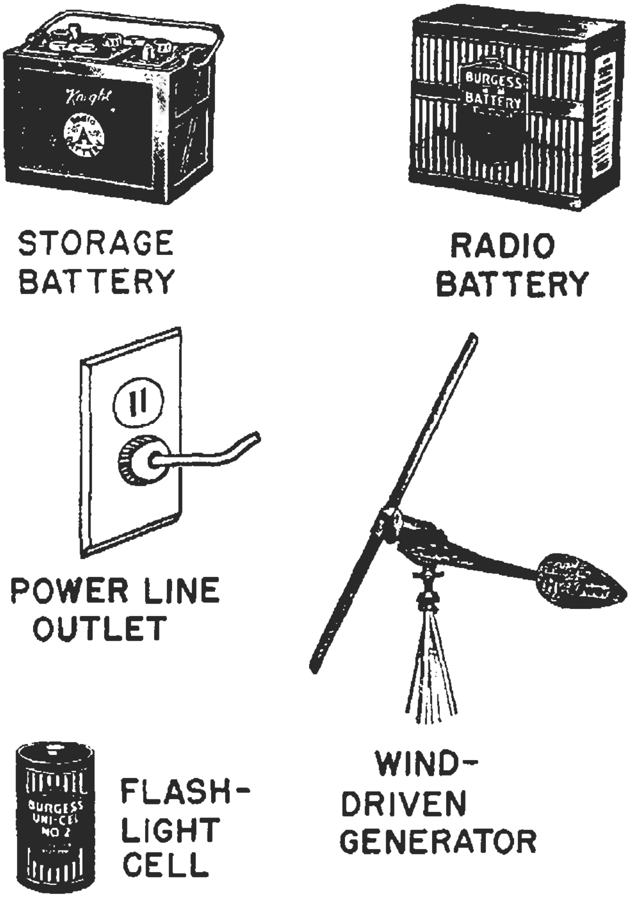


FIG. 2. Examples of sources of electricity used by radio men to make electrons move in radio circuits. Storage batteries are used with radio receivers in automobiles, ships, airplanes, and farm homes. Radio batteries are used chiefly in portable receivers. Power line outlets serve by far the greatest portion of the radio receivers in this country. Flashlight cells are used in small pocket-size portable receivers. Wind-driven generators keep radio storage batteries charged in farm homes.

Law of Electric Charges. Technically speaking, a law is simply a statement which always holds true. There are only a few of these laws which are important to a practical radio man. Once you understand these laws, you can use them to figure out how radio parts and circuits will behave under various conditions.

The first law which we take up is one which tells how electrons will behave when near other electrons or when near *electric charges.* An electric charge is simply a quantity of electricity.

There are two kinds of electric charges, quite unlike, and for convenience they are called *positive charges* and *negative charges.*

The electron is a *negative charge,* and is also the smallest amount of electricity which can exist by itself.

An object or terminal has a *negative charge* whenever it has *more* electrons than normal. An object or terminal has a *positive charge* whenever it has *fewer* electrons than normal.

Two electric charges cannot exist side by side without trying to move each other. Nature has its own law which tells which way they will move. If the two charges are *alike* (if both are *negative* or if both are *positive*), they will *repel* each other, or tend to push each other away. If the two charges are *unlike* (one is negative and the other is positive), they will *attract* each other and tend to move together.

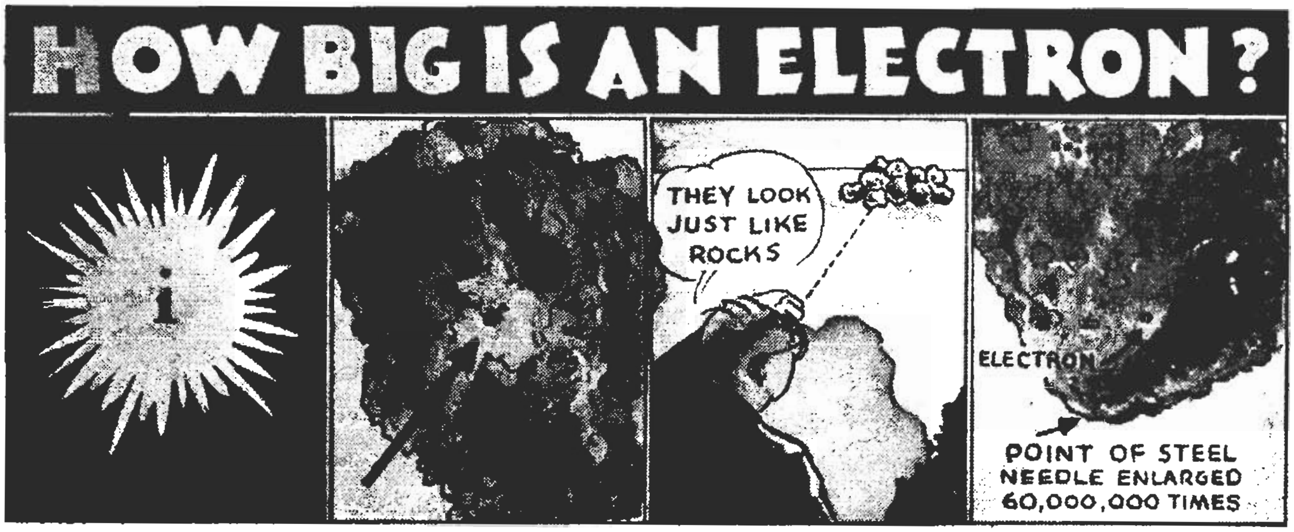
Let's repeat this law now in three-word statements which will be easy for you to remember:

LAW OF ELECTRIC CHARGES

Like charges repel.
Unlike charges attract.

Once you learn this simple law, you will have the true basic idea of how all radio tubes work. You will find that this law helps you to understand the use of test instruments, and aids you in many other ways when you are working on a radio receiver, transmitter or other piece of radio apparatus.

Here is a helpful suggestion: Write this law on a scrap of paper now, and place this paper where you will see it once in a while during the next few days.



Sixty billion electrons side by side would be needed to form a line across the dot in the letter "i" shown above.

A free electron can travel through metal as easily as an ant can travel through a sponge full of holes.

Sponges look as solid as rocks when you're standing a hundred feet away from them, and . . . .

A piece of metal would look as full of holes as a sponge if our eyes could see its actual metal structure.

Battery Terminals. An ordinary battery, such as a dry cell or an automobile storage battery, always has *two* terminals, one having more electrons than normal and the other having less electrons than normal. (Electrons, remember, are negatively charged particles.) The battery itself produces this condition by a chemical action which need not be studied here.

The battery terminal which has more electrons (more negatively charged particles) than normal is called the *negative terminal* of the battery. On radio diagrams, as well as on actual batteries, we use a minus sign (—) to indicate that this terminal is negative.

The battery terminal which has fewer electrons than normal is called the *positive terminal* of the battery. On diagrams and on batteries, we use a plus sign (+) to indicate that this terminal is positive.

Nature always tries to restore things to normal. That's the reason why the electrons on the negative terminal want to get over to the positive terminal of the battery. Yes, there's just one place those electrons on the negative terminal want to go—to the positive terminal of *their own battery.*

When we connect a wire between the two terminals of a battery, we secure a *complete circuit.* Here is what happens. The instant the circuit is completed by touching the wire to the — terminal, the extra electrons on this terminal tend to rush into the wire because they "sense" a clear path ahead to the + terminal. These fast-moving electrons from the battery bump into free electrons in the wire, and push the free electrons forward toward the positive terminal. In no time at all, every electron gets bumped.

All along the wire, electrons begin pushing other electrons toward the + terminal. Each time an electron is pushed into the + terminal, another electron enters the wire from the — terminal.

Suppose that we connect a length of wire to the positive terminal of an ordinary storage battery, as shown in Fig. *3A*. Our wire contains great numbers of free electrons which are ready to "go places," but nothing can happen yet. Our wire is merely an extension of the + terminal.

Suppose, however, that we connect the other end of the wire to the negative terminal of the storage battery, as shown in Fig. *3B*. We get action immediately. The wire gets warmer and warmer, a sure sign that electrons are moving.

Of course, a radio man would warningly point out that we are "shorting" the battery with the wire, but we can do this for a *short* time without seriously draining a good storage battery.

Which way are the electrons moving through our wire? Well, if the negative terminal wants to get rid of electrons because it has too many, and the positive terminal wants more electrons to make up its shortage, you should be able to figure out the answer yourself.

Yes, electrons move *from the negative terminal to the positive terminal* through the wire, just as is shown by the arrows in Fig. *3B*. This agrees with the law of electric charges, which says that electrons will be attracted by a positively charged terminal. Thus, we've made use of this law already!

The movement of electrons through a complete electrical circuit can be compared to the movement of marbles through the length of tubing shown in Fig. *4*. Each time you push a marble into one end of a filled tube, an entirely different marble pops out of the tube at the other end.

As soon as electrons move from the — terminal into the wire, the battery forces more electrons to the — terminal. This keeps up as long as we leave the circuit complete or until we have used up all the power stored in the battery. It is because a battery can supply electrons in this way that we consider batteries as *sources of electricity*.

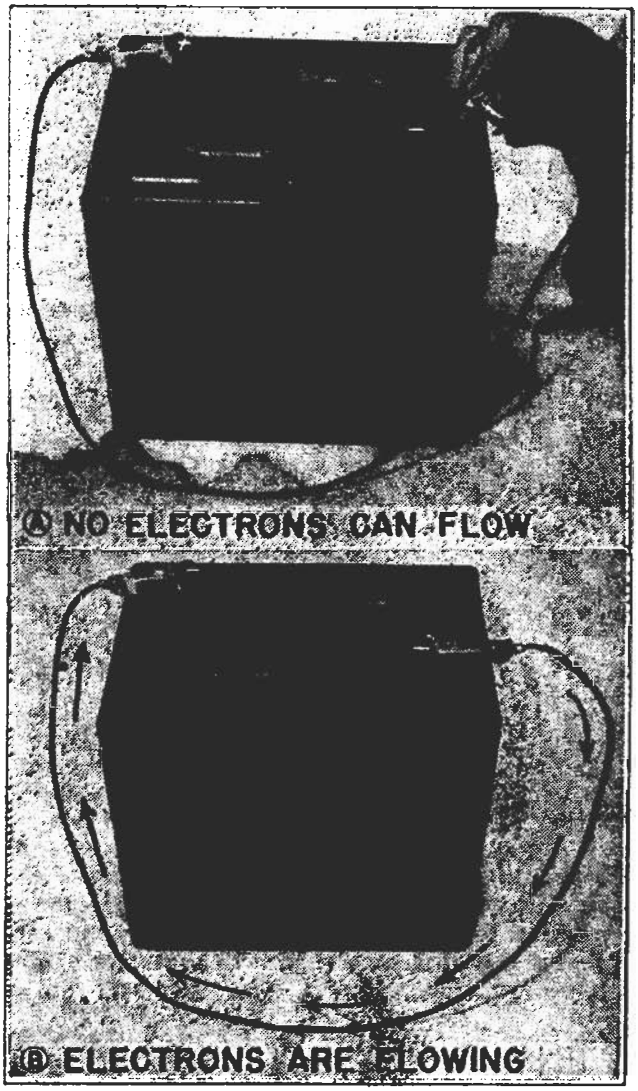


FIG. 3. Nothing happens when a wire is connected to only one terminal of a battery. There must be a complete path for electrons between the two battery terminals in order for electrons to flow. CAUTION: Never "short" a battery needlessly with a wire.

The movement of electrons through a complete circuit is called an *electric current* or simply a *current*. When the source of electricity forces electrons through a circuit in the same direction at all times, the resulting flow of electrons is known as a *direct current,* abbreviated as *d.c.* The more electrons we have moving past a given point in the wire each second, the greater is the value of direct current flowing through the wire.

Speed of Electricity. Whenever a wire is connected to the two terminals of a battery so as to give a complete circuit, the free electrons in the wire begin moving toward the positive terminal. These free electrons get into motion almost instantly, hence we say that the *effect* of electricity travels almost instantly from one point to another. (The actual speed of this electrical effect has been measured by scientists and found to be about 186,000 miles per second, which is the same as the speed of light.) The first effect of electricity travels at this speed regardless of battery strength.

Although the effect of electricity travels so rapidly during the first instant when a connection is made, the free electrons move slowly through the wire (only a fraction of an inch per second) once they are in motion. It is just as if we had a long line of soldiers, each standing with his bayonet pressed against the man ahead. When the man at the rear of the line moves forward, the entire line must jump into motion almost instantly so no one will be stabbed in the back. Once in motion, however, the soldiers march at a slow and steady speed corresponding to the slow movement of electrons through a wire.

The instant we complete the circuit, the free electrons in the wire start moving, and continue moving at the slow, steady rate determined by the strength of the battery. If we increase the strength of our battery more electrons will move out of the negative terminal each second and hence the *current* will *increase.* If we reduce the strength of the battery, the *current* will *decrease.* In radio, we often adjust the strength of each battery so exactly the desired number of electrons will be moving through each part in the circuit per second.

There is a need for a convenient way in which to specify the strength of a battery or other source of electricity. Radio men use the term *volts* for this purpose. Thus, you will often hear radio men speak of a 6-volt storage battery, a 115-volt power line, a 45-volt B battery or a 1½-volt A battery. In later lessons you'll learn a lot more about what volts mean in connection with these *voltage sources.* For the time being, just remember that *volts* tell you *how strong* a source of electricity is.

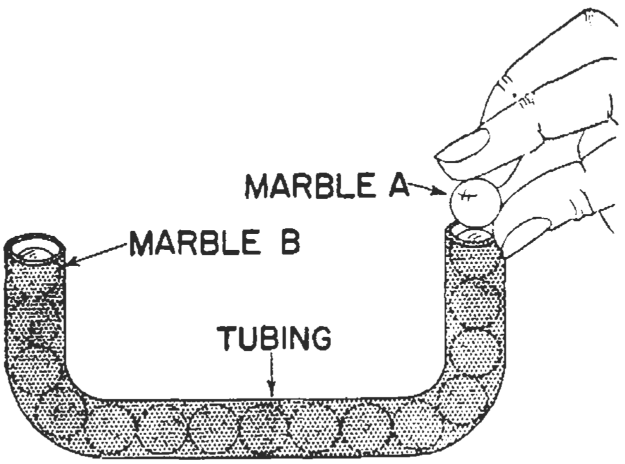


FIG. 4. When you push marble A into one end of this marble-filled tubing, marble B will pop out of the other end. Although marble B will move instantly, it will take some time before enough marbles can be pushed in to make marble A come out at the other end. Continuous electron flow through a wire occurs in much the same way.

A voltage which sends a direct current through a circuit is known as a *direct current voltage,* usually abbreviated as d.c. voltage. All batteries produce d.c. voltages. An automobile generator is also a d.c. voltage source.

Polarity. When giving the strength of a d.c. voltage source, it is often desirable to tell which terminal is positive or which is negative. We are then telling what the *polarity* (pronounced po-LAIR-i-tee) of the voltage source is. Thus, when a radio man says, "this wire of your auto radio should be connected to the + terminal of the car battery," he is telling what the *polarity* of the connections to the voltage source should be.

Conductors. The wire used for connecting parts together in radio circuits is made from copper. The wire used in making radio coils, transformers, loudspeakers and many other parts is likewise copper. The reason this metal is used so much in radio equipment is that it has large numbers of free electrons.

Silver, aluminum and brass are other metals which have plenty of free electrons. These metals and copper are known as *conductors,* because they pass or conduct electricity. A good conductor is said to have *low resistance,* because it offers little opposition or *resistance* to the flow of electrons.

Insulators. To make electrons work for us, we must make correct paths for them by using conductors like copper wire, and we must prevent these paths from touching undesirable paths. In other words, we must separate or *insulate* our desired wire paths from all other paths, so that electrons will go through every part in the path instead of taking short-cuts through other parts.

A wire can be insulated by covering it with an *insulator,* a material which offers a great deal of opposition to movements of electrons.

Silk, cotton, enamel, rubber, paper and glass are good insulators, because they are materials which have very few free electrons.

Free electrons have just as difficult a time in moving through an insulator as soldiers would have in moving through a barbed wire entanglement. Just as barbed wire is used to limit the movement of soldiers, so are insulators needed in radio circuits *to make electrons take the correct paths through radio parts and wires.* In other words, insulators offer high *resistance* to the flow of electrons.

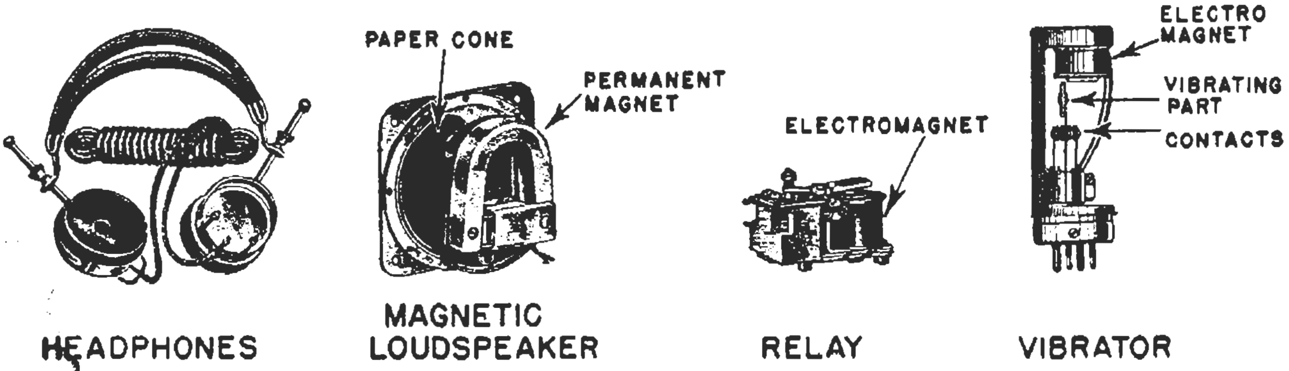
An insulator can become a conductor if the voltage is made high enough to cause actual destruction of the material. This breakdown is accompanied by an electric arc or spark which burns the insulating material, thereby providing a conducting *path* for electrons.

This is exactly what happens when the insulation in a radio part breaks down; the radio man simply says the part is *shorted,* but actually the insulation fails due to the heat of the spark, and electrons flow through the resulting charred hole in the insulation. The action is much like that of a tank traveling through a barbed wire entanglement; once the tank has forced its way through, soldiers have no difficulty in following.

Radio Uses for Magnetism

Without magnetism, *there would be no radio industry at all,* for magnetism and electricity working together give us *radio waves* to carry messages, music and programs through space.

There are also quite a few radio parts which could not work without magnetism. Both *magnetic loudspeakers* and modern *permanent magnet dynamic loudspeakers* use powerful *permanent magnets* to help make the large paper cone move and produce sound. Each *headphone* unit uses a tiny but powerful permanent magnet to help make the round metal disc move and produce sound.



Radio parts which use permanent magnets or electromagnets.

An *electrodynamic loudspeaker* has an *electromagnet*, a device which acts as a magnet only when current is actually flowing through the magnet coil.

Electromagnets are used in some television picture tubes to make a beam of electrons sweep back and forth in the correct manner for "painting" a picture or pattern on a screen.

You will also find electromagnets in auto radio *vibrators,* in the *relays* which do automatic switching work in radio transmitters, and in many special radio parts, which are taken up in later lessons.

Radio transformers depend upon magnetism for the transfer of signals and electric power from one circuit to another. The silent magnetic action in a transformer is just as important in a radio system as the humming sound of a vibrator, the chatter of a loudspeaker, or the clicking of a relay.

Since magnetism is so important to a radio man, let us pry into its secrets now, to see what it really is and how it can work in so many different ways in radio parts.

Permanent Magnets. The ancient Greeks discovered, near the city of Magnesia in what is now Turkey, a mineral which possessed the unusual ability to attract small pieces of iron. The Greeks called this material *magnes*, and from this term comes the word *magnet* which we know today.

Early experimenters found that they could make needles and other pieces of hard steel act like magnets simply by rubbing these steel objects on a piece of this magnetic ore. These *magnetized* objects were called *permanent magnets,* because the magnetic characteristics seemed to be permanent.

When a magnetized steel needle is placed on a cork which is floating in water so it can turn easily, the needle will always line up in a direction corresponding closely to north and south. This magnetic experiment is illustrated in Fig. *5*. It led to the first practical use for magnets, in the compasses of

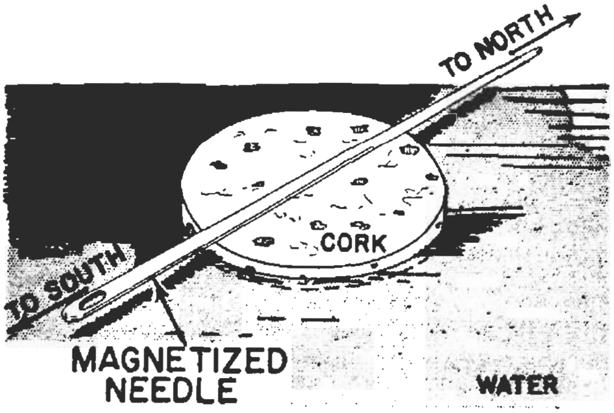


FIG. 5. If a magnetized steel needle is placed on a floating flat piece of cork, the needle will line up in the north and south directions like a compass, because the needle lines up with the magnetic field of the earth. In radio, we produce magnetic fields much stronger than those of the earth, and use these fields to make iron or steel objects move or line up in desired ways.

early sea voyagers and travelers. For practical reasons, the needle in a compass is mounted on a delicately pivoted bearing which turns just as easily as the cork in water.

Poles of a Magnet. The ends of a permanent magnet are called *poles,* probably because these ends point toward the *poles* of the earth when a magnet is pivoted. The magnet pole which points north is called the *north pole* of the magnet. The magnet pole which points south is called the *south pole.* On diagrams of magnets, the north pole is usually marked *N,* and the south pole is usually marked *S.*

One law which is particularly useful to a radio man is the law which tells how magnets will behave. It can be demonstrated with a compass needle and a bar magnet (a magnetized bar of steel) in the following manner:

If the north (*N*) pole of the bar magnet is held near the north pole of the compass, just as is shown in Fig. *6A,* a repelling action is noticed because the compass is itself a small bar magnet. This same repelling action occurs when the *S* pole of the bar magnet is brought near the *S* pole of the compass needle. Our conclusion is *that magnet poles which are alike repel each other.*

If the *S* pole of a bar magnet is brought near the *N* pole of a compass, a strong attracting action is noticed, just as is indicated in Fig. *6B.* Thus, *unlike magnet poles attract each other.*

This law of magnetism is fixed by nature, and always holds true. It is repeated here in two simple statements which will be easy for you to remember:

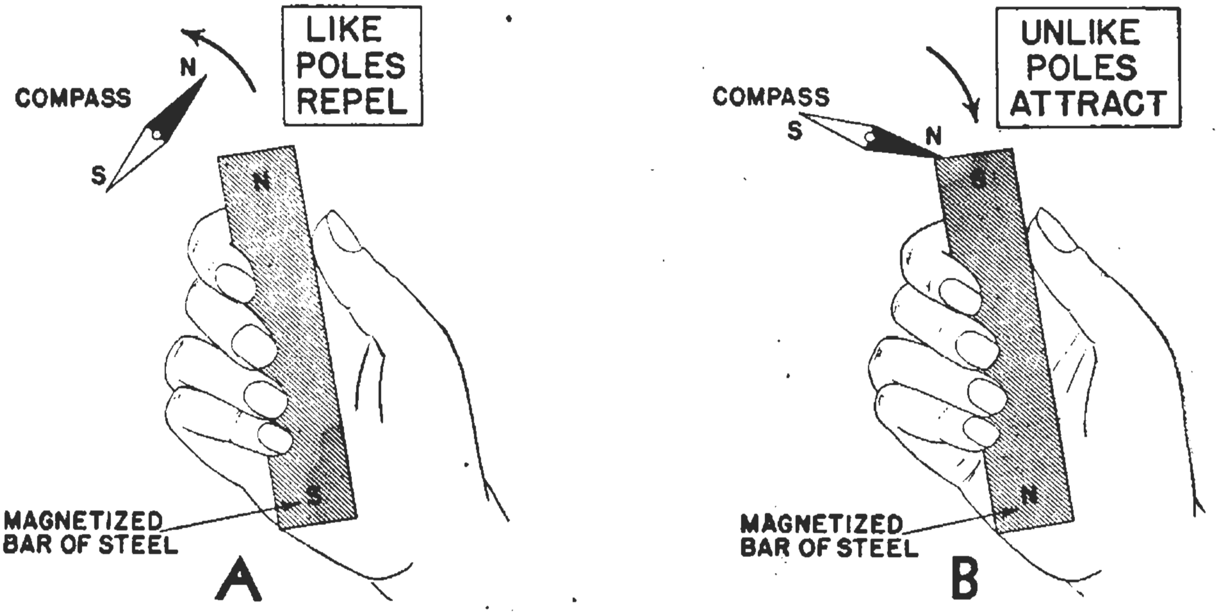


FIG. 6. A simple method of demonstrating the law of magnetism. This law applies to the operation of loudspeakers, headphones, relays, vibrators, motors and many other radio parts.

LAW OF MAGNETISM

Like magnetic poles repel.
Unlike magnetic poles attract.

Again you may want to write this law on a piece of paper so you can look at it often.

Magnetic Lines of Force. If a thin sheet of cardboard is placed over a bar magnet, and iron filings are sprinkled evenly over the cardboard, the iron filings will arrange themselves in definite lines, as shown in Fig. *7A.* If the experiment is repeated when the north poles of two bar magnets are end to end, the pattern shown in Fig. *7B* is obtained. If the experiment is repeated once more, with opposite poles of the two bar magnets near each other, the pattern shown in Fig. *7C* is obtained.

These experiments show definitely that there is some kind of force acting through the space surrounding a magnet. The scientist Faraday studied magnets for a long time, and finally decided that these forces must act along invisible but definite lines or paths in space. He said that these paths were the same as those traced out by the iron filings, and gave the name *"magnetic lines of force"* to the natural forces which a magnetic pole produces in space. Radio men still use this name today, and also say that all the magnetic lines of force around a given magnet make up the *magnetic field* of the magnet.

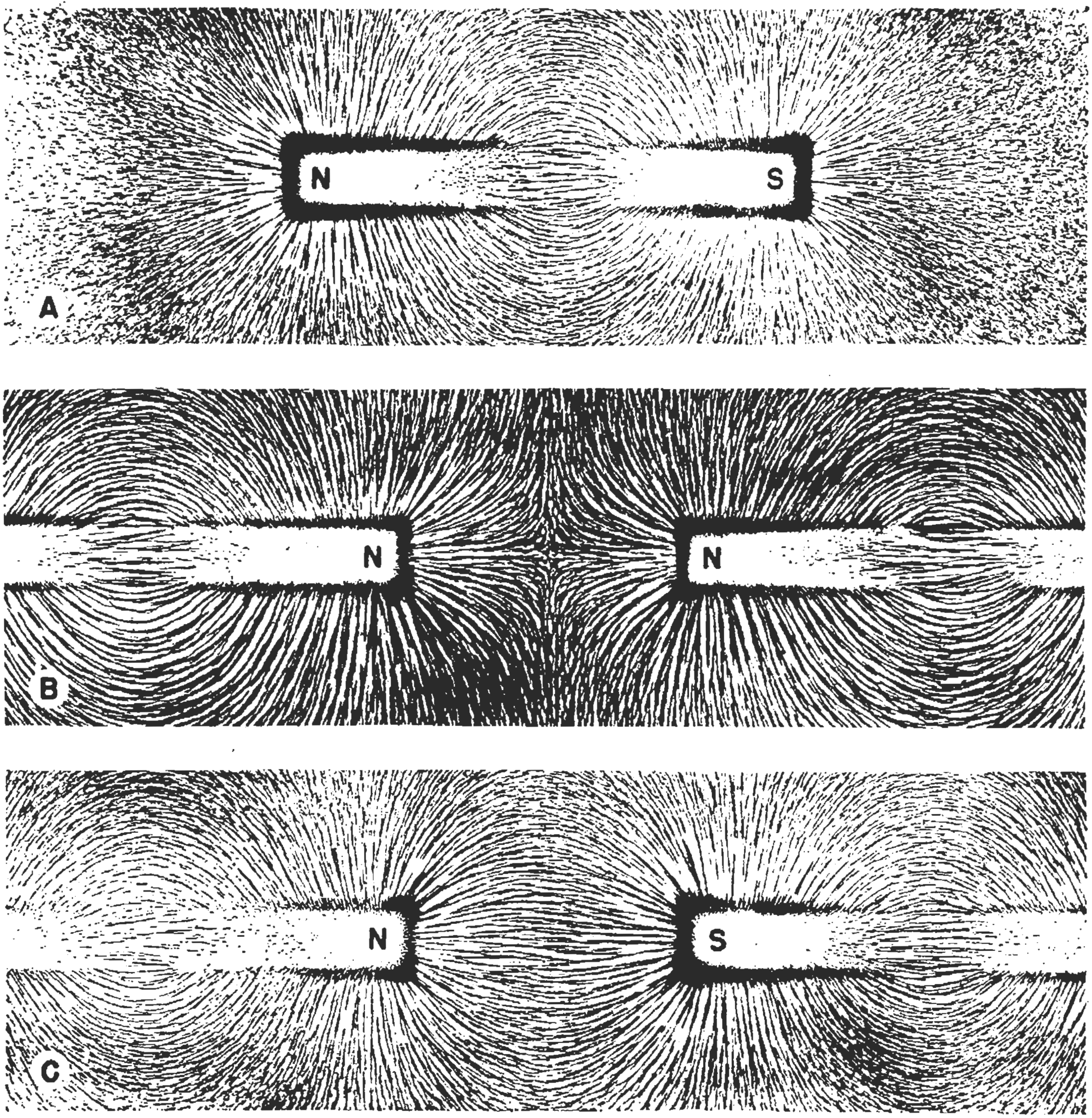


FIG. 7. Here are some of the results which can be obtained by placing sheets of cardboard over permanent bar magnets, then sprinkling iron filings over the sheets. Magnetic lines of force are traced out by the filings almost magically.

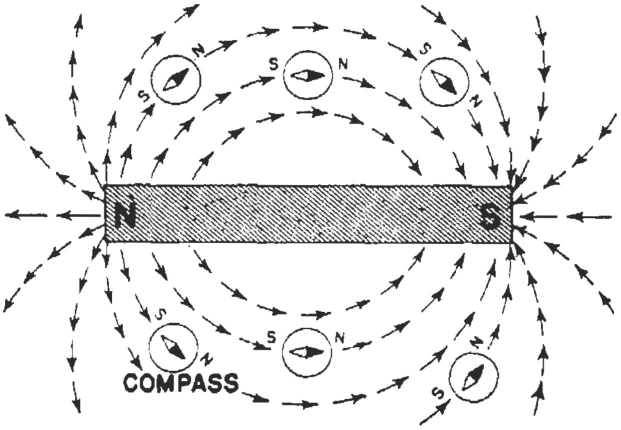


FIG. 8. A small compass can be used to trace magnetic lines of force near a permanent magnet.

When a small compass (which always has an N pole and an S pole) is moved to various positions in the vicinity of a bar magnet, as indicated in Fig. *8*, the compass needle will line up with the magnetic lines of force at each position, and will thus trace out the magnetic lines of force in the vicinity of the bar magnet. Compare Fig. *8* with Fig. *7A*, and you will see that the compass and iron filing experiments check perfectly.

Magnetic lines of force are considered to have a *direction* as well as a position in space. This direction is always that in which the *N* pole of a compass will point. Thus, the arrows in Fig. *8* show that magnetic lines of force come out of the *N* pole of a magnet, and enter the *S* pole. This rule is worth repeating here for reference purposes, even though you do not have to memorize it.

Magnetic lines of force come out of the *N* pole of a magnet, and go into the *S* pole. The *N* pole of a compass (painted a dark color) always points in the direction of magnetic lines of force.

Electromagnets. In 1820, the scientist Oersted discovered that when an electric current is flowing through a wire, the current produces *magnetic* effects in the space around the wire. When he moved a compass around a current-carrying wire, the compass needle definitely traced magnetic rings (circular magnetic lines of force) as shown in Fig. *9A*. (Only two rings are shown in Fig. *9A*, but actually there are many more magnetic rings surrounding a current-carrying wire, and these rings are of many different sizes.)

This experiment with a compass and a current-carrying wire proves *that electrons in motion produce magnetic effects* similar to those of a bar magnet.

The direction of the magnetic lines of force around a current-carrying wire depends upon the direction in which electrons are moving through the wire, and can be determined almost instantly with the Left-Hand Rule given here and illustrated in Fig. *9B*. This rule is well worth remembering.

LEFT-HAND RULE FOR A CURRENT-CARRYING WIRE

Imagine you are grasping the wire with your *left* hand in such a way that your thumb points *in the direction of electron flow*. Your fingers, curled around the wire, will then be pointing in the direction of the magnetic lines of force.

The magnetic lines of force which surround just a single current-carrying

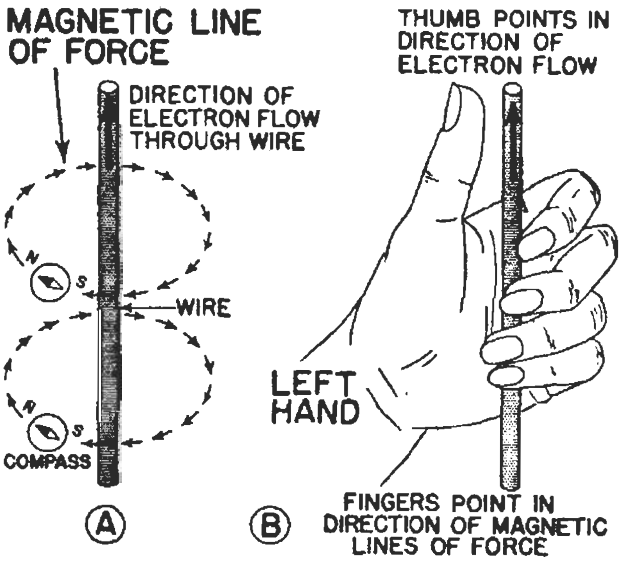


FIG. 9. Whenever electrons flow through a wire, magnetic lines of force surround the wire and have the direction shown here.

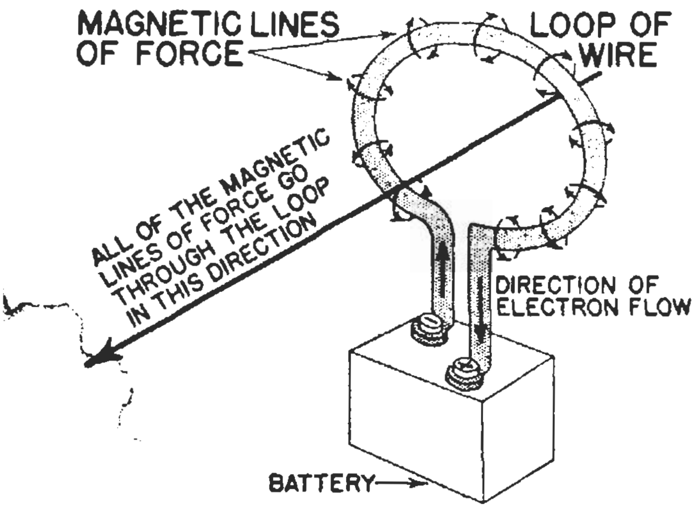


FIG. 10. When we send electrons through a loop of wire, the magnetic lines of force all go through the center of the wire loop in the same direction.

wire are weak and do not have much practical use, but we can concentrate these lines of force and make them more useful by bending the wire into a loop or single-turn coil, as shown in Fig. *10*. Now all the circular magnetic rings pass through the center of the coil in the same direction and reinforce each other.

If we add more turns of wire to this coil, as in Fig. *11*, the magnetic field inside the coil becomes much stronger even though the same current is still flowing through the wire. For this reason, radio coils usually have a great many turns of wire.

Whenever a coil like that shown in Fig. *11* is carrying a direct current, this coil acts exactly like a permanent magnet. If we trace out the magnetic lines of force with a small compass, we find that they all go into the right-hand end of the coil and come out of the left-hand end. The right-hand end of the coil corresponds to the *S* pole of the permanent magnet shown in Fig. *8*, so we call this end the *S* pole of the coil. Similarly, we call the left-hand end of the coil the *N* pole.

The more current we send through a given coil, the greater will be the strength of its magnetic field. This is logical, for more current means more electrons moving through the wire, and each additional electron in motion adds its share of magnetic rings to those passing through the center of the coil.

When a piece of iron or soft steel is placed in the center of a current-carrying coil, the magnetic field which passes through the coil becomes much stronger, because soft steel is a much better path for magnetic lines of force than air. Since the magnetic field exists only when electric current is flowing, coils with iron cores like this are called *electromagnets*.

The magnetic effect of an electromagnet is only temporary, for it disappears almost as soon as the current flow through the coil is stopped. This characteristic makes electromagnets more desirable than permanent magnets for many radio parts.

Any one who wants to demonstrate how an electromagnet picks up iron objects like tacks can make one from ordinary materials. Simply wind about 25 turns of insulated copper wire around a large nail, then connect the ends of the wire to the two terminals

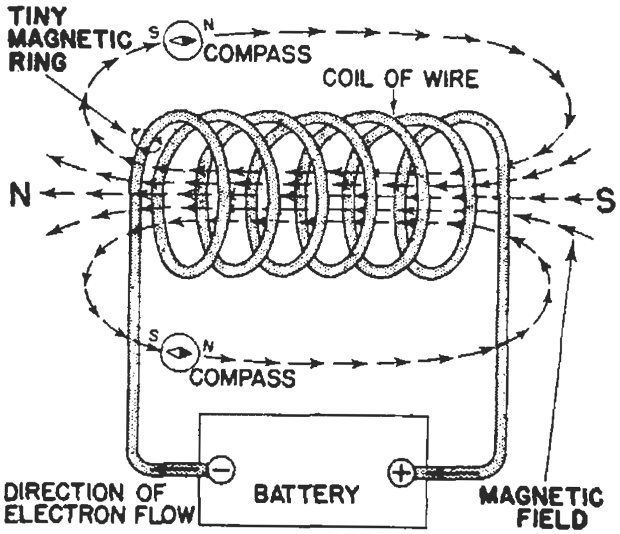
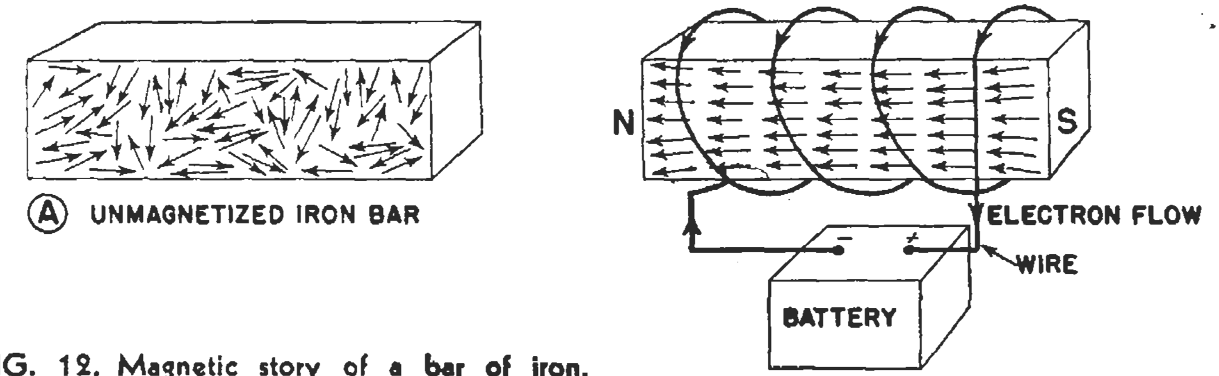


FIG. 11. The more turns of wire we have in a coil, the stronger will be the magnetic field when electrons flow through the coil.

of a flashlight cell and bring the nail near the tacks. (Leaving this electromagnet connected longer than a minute or two will drain the battery.)

The strength of an electromagnet having a particular size of iron core depends chiefly upon two things, the *number of turns* of wire used in the coil and the *amount of current* flowing through the coil. Increasing either one will make the electromagnet stronger. Reducing the current or removing some of the turns of wire will make the electromagnet weaker.



Ⓐ UNMAGNETIZED IRON BAR

Ⓑ IRON BAR MAGNETIZED BY CURRENT THROUGH COIL

FIG. 12. Magnetic story of a bar of iron. The small arrows represent invisibly tiny magnets inside the bar.

The magnet in every electrodynamic loudspeaker is an electromagnet. The coil of this electromagnet is known as the *field coil* of the loudspeaker, because it produces the *magnetic field* required to operate the loudspeaker. An electrodynamic loudspeaker will work only when current is flowing through the field coil, so this type of loudspeaker will always have two extra wires for this field current.

Explanation of Magnetism. What makes it possible for metals like iron to become magnets? The answer which scientists have for this question is that each invisible tiny particle of iron is a tiny permanent magnet. Ordinarily these tiny magnets are arranged "helter-skelter" in iron, as indicated in Fig. *12A*, so that their magnetic fields act in all directions and cancel each other.

If we place an iron bar in a strong magnetic field such as that existing inside a current-carrying coil, the tiny magnets within the bar will tend to line up with the magnetic lines of force of the coil. When this occurs, the entire bar becomes one large and powerful magnet, and we have the electromagnet illustrated in Fig. *12B*. When the magnetizing force is removed by stopping the current or taking the iron bar out of the coil, practically all of the magnets return to their original helter-skelter arrangement.

If a bar of hard steel is used instead of iron, however, the magnets remain in their new lined-up position even after the magnetizing force is removed, and we have a permanent magnet. The more tiny magnets we can line up in one direction, the stronger is the permanent magnet.

Iron is the most useful magnetic metal. Nickel and cobalt (a silver-white metal resembling nickel) have weak magnetic characteristics by themselves, but when one or both of these pure metals are mixed with other metals in definite ways to give magnetic alloys, the results are even better than are possible with steel. One example is *alnico,* a combination of *al*uminum, *ni*ckel and *co*balt which is now widely used for permanent magnets in loudspeakers.

Radio Tubes

Practically every piece of radio equipment being made today contains at least one radio tube, so there should be no question whatsoever regarding the importance of learning about tubes as soon as possible in your course. You already know where tubes are used in broadcasting systems—you know the vital facts about the electrons which make radio tubes possible—so now you're fully prepared to learn what radio tubes are like and how they work.

First Amplifier Tube. The invention by Lee DeForest in 1904 of the "audion" radio tube shown in Fig. *13* did more than anything else to make possible radio as we know it today. With tubes like this, it was possible for the first time to *amplify* a weak radio signal and thereby build up its strength hundreds or even thousands of times.

This first radio amplifier tube is remarkably simple, as you can see for yourself by examining the sketch in Fig. *13*. There are only three main parts or *electrodes* (pronounced *ee-LEK-troads*). Each electrode has its own name.

The *filament* of this tube is just like the filament of an ordinary electric lamp. When current is sent through this filament, it gets hot. On the surface of this filament is a chemical coating which actually gives off or *emits* electrons when heated. A filament which supplies free electrons in this manner is also serving as the *cathode* electrode.

The rectangular plate of metal in this tube is called the *plate*. When a voltage source is connected between the plate and the cathode in such a way that the positive terminal goes to the plate, the plate *attracts* the electrons which are emitted by the cathode. Under this condition, the plate electrode is said to be positive with respect to the cathode.

The *grid* is the important electrode introduced by DeForest; it is between the filament and the plate, in a position where it can be made to have a powerful control over the number of electrons which get to the plate.

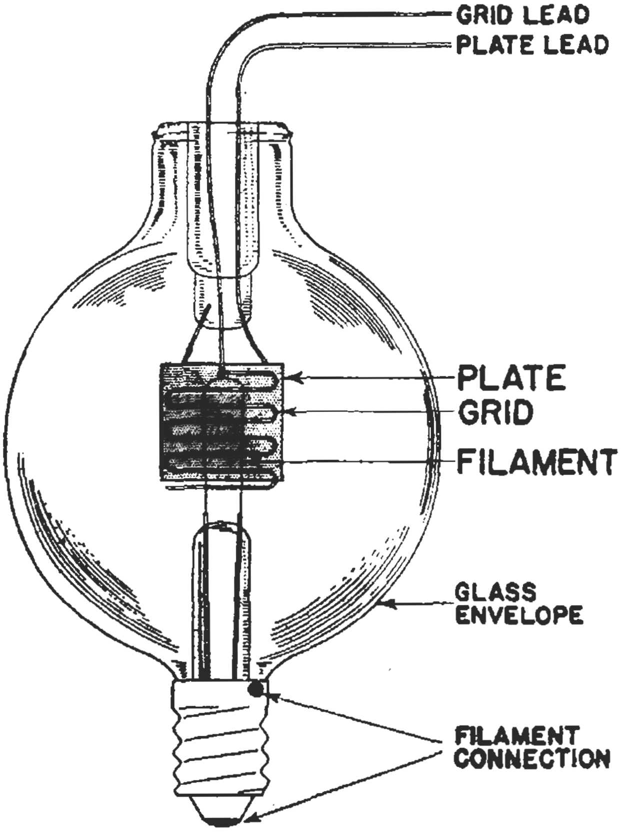


FIG. 13. DeForest "audion" radio tube, sketched from a tube in the N.R.I. collection of history-making tubes. If you ever visit N.R.I., be sure to look for this audion tube in the display rack on the third floor.

Many additional parts have been added to this first DeForest "audion" tube and many improvements have been made, but modern radio tubes still use the same control grid idea.

Modern Tube Construction. A cut-away diagram showing the construction of a typical modern radio tube is shown in Fig. *14*.

In the center of the tube is the *filament*, which becomes red-hot and supplies heat.

Surrounding the filament is a cylindrical or tubular-shaped electrode called the *cathode*, which emits electrons when heated by the filament.

The remaining two electrodes encircle the cathode. The outermost is a metal cylinder which attracts the electrons and is still called the plate even though it has no resemblance to the flat metal plates of early radio tubes. Between the cathode and the plate is a spiral wire arrangement called the *grid*, which is used to control the number of electrons moving from the cathode to the plate.

The electrodes of a vacuum tube are enclosed either in a metal or glass housing called the *envelope*, from which all air has been pumped out during manufacture so as to give a vacuum, necessary for maximum electron emission.

The tube electrodes are connected to prongs on the tube base. This base fits a socket which provides individual contacts for each electrode.

The filament is considered an electrode of a radio tube only when, in addition to its job of providing heat, it has the extra job of giving off electrons. Modern 1.4-volt battery-operated tubes and the old DeForest audion are examples in which the filament also serves as the cathode.

The least number of electrodes a tube can have is two: *1*. The *cathode*, which emits (gives off) the electrons; *2*. The *plate*, which attracts the emitted electrons. There is no definite limit to the maximum number of electrodes, but radio receiving tubes usually have somewhere between two and six electrodes. A tube can have two or more different types of grids, but for the present we will consider only tubes having one grid.

The tube in Fig. *14*, which we are using as an example, has three electrodes—a cathode, a plate, and a grid. For this reason, it is known as a triode (pronounced *"TRY-oad"*). Let us examine the important parts of this vacuum tube individually now, and see what voltage each part requires.

Filament. The filament in a tube like that in Fig. *14* is a fine hairpin-shaped wire, with heavier wire leads going from the ends of the filament to the two filament prongs on the tube base. The fine filament wire becomes red-hot when filament current is sent through it by a battery or other voltage source. This filament merely provides heat, so it cannot be called a cathode.

The filament voltage source is commonly designated by the letter "A." Thus, either an A battery or some other A voltage supply can be used to send current through the filament. In those battery receivers where the polarity of the filament voltage is important, the positive terminal is identified as "A+," and the negative terminal is marked "A—."

Cathode. Surrounding the filament of our tube is a metal sleeve about 1/16 inch in diameter, serving as the *cathode*. This cathode sleeve is coated with special chemicals, which have the ability to give off large quantities of free electrons when they are heated by the red-hot filament. Remember that the cathode is *the electrode which emits electrons.*

Plate. The metal cylinder farthest away from the cathode is the *plate*, sometimes known as the *anode*. *The plate in a vacuum tube attracts the electrons which are emitted by the cathode*, because the plate voltage source makes the plate highly positive with respect to the cathode. This is a practical example of the Law of Electric Charges; the electrons are negative and the plate is positive, so we have *unlike* charges which *attract* each other. The plate is firmly mounted and can't move toward the electrons, so the electrons move toward the plate.

Plate Current. When a vacuum tube is properly connected to its voltage sources, the electrons emitted by the cathode will be attracted by the plate. This electron flow (current) through the tube from cathode to plate is commonly called the *plate current* of the tube. The more positive the plate voltage is with respect to the cathode, the *higher* will be the plate current.

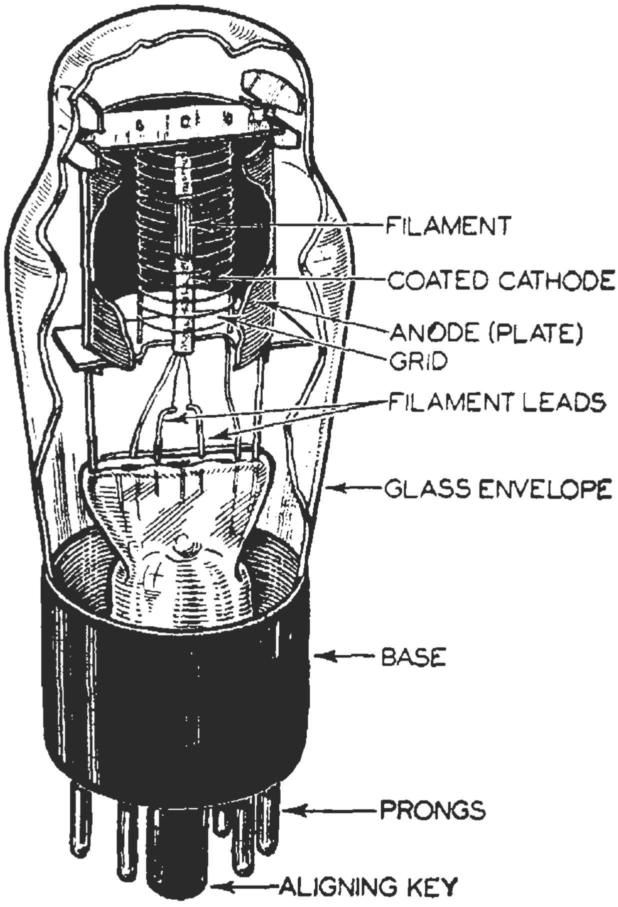
The plate voltage source is commonly designated by the letter "B". Thus, either a B battery or some other B voltage supply must be used to provide the required high positive voltage for the plate. The positive terminal of the B voltage supply is connected to the plate, and the negative terminal is connected to the cathode.

Radio men use the notation "B+" to identify the positive terminal of the plate voltage source and the plate *lead* to which this terminal should be connected. (A *lead,* pronounced *"leed,"* is a wire used for connecting purposes.) Likewise, "B—" is used for the negative terminal of the plate voltage source and the cathode lead to which this negative terminal should be connected.

The Grid. A radio tube must have one additional electrode besides the plate and the cathode before it can act as an *amplifier* for electrical signals. This additional electrode is the *grid;* it is usually in the form of a coil of fine wire mounted between the cathode and the plate, with considerable space between the turns of wire, as shown in Fig. *14*. The name "grid" comes from the fact that in early radio tubes, this in-between electrode was a grid-shaped wire (see Fig. *13*).

When there is no electrical charge (no voltage) on the grid, electrons can readily pass between the grid wires when traveling from the cathode to the plate.

When a charge is placed upon the grid of a vacuum tube, however, the grid controls the number of electrons which move from the cathode to the plate. This charge on the grid is commonly called the *grid bias voltage.*



Courtesy National Union Radio Corp.

FIG. 14. Cut-away sketch showing the construction of a typical radio tube. Part of the cylindrical plate electrode is cut away to show the grid and cathode, and part of the cathode is cut away to show the filament wires.

If a positive charge is placed upon the grid, the grid will attract electrons and speed them up, so that more electrons pass through the grid wires and reach the plate. If a negative charge is placed on the grid, it will repel electrons and reduce the number which reach the plate. This is simply an application of the fundamental electrical law that *like charges repel and unlike charges attract.*

In radio work, the grid usually is made *negative* with respect to the cathode, because a negative grid bias voltage permits more nearly perfect amplification of signals.

When a negative charge is placed on the grid, so it is more negative than the cathode, the electrons on the grid repel the free electrons coming from the cathode, and actually prevent some of these free electrons from passing through the grid wires. *The greater the negative charge on the grid of a radio tube, the less is the electron flow through the tube.*

We can place a negative charge on the grid of a vacuum tube simply by connecting the negative terminal of a voltage source to the grid, and connecting the positive terminal of the voltage source to the cathode.. The grid is then *negative* with respect to the cathode.

The grid voltage source is commonly designated by the letter "C," with the terminals being marked "C+" and "C—" respectively. Thus, a C battery can be used to make the grid negative with respect to the cathode. Radio men say then that the grid has a *negative grid bias voltage* or a *negative C bias voltage.*

Operating Voltages. We have thus seen that a modern three-electrode (triode) radio tube requires certain definite voltages. These are known as *operating voltages,* and can be summarized as follows:

1. The *filament voltage,* required to send current through the filament for heating purposes.

2. The *plate voltage,* required to make the plate highly positive with respect to the cathode, so the plate will attract the electrons emitted by the cathode.

3. The *grid bias voltage,* required to make the grid negative with respect to the cathode, so as to permit more nearly perfect amplification of signals.

More Tube Facts. We often deal with very weak signals, which must be boosted in strength (in voltage) without changing their nature. A radio tube is one device which can do this job successfully (a transformer is another).

With a definite grid bias voltage, a definite plate current flows through the tube. **When we apply a weak signal to the grid of a radio tube along with the grid bias voltage, this weak signal (still varying in strength from instant to instant) makes the grid voltage change rapidly above and below its definite grid bias value. As a result, the plate current of the tube varies above and below its original value in exactly the same way that the weak signal is varying. This varying plate current gives us an entirely new signal, much stronger but still having the same nature as the weak signal. This is how it is possible for a radio tube to** ***amplify*** **weak signals.**

In Great Britain, radio tubes are called *valves.* This is quite an appropriate name, because the grid does act as a sort of valve when it increases or decreases the stream of electrons flowing from the cathode to the plate.

Now what is the practical use for all this information about radio tubes? Here's the answer—it prepares you to understand the next lesson, which goes right ahead to give you a great deal of interesting and practical information about radio tubes at work.

Vacuum Tube Symbols. It is inconvenient to draw a picture or sketch

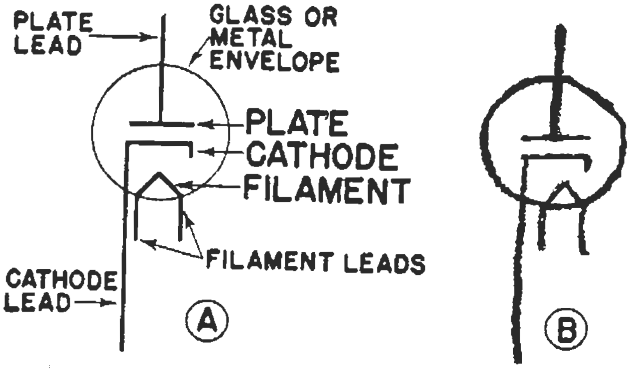


FIG. 15. Symbol for a two-electrode radio vacuum tube, as you might see it in textbooks, magazines and service manuals (A), and as you and other radio men might draw it free-hand for practical use (B).

of a vacuum tube each time we wish to show it in a circuit diagram. For this reason, radio men use simple designs or *symbols* to represent vacuum tubes as well as other radio parts. Symbols are a "shorthand" system of showing radio parts in simple form.

The symbol for a two-electrode vacuum tube having a heater-type cathode (a cathode heated by a filament) is shown in Fig. *15A*. The filament is shown as a V-shaped wire projecting inside the circle which represents the glass or metal envelope of the tube. The cathode is shown as a heavy line tending to surround the filament, just as it does in an actual tube. The plate is another heavy, straight line, parallel to the cathode and some distance away from it. Thus, you can see that each line on a symbol tells its own story.

Although tube symbols are carefully drawn with compass and ruler for diagrams which appear in textbooks and magazines, the radio man can make equally understandable symbols free-hand. For example, if a practical radio man were to draw the tube symbol of Fig. *15A* while explaining some circuit to a radio-minded friend, the symbol would probably look like that shown in Fig. *15B*. Try sketching this symbol roughly yourself a few times.

The symbol for a three-electrode vacuum tube having a heater-type cathode is shown in Fig. *16A*. The grid is shown on this symbol as a dash-dash line located between the cathode and the plate. When drawn free-hand, this symbol will appear somewhat as in Fig. *16B*. Try sketching this roughly a few times, pronouncing to yourself the names *filament, cathode, grid* and *plate* as you draw them in.

Battery Connections. A three-electrode radio tube requires three separate voltages. When these are provided by batteries as they are in modern portable receivers, we need an A battery for the filament, a B battery for the plate, and usually a separate C battery for the grid. These batteries all deliver the same kind of electricity (d.c. voltage), but the batteries vary in size because different voltages are required and because some parts of the tube draw more current than others.

The actual battery connections for a radio tube might be as shown in Fig. *17A*. The triode tube is shown in symbol form because a picture of a tube would not tell you how the connections were made to the electrodes.

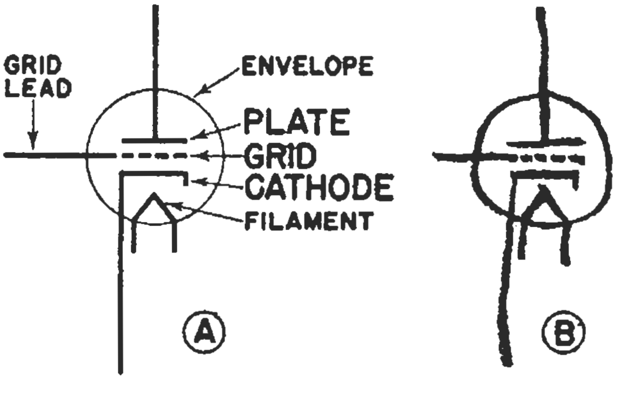


FIG. 16. Symbol for a three-electrode radio tube. Practice drawing it free-hand, as at B.

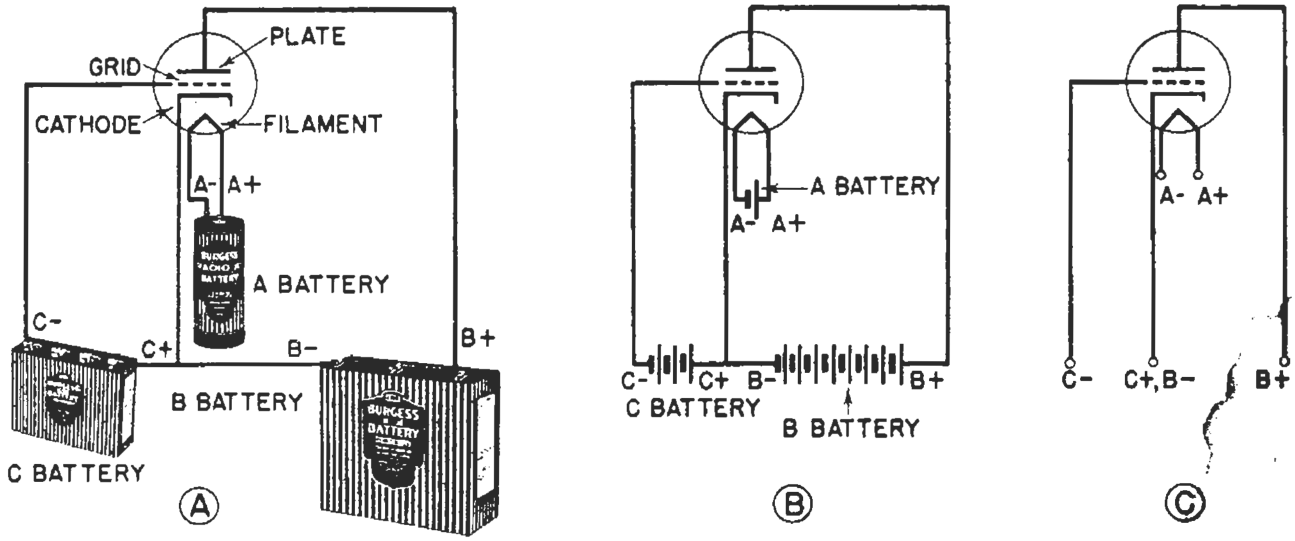


FIG. 17. These three types of diagrams each contain exactly the same amount of useful information about a vacuum tube circuit. Obviously, the diagram at C is the simplest to draw; for this reason, you will encounter diagrams like it most often in your radio studies and radio work. There is no need to make fancy diagrams like that at A when a simple diagram will serve just as well.

As you can see, the A battery in Fig. *17A* is connected to the two filament leads. The B battery is connected between the plate and the cathode, so as to make the plate *positive* with respect to the cathode. The C battery is connected between the grid and the cathode, so as to make the grid *negative* with respect to the cathode. Thus, both the + terminal of the C battery and the — terminal of the B battery are connected to the cathode. Each battery acts only in its own circuit, however, because the electrons which leave the — terminal of a battery always go to the + terminal *of that same battery.*

There is no need to draw a pictorial sketch of each battery, however. We can tell just as much with the battery symbols shown in Fig. *17B.* Each pair of long and short lines represents one cell or unit. The short line is always the — terminal of that cell, and the long line is +.

The A battery in the circuit of Fig. *17A* has only one cell, so we show only one long and one short line for it. (Of course, in other tube circuits, the A, B and C batteries may have entirely different numbers of cells.)

The C battery which we are using as an example has three cells, so we use three pairs of lines side by side to represent it in Fig. *17B.* Notice how there is a long line at the + end of the C battery, and a short line at the — end.

The B battery in this example actually has thirty cells. It isn't necessary to draw in thirty pairs of lines on our diagram, however. We just let the B battery symbol have a few more pairs of lines than the other batteries have, and specify the size of the B battery in some other way (such as by writing its voltage on the diagram.)

Even battery symbols are unnecessary and often omitted. It is entirely sufficient to label the circuit terminals which should go to voltage sources, as shown in Fig. *17C.* Furthermore, even the lettering A— and A+ on the filament leads is often omitted when a tube has both filament and cathode, for then the filament connections can be interchanged without affecting performance. Just remember that the notations A—, A+, B—, B+, C—, and C+ on radio circuit diagrams indicate connections which are to be made to A, B and C voltage sources.

To secure practice in making battery symbols, copy the diagram in Fig. *17B* several times freehand. Don't worry about making the short lines thicker than the long lines, and don't worry if your symbols look uneven. The sample sketch shown in Fig. *18* is certainly no marvel of perfection, yet it would be perfectly clear and acceptable to any radio man.

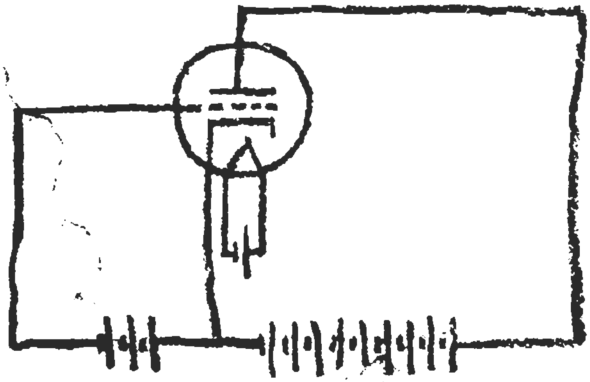


FIG. 18. This free-hand pencil sketch is typical of diagrams made by radio men.

How Tubes Amplify. Both the plate voltage and the grid voltage affect the amount of electron flow through a three-electrode vacuum tube. Since the grid is closer than the plate to the cathode, the grid has much more effect than the plate upon the electrons which are coming off from the cathode. This means that a small variation in the grid voltage will change the electron flow through the tube far more than will that same variation in the plate voltage.

For instance, a 1-volt change in the grid voltage might have *ten times greater effect upon electron flow* than a 1-volt change in plate voltage would have. In other words, the radio tube in this example makes a 1-volt radio signal in the grid circuit have the same effect on electron flow as a 10-volt signal would have in the plate circuit. We then say that the tube is able to *amplify* a signal ten times.

Suppose we connected a microphone to the grid of a tube along with the C battery, as shown in Fig. *19*. The audio signal voltage of the microphone will now alternately increase and decrease the total voltage which is acting between the grid and cathode. As a result, the electron flow from cathode to plate (the plate current) will vary in exactly the same manner as the microphone output voltage. Now if we place a suitable radio part in the plate circuit, we will find that the audio signal voltage across this radio part is many times stronger than

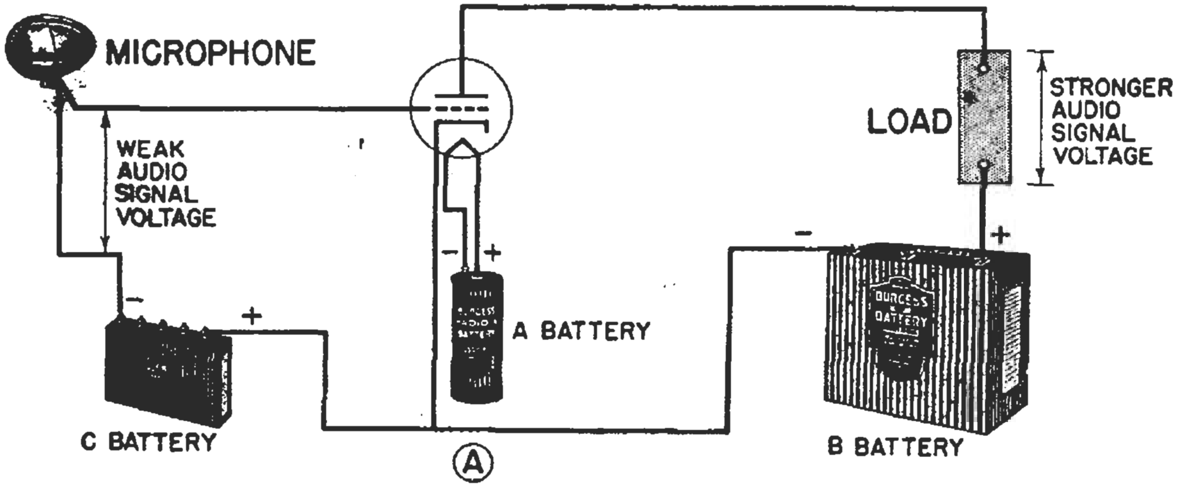


FIG. 19. Elementary diagram showing how a three-electrode radio tube can amplify the weak audio signal voltage of a microphone. Actual microphone connections would be quite different.

the microphone voltage. In other words, *we can use a three-electrode tube to amplify the microphone signal.*

It is not ordinarily practical, however, to connect a microphone directly to a radio tube; the connection is usually made through a simple device known as a *transformer.* Since a transformer is another highly important radio device, it will be worth while to consider briefly here its general characteristics.

Transformers

What Is a Transformer? A transformer in its simplest form is nothing more than two coils of wire mounted close to each other, with no wire connections whatsoever between the two coils. The coil across which we apply our original signal voltage (the *input* signal voltage) is called the *primary coil* or *primary winding.* The coil from which we take the new signal voltage (the *output* signal voltage) is called the *secondary coil* or *secondary winding.*


FIG. 20A. Typical iron-core transformer used in radio circuits.

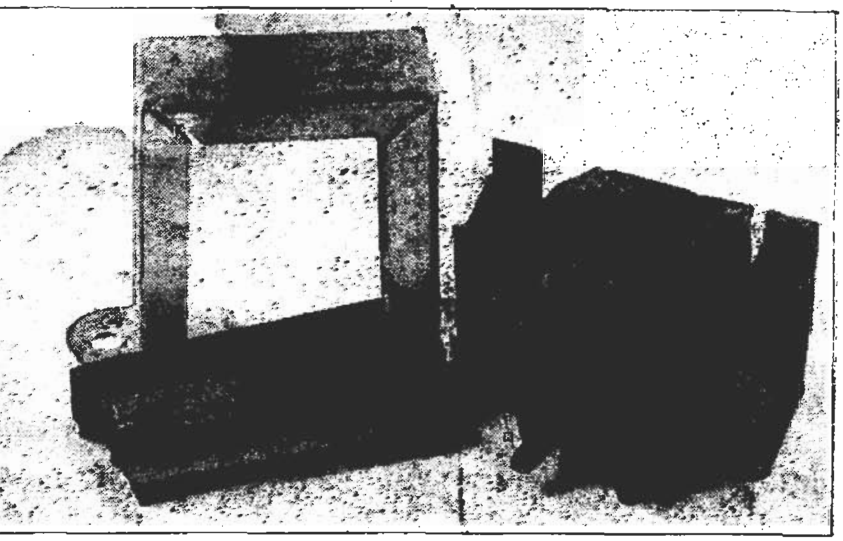


FIG. 20B. Iron-core transformer partly disassembled, to show how the coils fit over the center leg of the iron core. Note that the core is built up from many thin sheets of iron.

The material on which the coils of a transformer are wound is known as the *coil form.* When the coils are wound one over the other on a paper form inside of which is a *core* of thin iron sheets, we have an *iron-core transformer.* A typical transformer of this type is shown in Fig. *20A,* and details of its construction appear in **Fig.** *20B.*

If there is only insulating material like paper or fiber inside the coils (no iron), we have what is known as an *air-core transformer* or a *radio frequency transformer.*

Iron-Core Transformer. When a current is sent through the primary coil of an iron-core transformer, the iron will become magnetized. If the electric current is varying, as it is in the case of an audio signal, the number of magnetic lines of force flowing through the iron core will vary in an exactly corresponding manner.

Since the iron core passes through both the primary and secondary coils of the transformer, the varying magnetic lines of force are also passing through the secondary coil. These changing magnetic lines of force cause the electrons in the secondary coil to move just like the electrons in the primary coil are moving, and the result is that a signal voltage is *induced* (created) in the secondary coil.

You thus see that it is *magnetism* which flows through the iron core and makes it possible to transfer an electrical signal from one coil to another in an iron — core transformer. This is such an important action to a radio man that it is worth repeating here in a form which will be easy for you to remember.

Whenever we change the number of magnetic lines of force which pass through a coil, a voltage is induced in the coil.

If the secondary winding has the same number of turns of wire as the primary, the transformer merely transfers the signal without changing its voltage. For this condition, we use the symbol shown in Fig. *21A*, where the two windings are drawn to have the same number of loops. The letter *P* identifies the primary winding, while *S* identifies the secondary winding.

The straight lines between the coil symbols indicate that the transformer has an *iron* core. The freehand way of drawing the iron-core transformer symbol of Fig. *21A* is given in Fig. *21B;* practice drawing this several times right now, if you have a pencil handy.

If the secondary has more turns of wire than the primary, the voltage induced in the secondary will be higher than the voltage fed to the primary, and we say that the voltage has been *stepped up* by the transformer. The symbol in Fig. *21C* indicates this by having more loops or curls in the secondary. The microphone transformer in the control room of a radio station is one example of a *step-up transformer*.

If the secondary has fewer turns than the primary, the secondary voltage will be less than the primary voltage, and we say that the transformer has *stepped down* the voltage. The symbol in Fig. *21D* is used to show this condition. The output transformer in a radio receiver (the one usually mounted right on the loudspeaker) is an example of a *step-down transformer*.

When radio men draw transformer symbols, however, they sometimes do not bother to show which winding has more turns. In many cases, they're interested only in showing that there *is* a transformer in the circuit. As you acquire radio knowledge and experience, you will gradually become able to tell which winding should have more turns, regardless of how the symbol happens to be drawn.

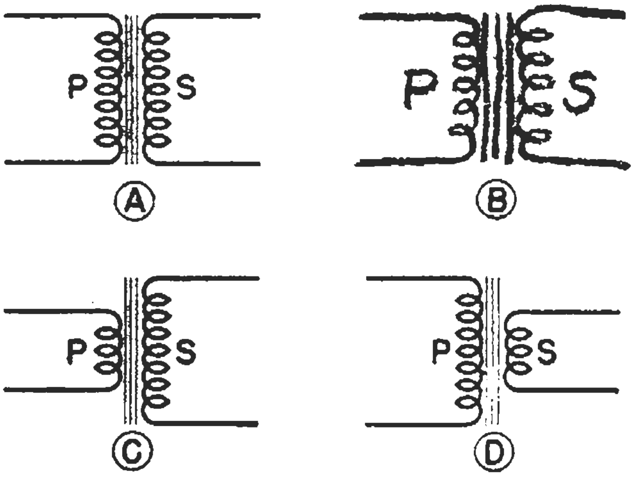


FIG. 21. Symbols for iron-core transformers.

Insist Upon Understanding

Now that you have completed your study of this lesson in the logical manner set forth in the Study Schedule on the inside front cover, won't you pause for a moment? Think over what you've learned about radio in just this one lesson.

Already you have a clear idea of what the main parts in a broadcasting system are. You really do know a great deal about electrons now. The word magnetism means a whole lot more to you today than it did last month. Did you ever expect that you would learn so much about tubes and transformers in the very first lesson?

Yes, already you are well started on a clear, interesting and satisfying Course in radio. You will agree that there has been nothing difficult or "over your head" in this first lesson.

The wonderful thing about the N.R.I. Course is that the remaining lessons will be just as interesting as the first, even though you keep learning more and more from each one. Your knowledge builds up by leaps and bounds once you master the fundamental laws and facts given in the early lessons.

A worth-while practical radio education is worth every bit of the time and effort you give to secure it. Every time you tackle a new idea *and master it,* you achieve still another advance in skill and experience.

In this Course, *you* will supply the ambition, but we're right behind you, ready to give you help whenever it is needed. *You* will do the thinking and studying, but we're eager to help you—we're willing to explain anything in a different way whenever you desire. You know when you understand an explanation and when you don't. Make sure always that you do understand.

Do your very best to master each idea yourself, but don't ever expect that you'll be able to understand everything without some help. Sooner or later, you will come to something which just doesn't seem to make sense to you. Whenever this happens, just remember that we are prepared and eager to give you personal instruction and special explanations, if you'll tell us exactly what your difficulties are. You have a Technical Consultation Service blank for this purpose. We'll send you another consultation blank with our reply. Don't be afraid to use the blank you have when necessary, for we don't want any missing stones in the foundation you're building for a successful radio career.

Looking Ahead

In this lesson, you visited the six main parts of a radio system, and secured a "bird's-eye view" of how radio programs and messages are broadcast and received. Before studying radio parts and circuits in earnest, it is natural for you to expect a more complete picture—a real insight into the radio work you hope to do. This desire will be satisfied in the very next lesson.

You will learn exactly *how* sound is picked up by the microphone in a broadcasting studio and converted into an electrical signal, then boosted in strength by amplifiers and given a ride through space on a radio wave. Following the radio wave again to a far-off receiver, you will study the fascinating radio tube circuits which convert the radio signals back into sound again. After this little journey, you will be able to recognize many radio parts and tell what their jobs are in a radio system.

Turn back to the inside front cover now, to see what comes next in your Study Schedule.

Lesson Questions

Be sure to number your Answer Sheet 1FR-3.

Place your Student Number on *every* Answer Sheet.

SPECIAL NOTICE: *Mail us your answers for this lesson immediately after you finish them.* This will make sure that the graded answers reach you while the subject matter is still fresh in your mind, and you will get the greatest possible benefit from our speedy personal grading service. *Never hold up a set of lesson answers.*

1. What is an audio signal?

2. Name, from memory, at least five of the six important sections in a complete broadcasting system.

3. Will an electron (a *negatively* charged particle) be attracted by another *negatively* charged object? (Remember that all charged particles and objects must obey the Law of Electric Charges, which tells what like and unlike charges will do.)

4. Which terminal of a battery has *more* electrons than normal?

5. Will the *current* in a complete circuit *increase, decrease* or *remain the same* when you increase the voltage of the battery?

6. Will the strength of an electromagnet be reduced when the current through the coil is reduced? yes

7. What is the name of the electrode which *attracts* the electrons emitted by the cathode in a radio tube?

8. Name the three operating voltages required by a three-electrode radio tube.

9. What flows through the iron core of a transformer and makes possible the transfer of electrical signals from the primary coil to the secondary coil?

10. Draw the simple SYMBOLS (not picture sketches) for the following radio parts:

    A—Symbol for a *radio tube* having a filament, cathode, grid and plate.
    B—Symbol for a *battery* having about six cells.
    C—Symbol for an *iron-core transformer* having about the same number of turns on both primary and secondary.